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- Back to the Future -

A meta-analysis of biases in innovation prediction

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Renate Berenett
Caroline Myrmel

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Content

List of Tables

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Summary

The contribution of this paper is to review predictions of the adoption and diffusion of smart home technology, and investigate whether, and how researcher bias might influence such predictions. The background for the study is the tendency of researchers and authors to make errors in their prediction of new technology diffusion by overestimating the technology's appeal, and underestimating the time perspective related to mainstream adoption. By reviewing relevant studies and looking at the factors that smart home predictions are based on, the authors intend to reveal whether the choice of emphasized factors, the use and interpretation of the chosen factors, and how these relate to adoption and diffusion of smart technology, are influenced by researcher biases. The findings indicate a clear bias where those who write about smart home diffusion, both belonging to academic literature and popular media, generally tend to be overly optimistic with regards to the technology's appeal and mainstream diffusion, compared to the actual diffusion rate in real life.

1.0 Introduction

"Within the next two decades, autos will be made with folding wings."

- Eddie Rickenbacker, pilot, 1924

"Nuclear-powered vacuum cleaners will probably be a reality in 10 years."

- New York Times, 1955

"Before man reaches the moon, your mail will be delivered within hours from New York to Australia by guided missiles. We stand on the threshold of rocket mail."

- US Postmaster General Arthur Summerfield, 1959

"During the next ten years, we will witness a revolution in the home similar to the office revolution of the last ten years."

- Burley, 1999

"With the current advancements in computing power and network technology, the concept of fully automated "smart" homes is not far fetched."

- Anand, 1999

Over the past decades, several researchers have tried to predict the future of the world through innovations - with varying success. We have seen many innovative technological trends through the course of history, where researchers, managers and the common man have tried to predict this development. It is not uncommon to read about "the next big thing" in technology, where statements indicate that the trend will be widely adopted and be an significant part of society. The overall findings from several studies however, are that researchers often are wrong in their endeavors to predict the adoption and diffusion process of new technological innovations. In fact, when looking at predictions of future technological changes made by Americans between 1890 and 1940, less than half of the predictions have been fulfilled (Wise, 1976). The tendency seems to be for researchers to underestimate the time perspective of the technological maturation process, regardless of when the predictions are made, and thereby make erroneous predictions about commercialization of innovation, often by a significant number of years.

"The most reliable way to forecast the future is to try to understand the present."

- John Naisbitt, u.d

Research aims to be as objective and unbiased as possible. To a large degree, it aims to present facts and objective analyses in order to draw valid and correct conclusion regarding the phenomenon in question. However, because research is conducted by human beings with human flaws, this is not always the case. Subtle and usually inadvertent bias that skews the conclusions of studies and often makes them unrepeatable (Sanders, 2015) is in fact a more prevalent issue in the social sciences today than fraud. The impact of such personal researcher bias when it comes to the accuracy of technological predictions has not been extensively studied. Although bias has been recognized as an issue in social sciences, most of the research on this phenomenon has focused on the individual manager- or firm level overconfidence, rather than technology-level and personal biases. One of the main contributions of this paper is therefore to examine how human biases may influence predictions of new technology diffusion. This is important because biased prediction errors may significantly harm investor and consumer confidence in new product development and commercialization.

"Homes are where the next wave of innovations are going."

- Anad et al, 1999

Throughout history humans have learned how to benefit from their environment. Whether this concerned how to catch food or make shelter, we learned how different habitats could provide fundamental elements for our survival and comfort (Cook et. al., 2009). As part of the continuous search for security and comfort, the modern society began to imbue their surroundings with technology in order to more easily obtain essential elements for the functioning of society. Thus the rise of the smart home began. Although the concept of smart homes has changed through the course of history, and the precise definition may vary across sources, the best definition of smart home technology, according to the smart home Foundation, is the integration of technology and services through home networking for a better quality of living (VanBerlo, 2002). Researchers, movies, popular press and academic articles have all tried to predict the adoption and diffusion of the smart home technology. The general tone of voice seems to be optimistic, and the majority of predictions and forecasts indicate that a fully smart environment is right around the corner – and has been for a long time.

"Since the mid-1940s, the home automation industry has promised to revolutionize our living environments."

- Mozer, 1998

"Smart homes will gain massive popularity in the future because current trends indicate that they are becoming the center of intelligent service consumption."

- Alam et al, 2012

"Smart homes have now become a reality, and we can currently program our house or use our mobile phone to ensure that the smell of fresh coffee and bread fills the air when we wake up, and that the hot tub awaits us when we get home from work."

- Brumitt et al, 2000

Despite praise and promises, predictions like the ones above have yet to be truly materialized. This raises the question of whether researchers or managers truly understand consumer preferences and needs related to smart home technology and how to properly read market signals. To date, little research has explored the reasons why people tend to consistently make mistakes when predicting technological development and adoption. Additionally, little attention has been given to the relationship between the factors that researchers and managers are using in their prediction, and the accuracy of the predictions. The research context for this paper is therefore to review predictions of the adoption and commercialization of smart home technology made during the last 50 years, look at which factors that are being emphasized in the research, and investigate how researcher bias might have influenced this.

In light of this, the authors propose the following research questions:

Q1. Do smart home researchers and managers truly understand consumer needs and how the technology can or should address such needs?

Q2. Do personal biases lead researchers and managers to misread signals from the market and thereby create overly optimistic predictions?

2.0 Background/Literature Review

2.1 Adoption and Diffusion Process and Market Adoption

When a new product or technology is introduced to the market, it must be adopted by consumers in order to survive. The adoption process can be described as the decision sequence that a potential user or organization goes through when adopting a technology (McIntyre, 1998). Diffusion on the other hand, describes the way in which a product or technology is passed along from one individual or organization to another. Diffusion research indicates that within a social system, the number of individuals adopting a product or technology within a given period of time roughly follows a normal bell-shaped curve (Rogers 1983). The purpose of the diffusion model is mainly to describe the successive increases in the number of individuals or organizations that are likely to adopt a new innovation, and thereby predict the continued development of a diffusion process that is already in progress (Mahajan et al 1990).

Rogers (2003) describes the innovation-decision process as “an information-seeking and information-processing activity, where an individual is motivated to reduce uncertainty about the advantages and disadvantages of an innovation”. In accordance with this, the innovation decision process involves five steps; knowledge, persuasion, decision, implementation and confirmation. In the knowledge stage, people learn about the existence of a given innovation and seek knowledge about it. This is followed by the more affective-centered persuasion stage, where the individual forms positive or negative attitudes towards the innovation, these attitudes are affected by a degree of uncertainty about the innovation’s functioning and social reinforcement. The persuasion stage is followed by the decision stage, where the individual chooses to adopt or reject the given innovation, followed by the implementation stage, where the innovation is put into practice. This stage is accompanied by the reinvention stage, where the innovation might be changed or modified by the user as part of the adoption process. When this stage is completed, the confirmation stage occurs, in which the individual seeks support for his or her decision regarding the innovation. According to Rogers (2003), the adoption decision may be reversed if the individual is exposed to conflicting information. However, people tend to stay away from such conflicting messages and rather seek supportive information that confirm their initial decision. Throughout these 5 stages, factors related to circumstances or the innovation itself may influence the diffusion process and whether the innovation is adopted or not. In Roger's description of the innovation-diffusion process as an uncertainty reduction process, he points to five attributes of innovations that help decrease uncertainty. These characteristics include relative advantage, compatibility, complexity, trialability, and according to Rogers, individuals' perceptions of these characteristics predict the rate of adoption of innovations (Sahin, 2006).

The traditional literature on adoption and diffusion processes has placed less importance on the role of the development of relevant infrastructure to support a given new product or innovation. However, the development of such associated infrastructure is often crucial when it comes to the development of high technology innovations, because such infrastructure reflects society's adoption of the potential of the new product (McIntyre, 1988). The market adoption process could potentially have strong implications when forecasting and predicting adoption and the commercialization of new innovations. Failure to take the market adoption process into account can therefore lead to forecasting errors.

2.2 Innovation Diffusion

"Innovation takes place via a process whereby a new thought, behavior, or thing, which is qualitatively different from existing forms, is conceived of and brought into reality."

- Robertson, 1967

The adoption and diffusion of innovations has received a great deal of attention across a broad spectrum of disciplines, including social science, marketing, engineering and management. However, relatively few studies have focused on advanced technology, "new to the world" systems innovations whose adoption necessitates organization-wide changes (Higgins & Hogans, 1999). When considering innovation diffusion in particular, previous research has argued that distinguishing between different types of innovations is essential in order to understand the adoption of a given innovation (Downs & Mohr, 1976; Knight, 1967; Rowe & Boise, 1974). Among the numerous typologies of innovation discussed in relevant literature, three classifications have gained the most attention: administrative and technical innovation, product and process innovation, and radical and incremental innovation.

The main difference between radical and incremental innovation is whether the innovation is perceived as a continuous modification of previously accepted practices (incremental), or whether it is new, unique, and discontinuous (radical) (Norman & Vergati, 2014). Researchers have suggested that there are differences between the factors that predict adoption of radical innovations and those that predict adoption of incremental innovations. Research has also highlighted that most radical innovations take considerable time to become accepted (Norman & Vergati, 2014).

Considering the complexity of many innovations, the different typologies and characteristics used to describe the new products or technology can play a significant role in the way consumers adopt a given innovation, and thereby which factors will be crucial in order to predict diffusion accurately. Smart home technology involves aspects of several of the innovation classification and characteristics described here. Some elements of the smart home can be categorized as radical, while other have a more incremental characteristic in that they provide improvements within a given frame of solutions (Norman & Vergati, 2014). Failure by researchers and managers to truly comprehend and address this complexity, might lead to misconceptions about the adoption and the diffusion process, which in turn has implications for prediction accuracy.

2.3 Personal Biases

A personal bias is a basic misstep in ones thinking or cognitive processes. It allows faster reasoning or information processing, but it can also cause people to create a subjective social reality based on their own perceptions (Nickerson, 2012). Because researchers are human beings, they are also subject to such thinking traps, with the result that their personal bias may potentially color their work. If a researcher believes strongly in the development of a certain technology for instance, this may lead him or her to search for or process information in a way that favors this technology, and underestimate or even disregard potential disadvantages or hazards related to the technology. One such bias theory is the phenomenon of selective exposure to information (Jonas et al, 2001). Research on selective exposure to information consistently shows that when a decision is made, people prefer supporting information over conflicting information. Such biases in the information search processes may lead to maintenance of the information seeker's position, even if this position is not justified or supported by all available information (Jonas et al, 2001). By mainly searching for information that supports her or his previously held beliefs, the author might become even more convinced about the benefits of the technology in question and thereby overestimate its appeal for consumers and society. When relating personal biases to the prediction of smart home adoption, such biases might influence several aspects of the prediction process, including the selection of factors to focus on in a given study.

Research also indicates that so called experts within a given field are more prone to certain biases, such as optimistic bias and advocacy bias, leading to a tendency to produce overly optimistic forecasts (Tyebjee, 1987). Leading experts tend to reduce complexity by closing their eyes to the fact that the introduction of a new technology entails a complex set of innovations, rather than a single technical innovation. Diffusion periods are often underestimated, implementation is assumed to be smooth, and serious obstacles might be overlooked (Tichy, 2004). Perceived controllability, commitment, and emotional investment are typical factors that influence an expert’s points of view. Experts are typically fascinated by their field and believe in its significance and future. They are strongly influenced by the desirability of the outcome and they believe in their ability to influence it (Tichy, 2004). With a significant amount of knowledge and confidence in a given technology, the researcher might easily make the assumption that consumers will share his/her view and overestimate the appeal of the innovation. Such issues may be particularly relevant in the case of complex technology with radical aspects, where usage and benefits might typically be more difficult for consumer to comprehend, and where adoption and diffusion often are more time consuming (Norman & Verganti, 2014). Smart home technology fits into this description, and it is therefore natural to question whether research and predictions related to the concept could be subjects to such biases.

2.4 Smart Homes

In recent years, the term smart home has received increasing attention in research and in popular media. The term however, is not new. The origin of smart homes was introduced in 1915-1920, where machines were introduced in the household to help with emerging labor shortage (i.e. sewing machines, vacuum cleaners, food processors). This was the first instance of domestic technology, the foreground for the connected home (Rothfeld, 2015). In 1939, the Popular Mechanics Magazine introduced "The Electric Home of the Future", which depicted cooking devices that used short-wave radio frequency. Fast forward to 1966 and the first home computer was introduced, while in the 1970s, the grandfather of automation, "X10", was a reality. This computer was made up of a simple system that utilized home power lines to foster communication between multiple appliances. However, due to the system's reliance on power lines, it was highly susceptible to electrical interference (Rothfeld, 2015). In 1984, the American Association of House Builders introduced the term "smart home" for the first time. This is key to what is understood as a smart home today, because it meant that a home is not smart because of how well it is built, how eco-friendly it is, or how efficiently it uses its space. Even though a smart home may include several of these aspects, what makes a home truly "smart" is the interactive technologies that it contains (Brown, 1997). Finally, in the 1990s, the idea of smart homes was introduced to the pop-culture. The movie "Dream House" portrays a smart home taking control of its occupants, to be followed by a cheekier, more family-friendly Disney flick Smart House with a similar concept.

> *"Technically, many of us today live in homes that were considered "smart" by 1960s standards. Thermostats and motion sensors that control lighting are commonplace. Now the bar has moved much higher: even the ability to link movement sensors to a security alarm for detecting intruders will not impress a society which regularly interacts with such facilities."*

- Cook & Jakkula, 2009

The above quote illustrates the difficulties in defining the term “smart home”. What was considered smart 50 years ago, is not quite as smart today. Some define smart homes to be a home which is capable to react ‘intelligently’ by anticipating, predicting and making decisions with signs of autonomy (Augusto and Nugent, 2006). These smart homes could potentially replace many routine everyday tasks. On the other hand, researchers such as Intille (2002) believe that the home that holds most value in the future will not use technology primarily to automatically control the environment but instead will help its occupants “learn how to control the environment on their own.” In other words, a home might not be truly smart on its own, but work as an assistant for the consumers.

Despite continuing innovations, smart home technology has not yet achieved full market penetration. Despite nearly three decades of producers claiming the inevitability of smart homes, very few consumers have adopted their version of futuristic products (Lindsay et al, 2016).

“Don't assume that what the technology can do in the household is the same as what the household wants to do with the technology.”

- Venkatesh, 1996

2.5 Internet of Things

The Internet of Things (IoT) is a vital concept related to smart home technology. IoT is a novel paradigm that is quickly gaining ground in modern wireless communication (Atzori et al., 2010). Even though there is no exact definition of IoT, The International Telecommunication Union (ITU) have defined it as: “a global infrastructure for Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies’’ (ITU, 2012). Extending this definition, IoT also serve as the key ingredients for ubiquitous computing, enabling smart environments to recognize and identify objects, and retrieve information from the internet to facilitate their adaptive functionality. This enables everyday objects (such as cars, refrigerators etc.) to communicate with each other (Weber and Weber, 2010). The effort by researchers to create human-to-human interface through technology in the late 1980s resulted in the creation of the ubiquitous computing discipline. The objective of this discipline was to embed technology into the background of everyday life, and this represented the start of the rise of IoT (Gubbi et. al., 2013).

“Internet of things has the potential to change the world, just as the internet did. Maybe even more so."

- Kevin Ashton, u.d

As for smart homes, the diffusion of IoT has been a widely discussed topic in recent years. A McKinsey Global institute report calls IoT “the fourth industrial revolution” and claims IoT is expected to have a value of over $10 trillion by 2025 (Liebenthal, n.d). This notion of a large and valuable IoT by 2025 has given rise to the question of why IoT does not already exist in a broader extent among consumers. One reason may be that IoT market is not yet well-quantified. For example, Intel states that there were 15 billion connected IoT devices worldwide in 2015, a number which the chipmaker predicts to be at 200 billion by 2020. On the other hand, Gartner counted less than 5 billion devices in 2015, and predicts a value of IoT devices at less than 21 billion by 2020 (Bershidsky, 2017). These discrepancies illustrate some of the difficulties related to innovation prediction, and highlights the importance and contribution of this paper.

3.0 Method

The objective for this meta-analysis is to collect evidence of smart home-related predictions from popular media and academic literature, from the time period 1960-2017. The data collection was conducted between January 2017 to March 2017 by using the internet to identify relevant articles and content.

Content analysis calls for the qualification of elements in a dataset, where an element or subdivision of the content may range from large to small. One of the large elements, and one of the most important for the current study, is theme - a single assertion about a subject. The theme is among the most useful units of content analysis because issues, values, beliefs, and attitudes are usually discussed in this form (Kassarjian, 1977). Therefore, despite the considerable number of articles that the search resulted in, only papers with information related to prediction of smart home usage (any kind of smart homes) were included in the data. A total of 79 papers were chosen to be considered for the final review.

Articles included in the final analysis were judged by the authors to have content related to smart home technology and predictions for future diffusion. This allowed the authors to compare the collected content with what has occurred within the framework of existing theories on bias and innovation diffusion. The material included both publications within academic sources and popular media, and the time period extended from 1969 to 2016.

Content analysis is no better than its categories, as they reflect the formulated thinking, the hypotheses, and the purpose of the study (Kassarjian, 1977). Therefore, the categories are, in essence, the conceptual scheme of the research design. While conducting the current analysis, the authors decided on a given number of content categories in order to systemize the relevant factors identified. These categories emerged while the authors reviewed the source materials in order to catalogue all predictions made on smart homes or technology similar to smart homes (i.e technology written prior to 1990, when the term was broadly used for the first time). When classifying the different factors used in relation to smart home prediction, the authors chose to base the further analysis on five main categories, with associated sub-categories; Users, Technology, Costs, Environment and Government. These categories were chosen because of their influence and emphases in the existing literature on smart homes. In particular, Users, Technology and Costs are essential factors for a smart home to be built and for it to function. Environmental- and Governmental factors received less attention in the reviewed research than the previous three, but they were still mentioned often enough in the literature for the authors to find them of interest. In addition, Governmental factors are relevant when it comes to enabling a national widespread diffusion process of smart home technology, and were therefore also included as main categories. The review resulted in a total of 285 identified factors, and the final selected content categories are displayed in Table 1.

Table 1
Content Category

Group n	285
1.0 Users	
1.1 Convenience	
1.2 Independence	
1.3 Privacy	
1.4 Security	
1.5 Readiness	
2.0 Technology	
2.1 Connectivity	
2.2 Network/Infrastructure	
3.0 Costs	
3.1 Direct Cost	
3.2 Potential savings	
3.3 Profitability for the industry	
4.0 Enviroment	
4.1 Enviroment concern	
5.0 Goverment	
5.1 Goverment/policy regulation	

The results from the analysis were broken down by time periods (before and after 1995) and by academic sources vs. popular media. As the internet is a key component in the smart home environment, and the internet did not spread to the general public until 1995 and the subsequent years, the authors found this to be a natural point of distinction. This enabled the authors to analyze the difference in personal bias and factors emphasized in the smart home literature before and after the rise of the Internet.

In order to investigate the bias in the sample, the authors further analyzed the tone of voice in the articles and classified how many articles that could be considered pro (optimistic) and con (pessimistic) smart homes. The authors also looked at the differences in the predictions being made and the emphasized factors related to this predictions, in order to evaluate whether and/or how this could be influenced by researcher bias.

Because the authors subjectivity must be minimized to obtain a systematic, objective description of the relevant factors, the issue of reliability becomes paramount. One of the most important types of reliability in a meta-analysis is inter-judge reliability, which is the percentage of agreement between several judges processing the same material (Kassarjian, 1977). In order to control for inter-judge reliability, the two authors read all of the articles (79 in total) and compared how many of the factors they identified and agreed on in the different articles. The results of the inter-judge reliability showed that out of a total of 285 factors, the authors agreed on 250 of them, leading to a coefficient of reliability of 87 percent (Table 3). Generally, the reported reliabilities in the dataset are extremely high. Berelson (1952) claims that the range between 66 and 95 percent is considered to be high. Therefore, the authors can claim that the inter-judge reliability in the current study is satisfying.

Table 3
Inter-judge reliability

Variable	% Agreement
Total	87 %
1.0 Users	**92 %**
1.1 Convenience	93 %
1.2 Independence	87 %
1.3 Privacy	95 %
1.4 Security	96 %
1.5 Readiness	74 %
2.0 Technology	**86 %**
2.1 Connectivity	83 %
2.2 Network/Infrastructure	89 %
3.0 Costs	**83 %**
3.1 Direct Cost	95 %
3.2 Potential savings	79 %
3.3 Profitability for the industry	33 %
4.0 Enviroment	**94 %**
4.1 Enviroment concern	94 %
5.0 Goverment	**33 %**
5.1 Goverment/policy regulation	33 %

4.0 Analysis and Results

A z-test was conducted in order to consider frequency and test whether the detected differences between the categories were significant. The results are presented in Table 2.

Table 2
Content Category frequency of factors.

		Total	Academic Papers	Popular media	Z-test/p	After 1995	Before 1995	Z-test/p
Group n	285	100 %	100,00 %	100,00 %		100,00 %	100,00 %	
1.0 Users		**46,30 %**	**47,00 %**	**44,12 %**	**0,417/0,6745**	**46,67 %**	**40,00 %**	**0,504/0,6171**
1.1 Convenience		15,10 %	15,21 %	14,71 %	0,101/0,9203	15,56 %	6,67 %	0,936/0,3472
1.2 Independence		8,10 %	7,83 %	8,82 %	-0,261/0,7949	8,15 %	6,67 %	0,205/0,8337
1.3 Privacy		7,40 %	7,83 %	5,88 %	0,538/0,5892	7,41 %	6,67 %	0,107/0,9124
1.4 Security		9,10 %	8,76 %	10,29 %	-0,384/0,7040	9,26 %	6,67 %	0,339/0,7279
1.5 Readiness		6,70 %	7,37 %	4,41 %	0,854/0,3953	6,30 %	13,33 %	-1,064/0,2819
2.0 Technology		**29,10 %**	**28,57 %**	**30,88 %**	**-0,366/0,7114**	**29,63 %**	**20,00 %**	**0,799/0,4237**
2.1 Connectivity		16,80 %	16,59 %	17,65 %	-0,203/0,8415	17,04 %	13,33 %	0,373/0,7114
2.2 Network/Infrastructure		12,30 %	11,98 %	13,24 %	-0,275/0,7872	12,59 %	6,67 %	0,681/0,4965
3.0 Costs		**16,50 %**	**16,13 %**	**17,65 %**	**-0,294/0,7718**	**15,93 %**	**26,67 %**	**-1,091/0,2757**
3.1 Direct Cost		7,00 %	5,99 %	10,29 %	-1,212/0,2263	6,67 %	13,33 %	-0,984/0,3271
3.2 Potential savings		8,40 %	9,22 %	5,88 %	0,864/0,3898	8,15 %	13,33 %	-0,704/0,4839
3.3 Profitability for the industry		1,10 %	0,92 %	1,47 %	-0,387/0,6965	1,11 %	0,00 %	0,4104/0,6818
4.0 Enviroment		**6,00 %**	**5,53 %**	**7,35 %**	**-0,554/0,5823**	**6,30 %**	**0,00 %**	**1,002/0,3173**
4.1 Enviroment concern		6,00 %	5,53 %	7,35 %	-0,554/0,5823	6,30 %	0,00 %	1,002/0,3173
5.0 Goverment		**2,10 %**	**2,76 %**	**0,00 %**	**1,385/0,1645**	**1,48 %**	**13,33 %**	**-3,112/0,0018**
5.1 Goverment/policy regulation		2,10 %	2,76 %	0,00 %	1,385/0,1645	1,48 %	13,33 %	-3,112/0,0018

4.1 Users

"…These devices sense and record user activities, predict their future behavior, and prepare everything one step ahead according to the user's preference or needs, giving him/her the most convenience, comfort, efficiency, and security".

- Li et al, 2011

The first main category of factors related to smart home prediction in the data is named "Users". This category includes factors related to users, or consumers of smart homes, and includes five sub-categories, Convenience, Independence, Privacy, Security and Readiness.

Looking at the data as a whole, factors related to Users are those that are most frequently mentioned in relation to prediction of smart home adaptation. 46,3 % of the total number of mentioned factors are related to Users, and the tendency to highlight Users applies to both academic journals and popular media, and to both time spans analyzed.

4.1.1 Convenience

"One of the main objectives of smart home research is to ease daily life by increasing user comfort."

- Alam et al, 2012

The first sub-category of Users is called Convenience, and this refers to how smart home technology aims at making life easier for its users, by increasing efficiency and convenience, by helping them to take care of everyday tasks, and thereby save time and resources. According to Alam et al (2012), this is the main objective of smart home technology, and according to the data, factors related to convenience are what researchers and other authors emphasize the most in relation to users in their prediction of smart home development.

"This sort of high end technology is supposed to facilitate the different life easing utilities to a new age and bringing things out of the box to as near as one's palm."

- Shahriyar, 2008

When comparing Convenience to all other factors described in the dataset, this is the second most dominant factor overall (15,1 %), only the technology-related factor Connectivity has a slightly higher frequency (16,8 %). One can see the same tendency to emphasize Convenience in both academic literature and in popular media, throughout the time periods we investigated.

4.1.2 Independence

"Increasingly, home automation is proving to be especially useful for elderly and disabled persons who wish to live independently."

- Bregman, 2010

The subcategory of Independence is related to health- and care taking services, especially targeting elderly and disabled, where providing assistance in the home can increase their independence. This also includes how smart home technology has the potential to decrease the need for external help from family, healthcare professionals and assisted living facilities, making it possible for people in need of assistance to live at home longer.

"The solution is to accommodate healthcare services and assistive technologies in patients' home environment."

- Alam et al, 2012

Allowing elderly people to remain at home and providing the services they need in a more efficient way is especially important due to the unsustainable demographic development of an aging population, where the society is facing more costs than it can currently bear in order to care for an aging population in the future.

"Healthcare applications developed in a smart community decrease the community residents' dependence on special caregivers and reduces their healthcare expenses through more efficient use of community health care resources and earlier detection of life-threatening emergency situations."

- Li et al, 2011

When looking at the dataset overall, Independence is the third most prominent factor related to users, mentioned with an overall percentage of 8,1. We observed a similar tendency within both academic journals and in popular media. A reason for this could be that the factor addresses the universal issue of how to best provide care, an issue that is usually considered to be an important aspect of society. In light of this, it might be surprising that the independence factor is not more prominent in our dataset. In fact, independence is mostly mentioned in papers with a medical perspective, and less emphasized in papers addressing smart home technology in general. A possible explanation for this could be that the authors of the papers are trying to engage the masses, and thereby emphasize factors more appealing to the general citizen. Creating a market for a larger part of the population is important in order to speed up the necessary development, create sufficient infrastructure and support systems and to reduce costs.

"Applications should be sought for such developments outside the immediate needs of disabled and elderly people. By doing this, the market is maximized, reducing costs and hence feeding benefits back to the disabled users."

- Allen, 1995

4.1.3 Privacy

The third User sub-category is labeled Privacy-issues and relates to potential concerns regarding surveillance, interference and abuse of personal information.

"Environmental hazards from software and connectivity pose distinct challenges for smart homes."

- Lindsay et al, 2016

When looking at the sample factors, Privacy-related factors are mentioned with an overall percentage of 7,4 %, placing it in the middle when it comes to importance for smart home prediction. What is perhaps more interesting is that despite of this, the articles that do mention Privacy tend to talk about it as one of the most important inhibitors of smart home development:

" The main concern expressed by everybody—regardless of age—was the question of data privacy."

- Paetz et al, 2011

"Consumer concern about hacking is the most serious barrier to adoption."

- Lindsay et al, 2016

This might be explained by the general development in society where more and more of our daily lives is happening and can be traced online and where hacking and privacy issues are receiving a great deal of attention. Because the foundation of smart home technology is associated with similar issues, it could be natural to connect the two. On the one hand, this might create a biased impression that privacy-issues are more important in the research than they actually are in reality, which in turn could deceive other researchers to continue to emphasize such factors. However, the fact that the data indicates that privacy factors are not particularly prominent in the literature of smart home prediction, could indicate a tendency for most researchers and authors of smart home development to underestimate the importance of privacy issues. This in turn can affect prediction accuracy.

4.1.4 Security

The fourth User-related sub-category covers Security-issues, meaning physical security related to the smart homes.

"Smart homes have the potential to enhance traditional security and safety mechanisms by using intelligent monitoring and access control."

- Alam et al, 2012

Security is the second most mentioned user-related factor, when looking at the overall sample factors, and is mentioned with an overall percentage of 9,1 %. This also makes it the fourth most important factor overall related to smart home prediction. One can see the same tendency in both academic journals and in popular media, and Security-related issues already appear in material from the early 90's. The home is often where one expects to feel the most secure, and home safety and security are typically key requirements for consumers (Lindsay at al, 2016). Therefore, it might not be a surprise that authors emphasize security-related issues when predicting smart home development.

4.1.5 Readiness

The final User sub-category, Readiness, involves the willingness or readiness to adopt new technology, both by users, developers and the industry in general. This category encompasses acceptance and trust, and potential resistance as a consequence of former negative experiences with new or related technology for instance.

"People's fear of using it (smart home technology) has decreased."

- Cook et al., 2009

Factors related to Readiness, are found in 6,7 % of the overall sample factors, making this the least prominent user-related factor. The lack of focus on readiness could indicate a bias among the researchers, where they themselves trust and embrace the technology, and then almost uncritically assume that the general consumer share their opinion.

4.2 Technology

"Technology can help us all. If we harness it the right way we can create a living home that will be the foundation of a home for our lifecycle needs."

- Burley, 1999

Technology is one of the most important components in the smart home system.

"The term 'smart home' is used for a residence equipped with technology that allows monitoring of its inhabitants and/or encourages independence and the maintenance of good health."

- Chan et. al., 2009

Without technology, the smart home concept would not exist. It therefore seems natural for researchers and other authors to dedicate a great deal of attention to technological aspects when predicting smart home diffusion.

"Smart homes will only manage to reach their potential if the technology and value are right."

- Lindsay et al, 2016

When looking at the Technology category as a whole, the factors related to this category are mentioned second most often in relation to smart home prediction, only being surpassed by factors related to Users. Of the total number of mentioned factors, 29,1 % are related to Technology, and the distribution between academic papers versus popular media and before 1995 versus after 1995 seem to be fairly equal.

4.2.1 Connectivity/Interface

"To address the problems of the current digital home we need a single network to connect the various subsystems together to make the digital home viable."

- Oborkhale & Salatian, 2011

The subcategory of Connectivity/Interface addresses factors related to the extent to which devices efficiently communicate with each other, and how devices efficiently communicate with humans. It also includes aspects of the IoT and aids and tools for connectivity and communication, such as sensors, robots, smart phones etc.

"A cluster of related technologies has already become available to the American households in the last 3 or 4 years. They include: cellular mobile phones,

videotext, home banking, electronic shopping, electronic bulletin board, home security networks, and database reference systems."

- Venkatesh et al., 1986

"The program replaces old-fashioned timers, allowing homeowners to use their PCs to manage lights and appliances."

- Brown, 1997

"More recently, home networking services have adopted varied wired/wireless networking technologies to connect not only the home appliances in a house but also mobile devices."

- Sung et al., 2007

As the above quotes illustrate, one can see the differences in how researchers talk about the smart home concept in different time periods. As mentioned earlier, the smart home concept has existed for decades, but in different shapes and forms. The main difference between the different time periods is the nature of connectivity. The 1986 quote does not mention the connectivity between the devices as the backup system and technology did not exist by then. Looking at the data, the connectivity category is mentioned most out of all the subcategories, both overall, in popular media and academic journals, and both before and after 1995. The main reason for this may be that even though the researchers are not talking about the same kind of connectivity throughout the years, the existing connectivity in the given period of time was still essential for the smart home concept, and therefore it is a natural factor to focus on.

4.2.2 Network/Infrastructure

"There is a requirement for supporting unicasting and multicasting. The seamless end-to end services provision on a national and international scale, on multiple network platforms, must be achievable within the digital home network."

- Oborkhale & Salatian, 2011

The second technological subcategory, Network/Infrastructure addresses the existence of a functioning backup/support/maintenance system, cooperation within the industry or between different parties or actors associated with smart homes, and the general development of society related to technology.

Factors related to Network/Infrastructure are mentioned with a percentage of 12,3% of the overall sample, making it the third most mentioned subcategory. There is no significant difference between the number of mentions in academic versus popular media papers or before versus after 1995.

"In addition to improving data security, Zauer says, vendors must also start focusing on partnering with utilities and telecommunications providers to bring smart-home platforms to a wider audience—not just technophiles and other early adopters."

- O´Connor, 2016

4.3 Costs

The third main category related to smart home prediction in the dataset is Costs. When it comes to any sort of new technology adoption, costs are always important for consumers, and society as a whole, because they can act as a driver or inhibitor.

" It seems the key to adoption is to design and create products that add significant value to a consumer's life—and to do so cheaply."

- Lindsay et al, 2016

The Costs category is divided into the subcategories of Direct costs, Potential savings, both for consumers and for society, and finally, Profitability for the industry. When looking at the overall sample, the category of costs is mentioned in 16,5 % of the overall factors.

4.3.1 Direct Costs

"The cost of something, which is not tangible or visible and has not a clear contribution to increased quality of living, has been a major barrier for really starting implementation."

- Van Berlo, 2002

The sub-category of Direct Costs is related to the development, implementation and maintenance of smart homes. In this study, direct costs are defined to be the amount someone has to give up in order to get something (WebFinance Inc, u.d).

“Over a period of time, users will have to invest heavily in household information technology. A major investment will be in the internal wiring of the home - a significant cost for existing structures.”

- Venkatesh and Vitalari, 1986

Cost can be understood in terms of financial costs, but also as more abstract costs related to health and time. An interesting finding is that direct cost is mentioned less often than potential savings in the articles (7% vs. 8,4%). This may be because of the researcher's personal bias. As most of the articles can be characterized as positive (68 %), it is natural for researchers to focus on the positive aspect of the smart home concept. Because direct costs can be perceived as more negative, a focus on this may harm the adoption of the innovation. Therefore, positive researchers may tend to focus more on savings, downplaying the direct costs.

4.3.2 Potential Savings

"Numerous benefits were perceived for all the technologies, the most important being monetary savings."

- Paetz & Dütschke, 2011

Potential savings addresses both socio-economic gains for society, in terms of for instance reduction of costs related to health care, and the potential reduction of domestic and other personal costs for consumers as a result of smart home technology.

“The agent’s goal is a function that maximizes comfort and productivity of its inhabitants and minimizes operating cost.”

- Cook et al., 2003

Looking at the results, the authors see that potential savings is the most prominent factor within the cost category. Potential savings is an important aspect of the goal of a smart home concept, and as discussed in the previous chapter; potential savings has more positive nature, and by highlighting it the researcher creates a more positive impression of the technology.

4.3.3 Profitability for the Industry

Profitability for the industry addresses aspects related to whether or not there is a business case for smart homes.

"Concerning the financial dimension, a clear business model is still lacking. This situation prevents the potentially huge Smart City market from becoming reality."

- Zanella et al, 2014

Factors related to the Profitability of the industry make up 1,1 % of the total sample factors, making it the least important factor in the research sample. This seems to be the case for both academic articles, popular media as well as before and after 1995. The indicated low importance could be related to challenges on other dimensions such as universal connectivity or infrastructure, which makes it difficult for companies to truly grasp its potential. It could also be related to researcher bias, as such difficulties makes researcher hesitant to discuss the business case related to smart homes.

4.4 Environment

4.4.1 Environmental Concerns

The Environment category has only one sub-category named Environmental concerns, which encompasses aspects like energy efficiency, reduction of energy consumption and other potential ways smart home technology can be beneficial for the environment. Of the overall sample factors, factors related to Environmental concerns make up 6,0 %, which means that it is one of the least emphasized factors related to smart home prediction in the dataset. What is perhaps more interesting is the fact that in the dataset, there are no mentions of environmental factors in relation to smart homes before the year of 2000. This could be explained by the raising attention given to environmental issues in the late 90s and early 2000s. Over the past few decades, climate change has been increasingly recognized as a severe global challenge. One could also look at prominent environmental influencers such as Al Gore, who really started receiving attention after the year of 2000. In order to adapt to the changes and to ensure more sustainable consumption, smart homes have been pointed to as a potentially important contributor (Li, 2013).

"European and national policies are aimed at reducing greenhouse gases and increasing energy efficiency—also in the household sector. For this purpose, new solutions for private homes based on information and communication technologies (ICT) are being developed and tested."

- Paetz & Dütschke, 2011

In light of this, it is perhaps surprising that environmental concerns are not given more emphasis in the general literature related to smart home technology predictions indicated by our data.

4.5 Government

4.5.1 Government/Policy Regulations

"It is observed that an urgent need exists for significant work in the area of governance of IoT."

- Bandyopadhya & Sen, 2011

The final category in the dataset is Government, and it contains only one sub-category which is related to governmental- and policy regulations and its influence on smart home development and diffusion.

"Government policy makers seek to shift the balance of care away from institutions to home-based services."

- Burley, 1999

The governance factor is the only factor in the dataset which is significantly different before and after 1995. The factor is mentioned with a frequency of 13,33 % before 1995 and only 1,48% after 1995. There may be many reasons for this, one being the influence that the government had in relation to the post-cold war era. These issues will be discussed later. However, Governance is the least important factor overall, only counting for 2,10 % of the overall factors. Another interesting finding is that the government related factors are only mentioned in the academic literature and not once in the popular media. Even though the relationship is not significant, such potential differences may be related to popular media's aim to engage its readers, and it might be perceived to be more exciting for consumers to read about technology, costs or user needs, than about government and policy makers.

4.6 Prediction

"It is dangerous, but necessary, to dream about the future. Dangerous because misguided dreams mislead designers, necessary because without vision navigation is difficult. Without dreams we risk stagnation, and lose the chance to make a better world."

- Shneiderman, 1990

In order to understand how and why researchers makes mistakes in their predictions of innovation diffusion, it is necessary to analyze the nature of such predictions.

Table 4
Prediction

	Total		Academic papers	Popular media	Z-test/p
Group n	79				
Concrete prediction		22 %	12 %	53 %	-3,788/0,0002
Vague prediction		56 %	65 %	26 %	2,958/0,0031
No prediction		23 %	23 %	21 %	0,207/0,8337

As shown in Table 4, of the overall prediction classification, vague predictions are by far the most common kind of prediction made among researchers and other authors. In particular, words like "soon" are very common within this category:

"This review shows that many projects are still in the prototype stage, but will soon make the transition from research to viable industrial products."

- Chan et al., 2008

Another interesting finding is that significantly more concrete predictions are made within popular media compared to academic papers (13% vs. 9%):

"Most respondents felt that smart-home technology is on a path to ubiquity, with 77 percent saying that by 2025, it will be as widely used as smartphones are today."

- O´Connor, 2016

"Cisco expects smart-home products will account for the largest volume of M2M connections during the forecast period, with 2.4 billion in 2015, growing to 5.8 billion by 2020."

- O´Connor, 2016

"By 2020, the number of smart home devices will more than double."

- Klein, 2015

Accordingly, there are significantly more vague predictions made within academic papers compared to popular media (49% vs. 6%):

"Presently available sensor technologies for in-house person tracking do not support such detailed and accurate tracking, but it is only a question of time when those technologies will appear."

- Nehmer et al., 2006

"Demonstrations such as the Smart House project and installations such as those by Custom Command Systems are a testing ground for the next generation."

- Schneiderman, 1990

These findings might not be entirely surprising as one would suspect that the consequences of being wrong is more severe within academic sources compared to popular media, and that the requirements are tougher. By stating a concrete prediction in form of numbers and years, the author takes a greater risk than by being vague. Additionally, as academic researchers are supposed to be "experts" in their field, being proved wrong might have significant negative impact on their reputation and credibility, more so than for a journalist. Moreover, one of the main task for a journalist is to sell papers. Because concrete information sells better than abstract information (Borgida & Nisbett, 1977), and the potential wow-factor that seduce readers is easier to accomplish with actual numbers, the journalist may have a higher incentive to be more concrete in his or her predictions.

Additionally, out of the 79 papers, 21,5 % of them mentioned some sort of scope in the article – to which extent smart home technology will be adopted in the population. In all of these cases, the scope is directed at reaching a larger scale of the population/market.

"There are many potential uses for a smart environment. Indeed, we anticipate that features of smart environments would pervade our entire lives."

- Cook et al., 2007

The fact that every article that mentions such a scope states that smart home technology will be adapted by the general public, may indicate a bias. Either in terms of overestimating the market potential or by wanting to increase the importance and relevance of the article, by indicating that the technology it discusses is relevant for the masses.

4.7 Biases

4.7.1 Tone of Voice

In order to undercover biases in the dataset, the authors analyzed the tone of voice in each article, evaluating whether and to which degree the given study could be characterized as optimistic, pessimistic, or neutral on behalf of large scale smart home adoption. The results from this analysis are displayed in Table 5 below.

Table 5
Bias - Tone of voice

	Total	Academic papers	Popular media	Z-test/p
Group n	79			
Optimistic	68 %	62 %	89 %	-2,271/0,0232
Pessimistic	5 %	7 %	0 %	1,155/0,2460
Neutral	27 %	32 %	11 %	1,818/0,0688

The analysis revealed that in total, 68% of the articles could be classified as optimistic, whereby 20% of these could be considered highly optimistic toward smart homes (see Table 5).

"Smart homes obviously have the ability to make life easier and more convenient."

- Optimistic argument; Robles & Kim, 2010

27% of the articles are classified as neutral, meaning that they maintain a more balanced view where they discuss fairly equal amounts of arguments for and against smart home adoption.

"Recent advancements in supporting fields have increased the likelihood that smart home technologies will become part of our everyday environments. However, many of these technologies are brittle and do not adapt to the user's explicit or implicit wishes."

- Neutral argument; Rashidi & Cook, 2008

5% of the articles in the dataset are classified as pessimistic, with significantly more pessimistic articles among academic papers compared to popular media. In fact, there was not one article that could be classified as pessimistic in the Popular Media category.

"No matter how hard the system designer tries to program contingency plans for all possible contexts, invariably the system will sometimes frustrate the home occupant and perform in unexpected and undesirable ways."

- Pessimistic argument; Intille, 2002

The significant differences in the tone of voice between academic papers and popular media in the data is an interesting finding. This may be partly because popular media is more concerned with attracting readers, and a balanced, more fact-based approach is simply less appealing. Another explanation could be that academic sources have stricter requirements, which forces the authors to better back their arguments.

4.7.2 Biased Source

"The Neural Network House is supported by the Sensory Home Automation Research Project."

- Mozer, 1998

"Acknowledgements; This research was carried out in co-operation with Nokia, Pikosystems, Tekes, and TUT's Institute of Electronics."

- Koskela et al., 2004

Overall, 25% of the articles were written by authors who were funded by potentially biased sources. With biased sources the authors refer to sources that have different benefits to gain from the article.

Table 6
Bias sources

Biased source	Not-biased source	Not specified
25 %	22 %	53 %

When researchers receive funding from such sources, they might be inclined to choose an approach that would benefit the funder due to the rule of reciprocation - we must repay, in any kind, what another person has provided us, a principle that runs deep in all humans (Cialdini, 2007). With this in mind, the researcher might feel an obligation to repay their funding, and the result may be a biased article.

4.7.3 Subjectivity

Another source of bias arises if the authors have certain affiliations that might be biased.

"The author is with General Electric R&D Center."

- Wise, 1976

"We are engaged in a project for the Joseph Rowntree Foundation to develop and demonstrate a model smart home for elderly residents which is cost effective and replicable in the social housing and low-cost owner occupied sector."

- Gann, 1998

As the above quotes illustrate, several of the authors in the data set had affiliations that could create a biased view. In fact, 16 % of all articles had potentially subjective authors (see Table 7). However, most of them (53 %), did not specify whether they had affiliation that could lead to a biased view.

Table 7
Subjectivity

Subjective	Not subjective	Not specified
16 %	30 %	53 %

5.0 Discussion

Despite all the praise of the potential of smart home technology, the reality of 2017 is that far from all of us live in a smart, connected home. The reality indicates that although smart home research was initiated several decades ago, the technology still faces problems and has yet to achieve mass market penetration. As Peine (2008) noted, “In spite of the fairly long history of the smart home idea itself, its diffusion in terms of market share and routine implementations is still emerging. In other words, the innovation process of the smart home has not yet fully stabilized.”

A tendency seems to be that regardless of when the predictions are made, researchers and other authors talk about large scale smart home diffusion as being only few years away. For instance, one can find examples of statements from 1986 predicting that one will see an explosion in smart home adoption during the 1990s (Ventkatesh & Vitalari, 1986), and articles from the late 1990s that talk about 2005 as the point in time where a fully smart living environment for the everyday man is a reality (Anand et al, 1999). However, when looking at the Hype’ Cycle for Emerging Technologies of 2016 developed by Gartner, the world’s leading information technology research and advisory company (Appendix 2), fully connected smart homes are still predicted to be 5 to 10 years away from mainstream adoption (Gartner, 2017).

These findings indicate a bias, where those who write about smart homes, both belonging to academic literature and popular media, tend to have more confidence in the technology and overestimate its appeal.

5.1 Factor Bias

5.1.1 Convenience

When trying to answer the question of why researchers, academics and other authors tend to make mistakes in their predictions of new technology such as the smart home technology, it is natural to question the factors they are basing their predictions on. From the analysis, user-related factors seemed to be emphasized in discussions of smart home potential, of which benefits and aspects related to convenience were highlighted the most. Convenience can mean different things to different people, but the consensus in the literature seems to be that convenience is related to making things easier, more comfortable and less time-consuming for consumers.

"There appears to be a consensus in terms of the main functions of a smart home; i.e., it should enhance the independence and improve the quality of life of residents."

- Demiris et al, 2004

"One of the main objectives of smart home research is to ease daily life by increasing user comfort."

- Alam et al, 2012

In recent years, the trend that people have less time has emerged in society, or at least it is perceived so, meaning that time is considered to be a scarce resource (The economist, 2014). This feeling of never having enough time leads consumers to seek products and services that increases their "return on time", and it is intuitive to assume that the smart home technology fits right into this trend. Another related trend is an increased demand for efficiency; things never seem to go fast enough, and one sees companies constantly developing and improving their services and products in order to deliver value to their customers faster and more efficiently than ever. Such immense focus on the time aspect in society may lead researchers and managers to assume that this demand applies to products and services inside one's home to the same degree as well, and thereby overestimate the appeal of smart home technology. Perhaps consumers do not have the same urge for efficiency inside their homes. And even if they do, they might not desire or need it enough for it to be worth the related costs or the potential risks in terms of privacy or technological malfunction. Additionally, privacy concerns in itself can be a hinder to the diffusion process.

"The end-users, the residents, do not ask for smart home technology."

- Van Berlo, 2002

Another emerging trend that might act as a hinder for smart home adoption is the fact that as a result of the intense technological development in recent years, where people find themselves in a constant state of connectedness, some consumers are actually looking to get less connected and less dependent on technology, not more. Horizon Media's Kirk Olson and Sheri Roder have been tracking this trend for some time, and they claim to observe that a wave of consumers is disconnecting from their digital devices in a quest for more authentic connections with others, more privacy and a sense of personal identity (Stilson, 2016). If this trend continues, it is bad news for smart home technology, and researchers need to acknowledge this in their evaluation of forecasts of adoption.

One could also question whether researchers on smart home technology truly understand what actually makes life more convenient for consumers.

“Seeking to be sensitive to users, smart home researchers have focused on the concept of control. They attempt to allow users to gain control over their lives by framing the problem as one of end-user programming.”

- Davidoff et al, 2006

“They optimize user comfort by using context awareness and predefined constraints based on the conditions of the home.”

- Alam et al 2012

The aspect of predefining and considering residents and families as users may be a problem in itself, and by its very essence, be perceived as inconvenient. For many people, flexibility is a big part of convenience, and family members may not really fit into the prototype of a user as it is perceived by engineers and designers, because their activities, routines and needs may not map well to programming tasks.

Another issue related to Convenience is that it is just about that – convenience. Although it might sound nice, people might not see smart home technology as something they really need in their lives. Researchers of smart home technology seem to agree that it has tremendous potential when it comes to making life easier and more convenient for consumers, but in their overconfidence state they could forget that consumers might not actually need or want this somewhat extravagant luxury in their homes. Aspects related to convenience do not address actual vital needs for people, and the tendency to put too much focus on factors such as convenience without really questioning the appeal, may lead to a potential overestimation of the potential market for smart home technology, which harms the prediction accuracy. Such challenges regarding convenience supports the authors' claim that there do exist indications that smart home researchers do not fully understanding customer needs and how to address such needs properly.

5.1.2 Independence

"The smart home concept is a promising and cost-effective way of improving access to home care for the elderly and disabled."

- Chan et al., 2008

As the results show, independence is the third most important factor within the User-category. Smart home technology as a way to facilitate independence for elderly and disabled people has received a great deal of attention in the literature. Researchers have focused a lot on the increasing social costs related to the growing aging population, where smart home technology has been advocated as a way to decrease such costs.

"The solution is to accommodate healthcare services and assistive technologies in patients' home environment."

- Alam et al, 2012

But is it really that simple? Do people really believe that technology is the solution? Several researchers seem to simplify the situation and indicate that as long as the proper technology is introduced into the home, the person in need of care will be properly and fully safeguarded and cared for.

"Smart home technology promises tremendous benefits for an elderly person living alone."

- Robles & Kim, 2010

"The smart home can replace nursing homes in some cases."

- Brumitt et al, 2000

This line of thinking may overestimate the trust among the public with regard to technology, especially among less technology prone users. There are challenges related to the functionality of smart home technology today, and while people might be willing to overlook or work around such challenges when using the technology for convenience or similar purposes, they might have higher demands for technology that addresses more vital needs, such as needed care. It may also underestimate the significance of human contact, where the company of the caretaker might be equally important for the patient as the actual care provided. If the public does not really buy the concept of smart home technology as a way to ensure care for vulnerable groups, it might not matter how convinced the researcher is about it is potential. By emphasizing aspects related to Independence as a selling point for smart home technology, the researcher might actually be talking to deaf ears, and the potential for adoption might be miscalculated.

"The lack of studies related to user needs is a major barrier to the implementation of health care technology in smart homes."

- Chan et. al., 2009

5.1.3 Privacy and Security

"Users' private lives should not be exposed to the public."

- Alam et al, 2012

Privacy-related issues were not among the prominent factors in the dataset. This might come as a surprise considering the increasing focus on hacking and privacy-issues within society in general, and the fact that those studies that do address privacy-issues highlight this as one of the most important prohibitors for smart home diffusion. If privacy concerns are in fact an important barrier for consumers related to smart home adoption, the lack of focus from researchers and managers again indicates a failure to understand consumer needs, and the lack of accuracy in smart home prediction might be unavoidable.

In contrast to privacy, security issues are among the most emphasized factors related to smart home prediction in the data. Several studies state that smart home technology has the potential to severely improve in-house security by using intelligent monitoring and access control, (e.g Alam et al, 2012) and that security systems can be built to provide an immense amount of help in case of an emergency (Robles & Kim, 2010). However, security might be a barrier of adaptation if it is not sufficiently fulfilled, and some suggest that consumer confidence in many elements of the smart home is low, and that safety and security concerns appear to be increasing (Lindsay et al 2016). However, it seems that researchers tend to focus on the benefits related to security rather than on the obstacles, which could be a part of a biased tendency to highlight positive aspects and overlook potential challenges. If the downsides of smart home technology are not sufficiently covered by the literature, this might lead to an inaccurate picture of smart home market potential.

"Smart homes are vulnerable to security threats."

- Alam et al, 2012

5.1.4 Readiness

Readiness, whether people are open and trusting when it comes to the adoption of new technology related to the smart home, does not emerge as a prominent factor in the analysis. This could indicate a bias among researchers, where those who research and write about smart homes are so familiar with the technology that they almost uncritically assume that everybody else share their trust and opinion. In reality however, people might not be as ready to adopt smart home technology as researchers seem to assume. This may be related to the fact that smart homes, as defined to date, are still a rather new phenomenon for the common consumer. Studies have shown that the brain experiences reading and listening in profoundly different ways; it activates different hemispheres for the exact same content. We place an inordinate amount of trust in the written word (Holiday, 2013), which comes from centuries of knowing that writing was expensive- that it was safe to assume that someone would rarely waste their resources by commit something untrue to paper. The written word and the use of it create deep associations with authority and credence that are thousands of years old. If the common consumer has not encountered sufficient amounts of "written down" smart home material, this might affect their trust in the technology. If such aspects are not acknowledged by researchers and managers, they very well might overestimate consumer readiness.

"Don't assume that what the technology can do in the household is the same as what the household wants to do with the technology."

- Venkatesh, 1996

5.1.5 Technology

"Key factors in the further technical development of smart homes are the proper electrotechnical infrastructure and flexible solutions in infrastructure and applications."

- Van Berlo, 2002

When closer evaluating the Technology category in the analysis, one can also detect potential sources of errors related to smart home predictions. Today, there seem to exist multiple different systems to ensure communication between devices and between devices and humans, but because of a lack of a universal standard within the technology, these systems do not necessarily communicate with each other in an efficient way.

"Presently, as new technologies and services emerge, no common standards are available for equipment service providers and suppliers - the digital home consists of several unconnected subsystems which conform to different standards."

- Oborkhale & Salatian, 2011

A detected tendency in the reviewed material is for authors to highlight different isolated technical solutions and focus on the potential and benefits of this solution alone. If these different systems are not integrated in a sufficient way, it might not matter how convincing and optimistic each study is in their prediction of technology diffusion, as it will not be as appealing to consumers.

"Currently the digital consists of various unconnected subsystems which cannot communicate with each other."

- Oborkhale & Salatian, 2011

The failure to properly account for integration with other technologies might also be related to the bias of experts to overestimate the importance of their own technical problem and underestimate the dependence on other technologies as well as the need for organizational innovations to support the technical ones (Tichy, 2004). Such issues are also related to factors involving network/infrastructure. For smart home technology to truly reach its potential, an important prerequisite is that a functioning backup-, support- and maintenance system must be in place (Bregman, 2010). The market adoption process should not be underestimated, as the development of the associated infrastructure is often crucial when it comes to advanced technology innovations, as it reflects society's adoption of the potential. If researchers of smart homes overestimate the development and the quality of this supporting infrastructure and underestimate obstacles, such failure to properly take the market adoption into account might lead to forecasting- or prediction errors.

5.1.6 Costs

"Smart home products promise to save time, energy and money for homeowners, with 45 percent of smart home product users saying these products have saved them $1,100 per year, and 87 percent saying they have made their lives easier."

- Klein, 2015

An interesting finding related to Cost-factors is that costs are more often discussed in terms of benefits and potential savings than in actual costs. A reason why costs are often mentioned in non-monetary value could be the researcher's personal bias, as it might be "easier" to talk about costs in non-monetary terms. A psychological explanation for this may be related to epistemic risk - the risk of being wrong (Parascandola, 2010). Scientists fear errors, such as claiming support for a hypothesis that turns out to be wrong. Therefore, scientists avoid epistemic risk; i.e. they tend to avoid drawing inferences that go beyond observable data. In light of this, researchers on smart home technology might fear talking about direct costs in concrete monetary value as they enter a rather risky area by doing so. Another explanation could be related to optimistic biases among the researchers. Most of the studies investigated seem prone to focus on positive aspects of the technology. Focusing on potential savings instead of negative costs might illustrate the biased inclination for researchers and managers to focus on pros rather than cons, and thereby create an overly optimistic picture of smart home technology.

5.1.7 Environment

According to the data, environmental concerns is the second least important factor and is not mentioned a single time until 1995. This is a somewhat surprising finding, considering that issues related to environmental concerns have been placed high on the social agenda in recent years and the need to implement actions to “save the environment” has received a great deal of attention. In fact, according to a McKinsey survey, 62 percent of consumers are driven by factors such as moderating user impact on the environment when considering smart home adaptation (Lindsay et al, 2016). If environmental concerns really are of importance for consumers, and the adoption of smart home technology may have positive impacts on the environment, the failure to dedicate more attention to such factors may prevent researchers and managers from exploiting some of its market potential. This finding therefore supports the previously indicated claim that smart home researchers do not fully understand customer needs and how they should address those needs.

5.1.8 Governance

“The tremendous amount of information transferred to households will create the need for new laws. Already a number of proposals have come before Congress regarding problems in national security, taxation of information, and interstate trade of information.”

- Venkatesh and Vitalari, 1986

As mentioned in chapter 4, the Government factor is the only significant factor in the dataset, when looking at the timespan before and after 1995. When looking at the American market, one of the reasons for the greater focus on Governmental factors in the older articles in the dataset could be related to the post war era and the government's action after the war. After the war, several sources reveal that the war undermined liberal reform and made many Americans deeply suspicious towards the government. The war also made Americans, especially the baby boomer generation, more cynical and less trusting of government and of authority (Digital History, 2016). Therefore, the government had a lot to prove, and its actions received a great deal of attention. This trend of focusing on the government might also have influenced researchers of very different fields, such as within smart home technology, which lead to increased focus on governmental factors within this time period. In addition, the issue of lack of trust went both ways, and as the private sector started to grow more and faster than before, the government saw the need to regulate the market better. One could argue that the government tried to set policies to undermine competitiveness and sap economic growth (Goergen, 2012). This could lead consumers and researchers to be more concerned about the issue of governmental regulation, thus the factor received more attention in the literature.

5.2 Media Influence Bias

"The news has always been riddled with errors, because it is self-referential instead of being self-critical."

- Holiday, 2013

Influence from the media has a potentially great impact on researchers, managers and the readiness of consumers when it comes to smart home adoption. In the dataset, there seemed to be a tendency for popular media to primarily be concerned about smart home technology after 1995. This could be linked to the tone of voice in broader media, where the focus on smart homes increased during the late 1990s. Additionally, movies and other actors of entertainment turned their attention to the phenomenon, with Disney's smart house movie from 1999 as an example (Lindsay et al, 2016). As smart home technology seemingly received less attention in the media prior to this, the common customer probably did not see or hear much about the technology until the late 1990s, which could partly explain why their knowledge and acceptance are far behind the researchers who are much more familiar with the concept.

In addition to bringing attention to a given phenomenon, the nature of the media might also influence the tone of voice in the presented materials. As the results from the analysis illustrate, significantly more articles were positive and optimistic within the popular media sources compared to academic papers (89% vs 62%). Furthermore, not one of the reviewed popular media articles could be considered skeptical, and the popular media category had significantly more concrete predictions compared to academic papers (53% vs 12 %). The media world has gone from scarcity to unbounded, where in the past there was only so much space in the newspaper, now space seems to be unlimited (Holiday, 2013).

Furthermore, while there used to be a severe cost for journalists of getting predictions wrong, this risk is decreased today as stories can theoretically be continuously corrected, which might lead to journalists pushing the envelope a bit when it comes to accuracy requirements. There is also more competition for customers' attention which means reporters need to be louder, more extreme and create more buzz to break through the noise, and they are also often paid based on the amount of traffic they generate. Thereby reporters are incentivized to exaggerate, speculate and be as sensational as they can. The potential result: more spectacular and perhaps less accurate predictions.

"A newspaper is a business out to make money through advertising revenue. That I´d predicated on its circulation and you know what the circulation depends on."

- Holiday, 2013

5.3 Historical Bias

Another interesting finding from the analysis could indicate that advocates for smart homes might overestimate the historical presence of this technology in the research literature. When starting this analysis, one of the initial assumptions was that smart home technology has been discussed for many years and has been predicted to become a large part of people's lives for decades. Many of the studies of smart homes in recent years make references as far back as the 40's and 50's, and indicate that the phenomenon has been prominent on the research- and popular agenda since then.

"Since the mid-1940s, the home automation industry has promised to revolutionize our living environments."

- Mozer, 1998

"The concept of home automation is nothing new. The national Association of Home Builders initiated the project in 1984."

- Brown, 1997

"The notion of a smart home as the push-button solution to domestic drudgery was a staple of mid-century World's Fairs, Walt Disney, and The Jetsons. But it

wasn't until the late 1980s that technology companies got on board, declaring "the house of the future" to be computing's next frontier."

- Lindsay et al, 2016

"Smart homes in the Internet of Things can revolutionize energy generation and consumption, realize the 1960s dreams of home automation, and offer customers new capabilities for safety and security."

- Lindsay et al, 2016

According to Robles and Kim (2010), smart home technology was developed in 1975, when a company in Scotland developed a system, which allowed compatible products to talk to each other over the already existing electrical wires of a home. However, very few of these studies makes precise references to actual authors or studies in previous decades, and when searching for work related to smart home technology predictions, surprisingly little relevant material seems to have been written before mid 1990. There could be several explanations for this, for instance that the concept of smart home would be very different in the 1960's, 70's and 80's compared to now, and the simple fact that older work may be less accessible. However, this could also be an indication of a bias in the research. Authors writing about smart home technology may be so familiar with the concept that they assume, and thereby create the impression of this technology having been more established and more widely known throughout recent history than what has actually been the case. If the authors believe that consumers are more familiar with the technology and its benefits than they actually are, this could partly explain why they predict that smart home technology would be adopted faster than it actually is. Another important and interesting aspect related to this is the fact that quotes like those presented above illustrate a long history of overestimation and overconfidence in smart home technology and its adoption. It is tempting to point out the irony in that this should make researchers aware of the tendency, and consequently make them more careful when making their own predictions. However, as the results from the analysis conducted in this paper indicate, this is clearly not the case - researchers do not seem to have learned much from their predecessor's mistakes.

5.4 Personal Bias

The authors have identified several sources of researcher- or personal bias that might explain why researchers and managers seem to fail when trying to present an accurate picture of smart home diffusion. One such interesting, and perhaps influential source of personal bias, can be related to academic funding.

"Pay every debt, as if God wrote the bill."

- Cialdini, 2007

As shown in chapter 4, 25% of the analyzed articles received funding from potentially biased sources. Such funding could have great impact on the content, the tone of voice and the predictions being made.

"Ubiquitous healthcare has been envisioned for the past two decades. IoT gives a perfect platform to realize this vision using body area sensors and IoT backend to upload the data to servers. So far, there are several applications available for Apple iOS, Google Android and Windows Phone operating system that measure various parameters."

- Gubbi et al., 2013

The example above demonstrates an article in the dataset's view of IoT. The article uses highly positive language when describing the concept, which illustrates the researchers optimistic approach. This particular article did receive funding from a potential biased source, and it is reasonable to question whether this source would benefit from the article's optimism, and thereby, whether the authors have been influenced by their sponsors;

"The work is partially supported by Australian Research Council's LIEF, Linkage grants and Research Network on Intelligent Sensors, Sensor networks and Information."

- Gubbi et al., 2013

Perhaps almost unconsciously, humans are prone to such funding bias as a result of the Rule of Reciprocation.

"The Rule of Reciprocation: The rule says that we should try to repay, in kind, what another person has provided us."

- Cialdini, 2007

The archaeologist Richard Leakey describes the essence of what makes us human through the reciprocity system: "We are human because our ancestors learned to share their food and their skills in an honored network of obligation" (Cialdini, 2007). When researchers receive funding from sources that might benefit from the success of the technology they are discussing, the researcher might feel obligated to give back. As a result, the researcher is influenced by the wish to repay his or her sponsors, which in turn may significantly influence the work conducted.

The affiliations of the author may also potentially influence his or her work and create a biased picture of smart homes. As the analysis revealed, 16 % of the articles were written by authors with an affiliation which could create a bias. But perhaps more concerning, 53 % of the authors did not specify whether they had affiliations that could lead to a biased view. This could of course be because the researchers considered themselves to be objective, and thus saw no need to specify this. However, there is a chance that biased authors chose to refrain from disclosing information regarding affiliation in order to maintain a high level of credibility. On the other side, one could point out that all humans carry with them some sort of affiliations that might influence their work to a certain degree. The challenge however, arises when such affiliations lead researchers to have something personal to gain from conducting biased work which may lead to an inaccurate portrayal of the given technology.

5.5 Expert Bias

A persisting issue for advanced technology adoption and diffusion seems to be that those closest to the technology, the developers, managers and researchers sometimes tend to be too distanced from the actual consumers.

"Unrealistic optimism may result from the overestimation of one's own capabilities and the underestimation of risks inherent in one's own work, well known in risk research."

- Tichy, 2004

When analyzing smart home adoption in light of Roger's innovation-decision process, one can identify aspects that might impede diffusion and that might have been overlooked by researchers and managers. At Roger's first stage in the decision process, the knowledge stage, it is not sufficient that consumers know about the innovation's existence, unless they also have the proper knowledge about how to use the innovation correctly or about principles describing how and why an innovation works (Rogers, 2003). Secondly, during the second stage, the persuasion stage, uncertainty plays an important part, and while more objective information about an innovation is available from outside experts, the subjective opinion of peers is often more convincing when it comes to reducing such uncertainty regarding a new innovation. When it comes to the decision stage, research indicates that if an innovation has a partial trial basis, it is usually adopted more quickly, and the compatibility of the innovation, the degree to which an innovation is perceived as consistent with existing values, past experiences and needs, is vital for adoption. In the final stages of implementation and confirmation, the innovation might still be rejected as a result of uncertainty or consequences, and if the innovation does not seem to meet the actual needs of the individual or provide a perceived relative advantage, this negatively affects the rate of adoption (Sahin, 2006). Such aspects provide important insights for managers and researchers to increase adoption, but also to adjust predictions about the adoption process. Because the adoption process of smart home technology seems to be slower than the research would indicate, challenges at several stages in the innovation-decision process might be overlooked. First, there might be too little focus on providing consumers with deeper knowledge of how and why smart home technology works. Second, researchers and managers may be putting too much trust in the ability of experts to convince and reassure people about the benefits of the smart home. Furthermore, for a smart home to truly work in the way it was intended, a fully connected home environment is required, which demands a certain level of commitment. This poses challenges for trialability, which may play a more important role than suspected. Finally, the concept of compatibility might also have been underestimated. As the analysis suggests, researchers might not have fully understood the needs of the consumers related to smart home technology and how the technology can and should address those needs. Thereby, the smart home technology might not be considered compatible with existing values or needs, which inhibits adoption.

A possible solution may be to focus more on the consumers in the research, as well as in the development process. User participation is viewed as a means of increasing user commitment and fostering a sense of user ownership for a system. It is also a way to improve system design quality by constructing a better fit of the system to the various needs in the market (Higgins & Hogan, 1999). By paying more attention to such aspects in the research it might also help researchers better understand what truly matters for the consumers and thereby which factors should be focused on when making predictions about technology diffusion.

6.0 Conclusion and Implications

The contribution of this paper has been to review predictions related to the adoption and diffusion of smart home technology, and to investigate whether and how researcher bias might influence such predictions. The background for the study is that researchers and other authors tend to make errors in their prediction of new technology diffusion, overestimate the technology's appeal and underestimate the time perspective related to mainstream adoption. By reviewing relevant studies over time and looking at the factors that smart home predictions are based upon, the authors have aimed to uncover whether the choice of which factors to emphasize, the use and interpretation of the factors chosen and how these relate to adoption and diffusion, are influenced by researcher biases. The findings indicate the presence of bias where those who write about smart home diffusion, both within academic literature and popular media, tend to be overly optimistic with regards to its appeal and mainstream diffusion, compared to what has actually been the case in real life.

The authors have identified several possible explanations for such prediction errors related to smart homes. First of all, the analysis indicates that researchers and managers of smart home technology might not truly understand consumer needs and how the technology can and should address such needs. Researchers may overestimate the appeal of some aspects of the smart home and overlook or underestimate important prohibitions. There are also indications in the findings that researchers and advocates of smart home technology assume that the technology has been more established in the literature than what has actually been the case, which could lead them to become impatient with regards to mainstream diffusion. There might also be sources of bias leading to prediction errors related to Rogers' innovation-decision model. Researchers and managers may have underestimated the need for providing knowledge about smart home technology beyond simply creating awareness about the technology's existence. They may also put too much trust in experts when it comes to convincing the consumers of potential benefits and reducing uncertainty. Additionally, the lack of sufficient trialability of smart homes may act as an important impediment for consumer adoption, and be one that might have been overlooked, or at least underestimated in past and current research of smart homes.

The authors have also identified several sources of personal bias among the researchers that might prevent them from creating an accurate picture of smart home technology and its diffusion potential. Researchers might be influenced by their affiliation, their inclination to please sponsors, or their expert status, and their close association with the technology might create an overly optimistic tunnel vision. Such biases might be further supported by selective exposure to- and processing of information, which could again contribute to the maintaining and straightening of preconceptions. These are all psychological concepts deeply rooted in all humans. Therefore, such inclinations may be hard to detect and even harder to change.

If researchers and managers fail to truly understand consumer needs and how smart home technology can or should address such needs, then perhaps it should not be such a surprise that the technology's appeal has been overestimated and that this has led to inaccuracies with regards to prediction about technology diffusion and adoption. It is easy to become consumed with the technology one is investigating and advocating, and become overconfident with regards to its potential. The benefits may be very clear and convincing for the experts, but may not be equally obvious for consumers. This might especially be the case for complex technology with radical aspects, which typically are more complicated for consumer to understand, and where adoption and diffusion is more time consuming. An important lesson and an implication of this study should be that researchers and managers investigating and writing about technology diffusion such as smart home technology, should be more critical in terms of their own personal biases and try to break out of their "research bubble" and not take for granted that consumers share their knowledge and point of view. Doing so will hopefully lead to more realistic forecasts and more accurate diffusion predictions in the future.

"Instead of trying to point yourself in the right direction, admit you have no idea what the right direction is, and try instead to be super sensitive to the winds of change."

- Paul Graham, u.d

7.0 Limitations & Future research

This paper has some limitations and opportunities for future research. First and foremost, after studying the phenomenon of bias, the authors would like to stress the fact that biased inclinations apply to all humans, and the authors are no exception.

A specific concern related to the use of meta analyses is the need to collect all studies, both published and unpublished, relevant in order for the subsequent inferences to be truly valid (Rosenthal, 1979; Begg and Berlin, 1988; Iyengar and Greenhouse, 1988; Dear and Begg, 1992; Hedges, 1992; Begg, 1994; Begg and Mazum- dar, 1994; Gleser and Olkin, 1996; Egger et al., 1997). Because the authors of this paper have collected the papers included in the dataset manually, the authors cannot be a 100% confident that all relevant papers have been included. Consequently, there is a potential for a skewed or non-representative proportion of significant studies, or studies differentially giving results in for example a positive direction, leading to a non-representative set of studies in the data set. This limitation increases as the dataset mostly includes papers from published sources. It is a common belief, backed by several empirical sources, that studies are not equally likely to be published in a scientific journal (Cooper, 1998, pp. 54-55; Dickersin, Min, and Meinert, 1992). Scientific significance is a major determining factor of publication, and some papers may not be submitted if they contain nonsignificant results. However, the authors believe that such potential issues apply to all meta-analysis. Therefore, a potential recommendation for future research is to re-do the analysis with others and/or more papers included to control for such aspects.

Another important limitation is the limited amount of studies of smart home diffusion detected before the 1990s. As a result of this limitation, the dataset from this period is also limited. As the dataset is too small to allow for generalizations based on the findings from this period, the authors have only been able to use these studies as indicators to discuss possible patterns detected. A future research opportunity could therefore be to more specifically focus on work conducted prior to the 1990s.

The fact that the current study does not take cultural differences into consideration is also a potential limitation. As this paper shows, the adoption of innovation is partly grounded in consumers' readiness, which is influenced by factors of the given society. In this sense, some countries and cultures may be more ready to adapt new innovations than others, both due to financial stability within the country and privacy concerns, but also due to social and cultural factors such risk tolerance or openness. For example, one reason that smart cities in Korea has developed more quickly compared to other countries is that there is a larger acceptance of loss of privacy by residents here (Cook et. al., 2009). Therefore, an interesting area for future research might be to compare different cultures and explore whether the biases predictions and adoption of innovations discussed in this paper, differ between countries and cultures.

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Appendix

Appendix 1 – Overview Articles

Number	Title	Year	References
1	Smart Homes - Current features and future perspective	2009	Chan, M., Campo, E., Estève, D., & Fourniols, J. Y. (2009). Smart homes—current features and future perspectives. *Maturitas*, *64*(2), 90-97.
2	A review of smart homes - Present state and future challanges	2008	Chan, M., Estève, D., Escriba, C., & Campo, E. (2008). A review of smart homes—Present state and future challenges. *Computer methods and programs in biomedicine*, *91*(1), 55-81.
3	Home smart home	1997	Home smart home Brown, Carolyn M, *Black Enterprise;* Mar 1997; 27, 8; ABI/INFORM Collection pg. 87
4	A smart fall and activity montior for telecare applications	1998	Williams, G., Doughty, K., Cameron, K., & Bradley, D. A. (1998, October). A smart fall and activity monitor for telecare applications. In Engineering in Medicine and Biology Society, 1998. Proceedings of the 20th Annual International Conference of the IEEE (Vol. 3, pp. 1151-1154). IEEE.
5	Smarter housing and care for the silver generation	1999	Burley, R. (1999, October). Smarter housing and care for the silver generation. In Department of Trade and Industry Healthcare Seminars, Singapore and Tokyo.
6	Will technological innovation create true lifetime home?	2004	Barlow, J., & Venables, T. (2004). Will technological innovation create the true lifetime home?. Housing Studies, 19(5), 795-810.

7	Research and application on the smart homes based on component technologies and Internet of Things	2011	Li, B., & Yu, J. (2011). Research and application on the smart home based on component technologies and internet of things. *Procedia Engineering*, *15*, 2087-2092.
8	An integrated approach to Smart House technology for people with disabilities	1995	Allen, B. (1996). An integrated approach to smart house technology for people with disabilities. Medical engineering & physics, 18(3), 203-206.
9	Smart Home: A peek in the future	1999	Anand, M., Jalal, A. M., Mickunas, M. D., & Campbell, R. H. (1999). Smart Home: A peek in the future. Urbana, 51, 61801.
10	Designing Smart Health Care Technology into the Home of the Future	1999	Warren, S., Craft, R. L., & Bosma, B. (1999, April). Designing smart health care technology into the home of the future. In Workshops on Future Medical Devices: Home Care Technologies for the 21st Century (Vol. 2, p. 667).
11	The Neural Network House: An Environment hat Adapts to its Inhabitants	1998	Mozer, M. C. (1998, March). The neural network house: An environment hat adapts to its inhabitants. In Proc. AAAI Spring Symp. Intelligent Environments (Vol. 58).
12	Smart home technology: Have older people paved the way?	2002	Berlo, A. V. (2002). Smart home technology: Have older people paved the way?. *Gerontechnology*, *2*(1), 77-87.

13	Internet of Things: Ubiquitous Home Control and Monitoring System using Android based Smart Phone	2013	Piyare, R. (2013). Internet of things: ubiquitous home control and monitoring system using android based smart phone. *International Journal of Internet of Things*, *2*(1), 5-11.
14	Smart City and the Applications	2011	Su, K., Li, J., & Fu, H. (2011, September). Smart city and the applications. In *Electronics, Communications and Control (ICECC), 2011 International Conference on* (pp. 1028-1031). IEEE.
16	The Smart Home meets the Web of Things	2010	Kamilaris, A., Pitsillides, A., & Trifa, V. (2011). The smart home meets the web of things. *International Journal of Ad Hoc and Ubiquitous Computing*, *7*(3), 145-154.
17	Private and Public Spaces - the use of Video Mediated Communication in a Future Home Environment	2000	Junestrand, S., Tollmar, K., Lenman, S., & Thuresson, B. (2000, April). Private and public spaces: the use of video mediated communication in a future home environment. In *CHI'00 Extended Abstracts on Human Factors in Computing Systems* (pp. 16-17). ACM.
18	Keeping the Resident in the Loop: Adapting the Smart Home to the User	2008	Rashidi, P., & Cook, D. J. (2009). Keeping the resident in the loop: Adapting the smart home to the user. *IEEE Transactions on systems, man, and cybernetics-part A: systems and humans*, *39*(5), 949-959.

19	Principles of Smart Home Control	2006	Davidoff, S., Lee, M. K., Yiu, C., Zimmerman, J., & Dey, A. K. (2006, September). Principles of smart home control. In *International Conference on Ubiquitous Computing* (pp. 19-34). Springer Berlin Heidelberg.
20	The use of temporal reasoning and management of complex events in smart homes	2004	Augusto, J. C., & Nugent, C. D. (2004, August). The use of temporal reasoning and management of complex events in smart homes. In Proceedings of the 16th European Conference on Artificial Intelligence (pp. 778-782). IOS Press.
21	Internet of Things for Smart Cities	2014	Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014). Internet of things for smart cities. *IEEE Internet of Things journal*, *1*(1), 22-32.
22	Evolution towards smart home environments: empirical evaluation of three user interfaces	2004	Koskela, T., & Väänänen-Vainio-Mattila, K. (2004). Evolution towards smart home environments: empirical evaluation of three user interfaces. *Personal and Ubiquitous Computing*, *8*(3-4), 234-240.
23	Smart Cities and the Future Internet: Towards cooperation frameworks for open innovation	2011	Schaffers, H., Komninos, N., Pallot, M., Trousse, B., Nilsson, M., & Oliveira, A. (2011, May). Smart cities and the future internet: Towards cooperation frameworks for open innovation. In *The Future Internet Assembly* (pp. 431-446). Springer Berlin Heidelberg.

24	Enabling Smart Cities through a Cognitive Management Framework for the Internet of Things	2013	Vlacheas, P., Giaffreda, R., Stavroulaki, V., Kelaidonis, D., Foteinos, V., Poulios, G., ... & Moessner, K. (2013). Enabling smart cities through a cognitive management framework for the internet of things. *IEEE Communications Magazine*, *51*(6), 102-111.
25	A Review of Smart Homes – Past, Present, and Future	2012	Alam, M. R., Reaz, M. B. I., & Ali, M. A. M. (2012). A review of smart homes—Past, present, and future. *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)*, *42*(6), 1190-1203.
28	A Gesture Based System for Context–Sensitive Interaction with Smart Homes	2011	Neßelrath, R., Lu, C., Schulz, C. H., Frey, J., & Alexandersson, J. (2011). A Gesture Based System for Context–Sensitive Interaction with Smart Homes. In Ambient Assisted Living (pp. 209-219). Springer Berlin Heidelberg.
29	The sweet-home project: Audio technology in smart homes to improve well-being and reliance	2011	Vacher, M., Istrate, D., Portet, F., Joubert, T., Chevalier, T., Smidtas, S., ... & Méniard, S. (2011, August). The sweet-home project: Audio technology in smart homes to improve well-being and reliance. In Engineering in Medicine and Biology Society, EMBC, 2011 Annual International Conference of the IEEE (pp. 5291-5294). IEEE.

30	Ethical issues arising from a research, technology and development project to support frail older people and their family carers at home	2003	Magnusson, L., & Hanson, E. J. (2003). Ethical issues arising from a research, technology and development project to support frail older people and their family carers at home. *Health & social care in the community*, *11*(5), 431-439.
33	An overview of smart technology	1997	Li, B., & Yu, J. (2011). Research and application on the smart home based on component technologies and internet of things. *Procedia Engineering*, *15*, 2087-2092.
34	Privacy and senior willigness to adapt smart home information technology in residental care facilities	2008	Courtney, K. L. (2008). Privacy and senior willingness to adopt smart home information technology in residential care facilities.
35	The smart home concept: our immadiate future	2006	Ricquebourg, V., Menga, D., Durand, D., Marhic, B., Delahoche, L., & Loge, C. (2006, December). The smart home concept: our immediate future. In *E-Learning in Industrial Electronics, 2006 1ST IEEE International Conference on* (pp. 23-28). IEEE.
36	MavHome: An agent-based smart home	2003	Cook, D. J., Youngblood, M., Heierman, E. O., Gopalratnam, K., Rao, S., Litvin, A., & Khawaja, F. (2003, March). MavHome: An agent-based smart home. In *Pervasive Computing and Communications, 2003.(PerCom 2003). Proceedings of*

			the First IEEE International Conference on (pp. 521-524). IEEE.
37	Prediction models for a smart home based health care system	2007	Jakkula, V. R., Cook, D. J., & Jain, G. (2007, May). Prediction models for a smart home based health care system. In *Advanced Information Networking and Applications Workshops, 2007, AINAW'07. 21st International Conference on* (Vol. 2, pp. 761-765). IEEE.
38	Smart Home: Integrating Internet of Things with Web Services and cloud computing	2013	Soliman, M., Abiodun, T., Hamouda, T., Zhou, J., & Lung, C. H. (2013, December). Smart home: Integrating internet of things with web services and cloud computing. In *Cloud Computing Technology and Science (CloudCom), 2013 IEEE 5th International Conference on* (Vol. 2, pp. 317-320). IEEE.
39	Designing a home of the future	2002	Intille, S. S. (2002). Designing a home of the future. *IEEE pervasive computing*, *1*(2), 76-82.
40	Ambient intelligence: Technologies, applications, and opportunities	2009	Cook, D. J., Augusto, J. C., & Jakkula, V. R. (2009). Ambient intelligence: Technologies, applications, and opportunities. *Pervasive and Mobile Computing*, *5*(4), 277-298.

41	How smart are our enviroments? An updated look at the state of the art	2007	Cook, D. J., & Das, S. K. (2007). How smart are our environments? An updated look at the state of the art. *Pervasive and mobile computing*, *3*(2), 53-73.
42	Older adults attitudes toward and perceptions of smart home technologies: a pilot study	2004	Demiris, G., Rantz, M. J., Aud, M. A., Marek, K. D., Tyrer, H. W., Skubic, M., & Hussam, A. A. (2004). Older adults' attitudes towards and perceptions of 'smart home'technologies: a pilot study. *Medical informatics and the Internet in medicine*, *29*(2), 87-94.
43	The role of prediciton algorithms in the machome smart home artchitecture	2002	Das, S. K., Cook, D. J., Battacharya, A., Heierman, E. O., & Lin, T. Y. (2002). The role of prediction algorithms in the MavHome smart home architecture. *IEEE Wireless Communications*, *9*(6), 77-84.
44	Learning to Control a Smart Home Environment	2003	Cook, D. J., Huber, M., Gopalratnam, K., & Youngblood, M. (2003). Learning to control a smart home environment. In *Innovative applications of artificial intelligence*.
45	Technologies for an aging society: a systematic review of "Smart Home" applications	2008	Cook, D. J., Huber, M., Gopalratnam, K., & Youngblood, M. (2003). Learning to control a smart home environment. In *Innovative applications of artificial intelligence*.
46	The accuracy of technological forecast 1890-1940	1976	Wise, G. (1976). The accuracy of technological forecasts, 1890–1940. *Futures*, *8*(5), 411-419.

47	Living assistance systems - An ambient intelligence approach	2006	Nehmer, J., Becker, M., Karshmer, A., & Lamm, R. (2006, May). Living assistance systems: an ambient intelligence approach. In *Proceedings of the 28th international conference on Software engineering* (pp. 43-50). ACM.
48	Smart Community: An internet of Things application	2011	Li, X., Lu, R., Liang, X., Shen, X., Chen, J., & Lin, X. (2011). Smart community: an internet of things application. *IEEE Communications Magazine*, *49*(11).
49	Internet of Things (IoT): A Vision, Architectural Elements, and Future Directions	2013	Gubbi, J., Buyya, R., Marusic, S., & Palaniswami, M. (2013). Internet of Things (IoT): A vision, architectural elements, and future directions. *Future generation computer systems*, *29*(7), 1645-1660.
50	A smart home application to eldercare: current status and lessons learned	2009	Skubic, M., Alexander, G., Popescu, M., Rantz, M., & Keller, J. (2009). A smart home application to eldercare: Current status and lessons learned. *Technology and Health Care*, *17*(3), 183-201.
51	Future directions for human-computer interaction	1990	Shneiderman, B. (1990). Future directions for human‐computer interaction. *International Journal of Human‐Computer Interaction*, *2*(1), 73-90.
52	Smart home dividend: Utility finds connected homes conserve more energy	2015	O'Connor, M. (2015, October 16). Smart Home Dividend: Utility Finds Connected Homes Conserve More Energy. Retrieved February 28, 2017, from

			http://www.iotjournal.com/articles/view?13624
53	Smart homes, cybersecurity and personal data: what consumers care about	2016	O'Connor, M. (2016, March 31). Smart Homes, Cybersecurity and Personal Data: What Consumers Care About. Retrieved February 27, 2017, from http://www.iotjournal.com/articles/view?14267
54	Current´s plan to solve smart-home connectivity problems	2016	O'Connor, M. (2016, June 29). Cirrent's Plan to Solve Smart-Home Connectivity Problems. Retrieved February 28, 2017, from http://www.iotjournal.com/articles/view?14678%2F2
55	Personalization and Multi-user management in smart homes for disabled people	2009	Kadouche, R., Abdulrazak, B., Mokhtari, M., Giroux, S., & Pigot, H. (2009). Personalization and multi-user management in smart homes for disabled people. *Int J Smart Home*, *3*(1), 39-48.
56	The customized personal services for providing active action the variable circumstance and location on homenetwork system	2007	Sung, K., Na, W., Oh, K. S., & Oh, H. (2007). The customized personal services for providing active action the variable Circumstance and Location on Homenetwork system. *Context*, *1*(1).
57	The ubiquitous home	2007	Yamazaki, T. (2007). The ubiquitous home. *International Journal of Smart Home*, *1*(1), 17-22.

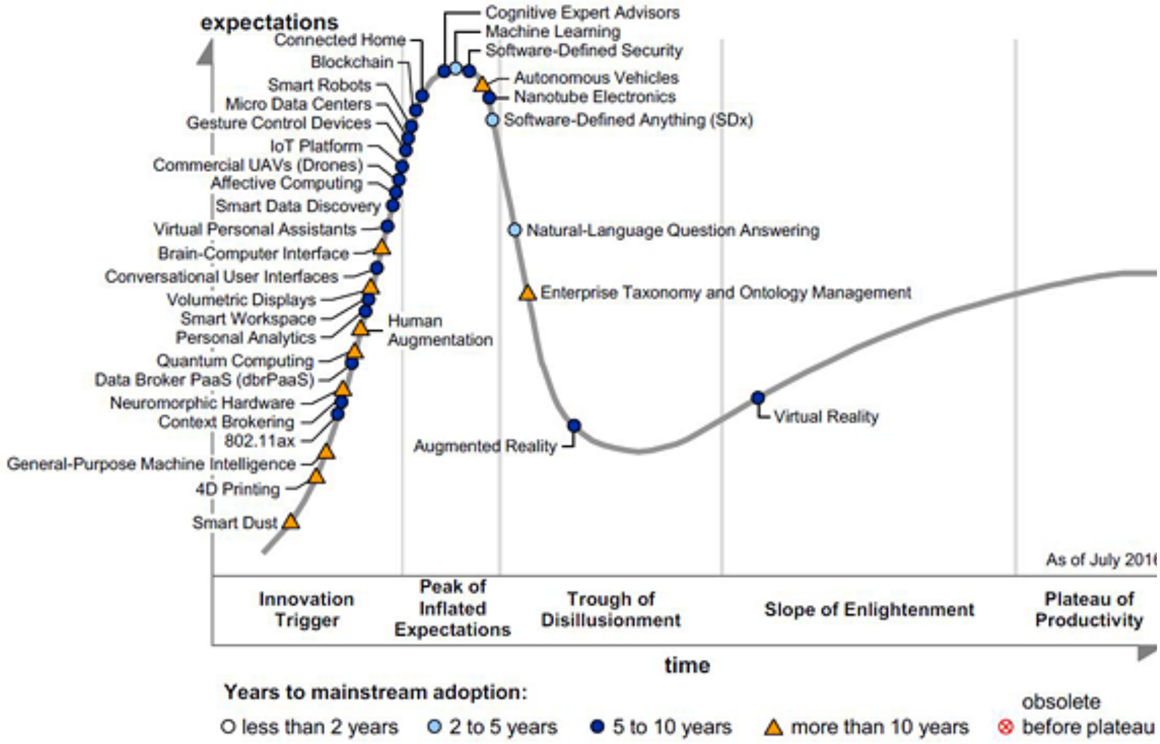
58	Computing technology for the Home: Product strategies for the next generation	1986	Venkatesh, A., & Vitalari, N. P. (1986). Computing technology for the home: Product strategies for the next generation. *Journal of Product Innovation Management*, *3*(3), 171-186.
59	Towards the evolution of smart home enviroments: a survey	2016	Andrés, B., Alejandra, F., Miguel, J., Augusto, S., & Pedro, W. (2016). Towards the Evolution of Smart Home Environments: A Survey. *International Journal of Automation and Smart Technology*, *6*(3), 105-136.
60	2016 predictions for IoT and smart homes	2015	Klein, C. (2015, December 23). 2016 predictions for IoT and smart homes. Retrieved March 2, 2017, from https://thenextweb.com/insider/2015/12/23/2016-predictions-for-iot-and-smart-homes/#.tnw_2Qvlh57x
61	Internet of Things By The Numbers: Market Estimates And Forecasts	2014	Press, G. (2014, November 13). Internet of Things By The Numbers: Market Estimates And Forecasts. Retrieved March 2, 2017, from https://www.forbes.com/sites/gilpress/2014/08/22/internet-of-things-by-the-numbers-market-estimates-and-forecasts/#1ec068b5b919
62	Why the DIY smart home revolution won't work	2015	Plaehn, M. (2015, May 24). Why the DIY smart home revolution won't work. Retrieved March 1, 2017, from https://thenextweb.com/insider/2015/05/24/why-the-diy-smart-home-revolution-wont-work/#.tnw_DTN2zpOD

63	Augmenting user interaction in a smart home applying commonsense knowlegde	2008	Andrés, B., Alejandra, F., Miguel, J., Augusto, S., & Pedro, W. (2016). Towards the Evolution of Smart Home Environments: A Survey. *International Journal of Automation and Smart Technology*, *6*(3), 105-136.
64	The usage of automation system in smart home to provide a sustainable indoor enivroment: a contnet analysis in Web 1.0	2013	Li, R. Y. M. (2013). The usage of automation system in smart home to provide a sustainable indoor environment: a content analysis in Web 1.0.
65	Im afraid I cant let you do that Dave: Scientists predict smart homes controlled by computer will be a reality in 10 years	2012	Cohen, T. (2012, March 29). 'I'm afraid I can't let you do that, Dave': Scientists predict 'smart' homes controlled by computer will be a reality in 10 years. Retrieved March 1, 2017, from http://www.dailymail.co.uk/sciencetech/article-2122343/Scientists-predict-smart-homes-controlled-reality-10-years.html
66	Remote-Controlled Home Automation Systems with Different Network Technologies	2006	Delgado, A. R., Picking, R., & Grout, V. (2006). Remote-controlled home automation systems with different network technologies.
67	The accuracy of technological forecasts, 1890–1940	1976	Wise, G. (1976). The accuracy of technological forecasts, 1890–1940. *Futures*, *8*(5), 411-419.
68	The Past and Future of Home- and Community-based	1988	Weissert, W. G., Cready, C. M., & Pawelak, J. E. (1988). The past and future of home-and community-based

	Long-term		long-term care. *The Milbank Quarterly*, 309-388.
69	The Pattern of Prediction 1763–1973: The first forecast of the future	1969	Clarke, I. F. (1969). The Pattern of Prediction 1763–1973: The first forecast of the future. *Futures*, *1*(4), 325-330.
70	Computer and other Interactive Technologies for the Home	1996	Venkatesh, A. (1996). Computers and other interactive technologies for the home. *Communications of the ACM*, *39*(12), 47-54.
71	Internet of Things: Applications and Challenges in Technology and Standardization	2011	Bandyopadhyay, D., & Sen, J. (2011). Internet of things: Applications and challenges in technology and standardization. *Wireless Personal Communications*, *58*(1), 49-69.
72	Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions	2011	Paetz, A. G., Dütschke, E., & Fichtner, W. (2012). Smart homes as a means to sustainable energy consumption: A study of consumer perceptions. *Journal of consumer policy*, *35*(1), 23-41.
73	Review: Context Aware Tools for Smart Home Development	2010	Robles, R. J., & Kim, T. H. (2010). Review: context aware tools for smart home development. *International Journal of Smart Home*, *4*(1).
74	A Universal Implementation Model for the Smart Home	2009	Bregman, D., & Korman, A. (2009). A universal implementation model for the smart home. *International Journal of Smart Home*, *3*(3), 15-30.
75	Networking Mobile Devices and Computers in an Intelligent Home	2009	Zoref, L., Bregman, D., & Dori, D. (2009). Networking mobile devices and computers in an intelligent home. *International Journal of Smart*

			Home, *3*(4), 15-22.
76	Challenges of the Digital Home in a Developing Economy	2011	Oborkhale, L., & Salatian, A. (2011). Challenges of the Digital Home in a Developing Economy. *Int. J. Smart Homes*, *5*, 31-36.
77	Smart Home Intelligence - The eHome that Learns – 2010	2010	Bregman, D. (2010). Smart Home Intelligence–The eHome that Learns. *International journal of smart home*, *4*(4), 35-46.
78	User Authentication Using Neural Network in Smart Home Networks	2007	Reyhani, S. Z., & Mahdavi, M. (2007). User authentication using neural network in smart home networks. *International Journal of Smart Home*, *1*(2), 147-154.
79	Smart Homes and the Internet of Things	2016	Lindsay, G., Woods, B., & Corman, J. (2016). Smart homes and the internet of things. *Atlantic Council*, 1-12.

Appendix 2 – Lifecycle



Source: Gartner (July 2016)

Appendix 3 – Content Category Frequency of Factors

Table 2
Content Category frequency of factors.

		Total	Academic Papers	Popular media	Z-test/p	After 1995	Before 1995	Z-test/p
Group n	285	100 %	100,00 %	100,00 %		100,00 %	100,00 %	
1.0 Users		**46,30 %**	**47,00 %**	**44,12 %**	**0,417/0,6745**	**46,67 %**	**40,00 %**	**0,504/0,6171**
1.1 Convenience		15,10 %	15,21 %	14,71 %	0,101/0,9203	15,56 %	6,67 %	0,936/0,3472
1.2 Independence		8,10 %	7,83 %	8,82 %	-0,261/0,7949	8,15 %	6,67 %	0,205/0,8337
1.3 Privacy		7,40 %	7,83 %	5,88 %	0,538/0,5892	7,41 %	6,67 %	0,107/0,9124
1.4 Security		9,10 %	8,76 %	10,29 %	-0,384/0,7040	9,26 %	6,67 %	0,339/0,7279
1.5 Readiness		6,70 %	7,37 %	4,41 %	0,854/0,3953	6,30 %	13,33 %	-1,064/0,2819
2.0 Technology		**29,10 %**	**28,57 %**	**30,88 %**	**-0,366/0,7114**	**29,63 %**	**20,00 %**	**0,799/0,4237**
2.1 Connectivity		16,80 %	16,59 %	17,65 %	-0,203/0,8415	17,04 %	13,33 %	0,373/0,7114
2.2 Network/Infrastructure		12,30 %	11,98 %	13,24 %	-0,275/0,7872	12,59 %	6,67 %	0,681/0,4965
3.0 Costs		**16,50 %**	**16,13 %**	**17,65 %**	**-0,294/0,7718**	**15,93 %**	**26,67 %**	**-1,091/0,2757**
3.1 Direct Cost		7,00 %	5,99 %	10,29 %	-1,212/0,2263	6,67 %	13,33 %	-0,984/0,3271
3.2 Potential savings		8,40 %	9,22 %	5,88 %	0,864/0,3898	8,15 %	13,33 %	-0,704/0,4839
3.3 Profitability for the industry		1,10 %	0,92 %	1,47 %	-0,387/0,6965	1,11 %	0,00 %	0,4104/0,6818
4.0 Enviroment		**6,00 %**	**5,53 %**	**7,35 %**	**-0,554/0,5823**	**6,30 %**	**0,00 %**	**1,002/0,3173**
4.1 Enviroment concern		6,00 %	5,53 %	7,35 %	-0,554/0,5823	6,30 %	0,00 %	1,002/0,3173
5.0 Goverment		**2,10 %**	**2,76 %**	**0,00 %**	**1,385/0,1645**	**1,48 %**	**13,33 %**	**-3,112/0,0018**
5.1 Goverment/policy regulation		2,10 %	2,76 %	0,00 %	1,385/0,1645	1,48 %	13,33 %	-3,112/0,0018

Appendix 4 – Preliminary Thesis Report

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Preliminary thesis report

- Innovation prediction -

A meta-analysis of wrongly predicted innovation

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Erik Olson

Content

1.0 Introduction

"Never before in history has innovation offered promise of so much to so many in so short time"

- Bill Gates

Over the past decades, several researchers have tried to predict the future of the world through innovations. We have seen many innovative technological trends through the course of history, and researchers, managers and the common man have tried to predict this development. It is not uncommon to read about "the next big thing" within technology, where statements indicate that this will be wildly adapted and it might sometimes sound like the new trend will take over society. The overall findings from several studies however, are that researchers are often wrong when trying to predict the adoption and diffusion process of new technological innovations. The tendency seems to be for researchers to underestimate the time perspective of the technological maturation process and thereby miss in their predictions of innovation commercialization with a given number of years.

"The most reliable way to forecast the future is to try to understand the present"

- John Naisbitt

The phenomenon of miss-prediction of innovation adoption and commercialization seems to be evident when it comes to several areas of technological innovations. For instance, in the research literature, we find examples of such miss-predictions within the area of electric fuel and smart homes. Some researchers argue that one of the reasons behind these errors in predictions of innovations stems from the fact that the current theory of innovation processes is rather superficial. The issue arises from the concern that theory indicates that a universalistic theory of the innovation process can be developed that applies to all types of innovations. The search for a universalistic theory may be inappropriate given the fundamental differences that exist across innovation types (Downs and Mohr 1976). The fact that one can find examples of prediction errors within several areas of technological innovations, indicates that there seem to be some common ground for mistakes leading to this phenomenon.

The authors of this paper therefore aim to identify the most important factors that predictions of innovation adoption and commercialization are built upon and identify sources of mistakes.

In addition to identifying factors of innovation adoption, this paper will be focusing on the development and adoption of so-called smart technology and smart homes in particular. “As this technology is still evolving, there are neither an appropriate definition of a ‘smart home’ nor an exact distinction from similar systems or terms used in relation to ‘smart homes’” (Chan et. al, 2009) . However, several researchers have tried to defined the term. Some defines Smart Homes to be a home which is capable to react ‘intelligently’ by anticipating, predicting and taking decisions with signs of autonomy (Augusto and Nugent, 2006). These Smart Homes could potentially replace many routine everyday tasks. If we are to believe many movies, popular press and articles, these homes can be so fully automated and “smart” that we in many aspects of life do not need to think about everyday tasks at all. As Smart Homes is a relatively “new” innovation, which is still evolving, it is a good fit for being the dependent variable of the current study.

As the prediction error related to innovation adoption is still present today, the main contribution of this paper is to try to close this gap. By conducting a comprehensive meta-analysis of relevant literature within the field, the authors will aim to identify the most important factors inhibiting and enhancing the commercialization, adoption, and accurate diffusion prediction of innovation, and based on this; develop and present a theoretical framework in order to highlight factors leading to such prediction errors among researchers and managers. The goal is that this framework can be used to better predict the adoption and commercialization of new innovations in the future.

2.0 Literature review

In order to get a more comprehensive understanding of the phenomena that is to be investigated, this paper will start with a review of previous and current literature of relevant topics. The literature review will begin with looking at the concept of innovation, and identify the characteristics and the classifications related to this. It will also review the literature of smart technology and smart homes in particular, and briefly look into the supporting infrastructure such as the

Internet of Things. Furthermore, a more comprehensive review of the theories of product- and market adoption and the diffusion process will follow. The aim is that this will give the authors a better foundation for conducting the proposed meta-analysis and answering the following research question:

"What factors inhibit and enhance the commercialization, adoption, and accurate diffusion prediction of innovation."

Through this we will identify which most important factors inhibit and enhance the commercialization, adoption, and accurate diffusion prediction of innovation.

2.1 Types of innovation

> *"Innovation takes place via a process whereby a new thought, behaviour, or thing, which is qualitatively different from existing forms, is conceived of and brought into reality"*
>
> \- Robertson, 1967

Past research has argued that distinguishing between the different types of innovation is essential in order to understand the adoption of a given innovation (Downs & Mohr, 1976; Knight, 1967; Rowe & Boise, 1974). Among the numerous typologies of innovation advanced in the relevant literature, three have gained the most attention: administrative and technical, product and process, and radical and incremental.

The different classification between administrative and technical innovations is important because it relates to a more general distinction between social structure and technology (Evan, 1966). Henceforth, it implies that different decision making processes (Daft, 1978) can help to understand how managers think and why they predict wrong when it comes to innovation. Technical innovations refer to products, services, and production process technology. In other words, they are related to basic work activities (Damanpour & Evan, 1984; Knight, 1967). Administrative innovations concern organizational structure and administrative processes and are related to the basic work activities within an organization.

Another reason for why managers and researchers are predicting innovation wrong could be the fact that the adoption of products are different during the stages of developing of a business (Utterback & Abernathy, 1975). Product innovation can be defined as: new products or services introduced to meet an external user or market need, and process innovations are new elements introduced into an organization's production or service operations-input materials, task specifications, work and information flow mechanisms, and equipment used to produce a product or render a service (Knight, 1967; Utterback & Abernathy, 1975).

Damanpour et al (1991), state that the radicalness of innovation could also moderate the determinant-innovation relationship. The adoption of a certain innovation changes the structure of organizations. On the other hand, the extent of these changes is not equal for all innovations. Henceforth, innovation can be differentiated according to the degree of change they influence.

Theoretically, one can distinguish between radical and incremental innovation introduction and adoption. One factor that separates the two is whether or not the innovation incorporates technology that is clearly different from existing practice (Hage, 1980). One of the theoretical typologies that have emerged in the literature on organizational innovation is the dichotomy of radical versus incremental innovation introduction and adoption. If a technology is new (Daft and Becker 1978), or if it requires both process and product/service change (Hage 1980), the magnitude and cost of change required by the organization is sufficient to justify the designation of a rare and radical innovation.

Furthermore, researchers have suggested differences between predictors of the adoption of radical and incremental innovations. For example, managerial belief towards change and technical knowledge resources has been expected to facilitate radical innovations (Dewar & Dutton, 1986; Hage, 1980), whereas structural complexity and decentralization should lead to incremental innovations (Ettlie et al., 1984). Both radical and incremental innovations have varying levels of contribution to the effectiveness of an adopting organization. To illustrate, the manufacturing sector in the 1960s and 1970s, the success of Japanese companies could in part be attributed to the introduction of incremental innovations, whereas the success of American companies could be associated with the insertion of radical innovations (Hull et al., 1985).

Henceforth, the different types of innovation play a huge factor in the way consumers adopt them, and thereby what factors will be crucial in order to predict the time aspect of the innovation.

2.2 Characteristics of innovation

In order to fully understand what kind of factors that are inhibiting and enhancing innovation commercialization, adoption, and accurate diffusion prediction, it is necessary to get a grasp on the different characteristics of innovation. Zaltman, Duncan, and Holbek (1973) have identified around 21 characteristics of innovations, which were drawn primarily from studies on the diffusion of innovation.

Based on a review of 75 studies, looking at the relationship between perceived innovation characteristics and innovation adoption, three characteristics of innovations were identified. These are: compatibility, relative advantage, and complexity, and are believed to have the most consistent significant relevance for innovation adoption (Tornatzky and Klein 1982). Furthermore, Downs and Mohr (1976) identified that innovation characteristics can be distinguished between primary and secondary attributes. Primary attributes enable differentiating innovation between organizations, while secondary attributes enable differentiating innovations within organizations (Wilson, Ramamurthy, and Nystrom 1999,311). In other words, innovation characteristics can be explained by two constructs: a macro construct that reflects the characteristics that facilitate or inhibit innovation adoption by organizations, and a micro construct that reflects the perceived characteristics by members of the organizational that facilitate or inhibit innovation use (Damanpour and Schneider, 2009).

2.3 Smart Homes

> *"Without technology humanity has no future, but we have to be careful that we don't become so mechanised that we lose our human feelings."*
>
> \- Dalai Lama

In the recent years, the term Smart Home has received more and more attention in research and in popular media. However, as mentioned before, the term Smart Home can be vague and hard to precisely define. The American Association of House Builders first introduced the term back in 1984. However, the first "wired homes" were built by hobbyists as far back as the 1960s (Aldrich, 2003). Their development is key to what is meant by Smart Homes, as a home is not smart because of how well it is built, how eco friendly it is or how efficiently it uses it space. Even though a Smart Home may include a lot of these things, what makes a home truly "smart", is the interactive technologies that it contains.

Developers, researchers and managers have predicted several features and abilities of Smart Homes. Examples of such predictions are for instance "a robot chef" like Moley that can, by motion tracking, cook meals to perfection. Smart fridges are another innovation included in the Smart Homes, where the fridge is linked to both your phone (for notification on low supplies etc) and your supermarket (to reorder). When it comes to the toilet, some variations of smart toilets are already on the market. However, MIT SENSEable City Lab is working on a toilet that can not only recognise the be-throned, but also analyse its excrement to shed light in the state of the consumer's health. Furthermore, innovators are currently working on smart mattress. These mattresses cannot only track sleep patterns, but also sleeping rate and heart beat (Davis & Davis, 2015).

2.4 The Internet of Things

The Internet of Things (IoT) is a novel paradigm that is quickly gaining ground in the modern wireless communication (Atzori et al., 2010). Even though there is no exact definition of IoT, The International Telecommunication Union (ITU) have made an attempt to defined it as: "a global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies'' (ITU 2012).

Extending this original application scope, the Internet of Things also serve as the key ingredients for ubiquitous computing, enabling smart environments to recognize and identify objects and retrieve information from the internet to facilitate their adaptive functionality. Through this, everyday objects (such as cars, refrigerators etc.) will be able to communicate with each other (Weber and Weber, 2010).

Even though IoT is a concept which is broadly known, the question has been raised of why the IoT does not already exist in a broader extent among consumers. One of the reason may be that the IoT market is not yet well-quantified. For example, Intel states that there were 15 billion connected IoT devices worldwide in 2015, a number chipmaker predicts to be at 200 billion by 2020. On the other hand, Gartner counted less than 5 billion devices in 2015 and predicts less than 21 billion by 2020 (Bershidsky, 2017) These discrepancies in the predictions illustrates some of the difficulties related to innovation prediction, and thereby highlights the importance and contribution of this paper.

2.5 Product Adoption and Diffusion Process

In the current research literature, it has been written a lot about the product life cycle and how a new successful product will go through various stages, typically described as introduction, growth, maturity and decline. The underlying concepts related to this life cycle are the adoption process and the diffusion process. The adoption process can be described as the decision sequence that a potential user or organization goes through when adopting an innovation (McIntyre, 1998). Innovation diffusion on the other hand, describes the way in which a product or an innovation is passed along from one individual or organization to another, and can be defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 1983). Rogers describes the diffusion process as an orderly sequence of events, and proposes a diffusion curve, which is essentially a normal curve of distribution.

The rate of diffusion, or rate of adoption of a new product or concept, is the relative speed to which members of a social system adopt the innovation. Such an adoption rate is generally measured as the number of individuals who adopt the innovation within a specified time period (Brancheau & Wetherbe, 1990). Innovation diffusion research indicates that within a social system, the number of individuals adopting within a given period of time roughly follows a normal bell-shaped curve (Rogers 1983). Furthermore, consumers differ from each other with regards to the concept of innovativeness and adopter categories. Innovativeness is the relative earliness or lateness that an individual adopts an innovation compared to other members of the social system. This distinction leads the potential adopters to be classified into five categories labelled as pioneers, early adopters, early majority, late majority, and laggards (Brancheau & Wetherbe, 1990). To a large degree, the purpose of the diffusion model is to describe the successive increases in the number individuals or organizations to adopt a new innovation, and thereby predict the continued development of a diffusion process already in progress (Mahajan et al 1990).

2.5.1 Heterogeneity

Another important aspect related to the diffusion process is the fact that the diffusion of an innovation in a population involves adoption by individuals in the relevant population, which most often are relative heterogeneous. Whether to adopt or not involves a deliberate choice decision by the individual, especially in the case of high involvement products, and heterogeneity in the population suggests systematic differences in the adoption process (Chatterjee & Eliashberg, 1990). The traditional mathematical model proposed by Bass (1969) assumes that the potential adopter population is homogeneous, which implies that, at any point in the process, all individuals who are yet to adopt the innovation have the same probability of adopting in a given time period This means that differences in individual adoption times are purely stochastic (Tanny & Derzko, 1988). An alternative micromodeling approach proposed by Chatterjee and Eliashberg (1990) aims to explicitly consider the determinants of adoption at the individual level while allowing for heterogeneity with respect to such determinants across the population (Chatterjee & Eliashberg, 1990). Failing to account for heterogeneity of the population in the adoption process may contribute to prediction errors.

2.5.2 Why do organizations adapt innovations?

It is not only on the individual level that innovations are adopted. New products or new innovations are also adopted by organizations. Within the research literature on new product and innovation diffusion, it has long been recognized that the number and the increase in the number of organizations that adopt an innovation influences the remaining organizations, and whether they will follow with the adoption as well (Mansfield, 1961). There are at least two theories that aim to explain this phenomenon. Theories of rational-efficiency assume that organizations make rational choices of whether to adopt an innovation or not based on available information about the technical efficiency or returns of the given innovation. An important factor related to this is whether one makes the assumption of complete information or not (Abrahamsen & Rosenknopf, 1993). Advocates of such theories assuming complete information, argue that as the number of adopters of an innovation increases, its costs decrease or its returns increase, causing more adoptions by other organizations. Some theorists argue that returns may increase because of network externalities (Farrell & Saloner, 1985). Supporters of rational-efficiency who assume incomplete information argue that as the number of adopter organizations increases, the more knowledge of the benefits of the innovation is generated and spread, which again leads to more new adopting organizations.

Rational-efficiency theories have two main limitations. First, even though information about who has adopted an innovation spreads rapidly among competitors, there are many circumstances in which such information about the technical efficiency or returns of an innovation will not always influence non-adopters' decisions to adopt. Furthermore, in order for this to influence non-adopters' decisions, information must flow through channels from early adopters to non-adopters. For this to happen, there are several conditions that must be met. There must exist information, channels for this information to be spread through, a propensity of early adopters to spread this information, and a propensity of non-adopters to be influenced by it. If any of these four conditions are not met, then new product or innovation diffusion cannot be explained by rational-efficiency theories (Abrahamsen & Rosenknopf, 1993).

The second main limitation of such theories is that they reinforce pro-innovation biases (Abrahamson, 1991). What lies in this is that the theories' assumption that organizations makes rational choices of whether to adopt based on available information of the given innovation indicates that they are also capable to efficiently detect ineffective innovations and reject these accordingly. Such theories therefore fail to explain why organizations sometimes adopt inefficient innovations or why they reject innovations that are indeed efficient or profitable.

The other branch of theories that tries to explain why an increase in the number of organizations that adopt an innovation influences the remaining organizations and whether they will follow with the adoption as well, is the so-called theories of fads. In contrast to rational-efficiency theories, theories of fads assume that organizations choose to adopt an innovation based on whether other organizations have adopted it, rather than the technical efficiency or returns related to the innovation itself (Abrahamsen & Rosenknopf, 1993). One such theory is related to the so-called bandwagon effect. When a number of organizations adopts an innovation, this can eventually lead to a bandwagon effect, where pressure is created for other organizations to do the same. According to research, one say that a bandwagon occurs when a given organization adopts an innovation because of such pressures, rather than an individual assessment of the benefits provided by the innovation itself. The same way one say that a counter-bandwagon effect occurs when organizations reject an innovation because of bandwagon pressure, rather than their updated assessments of the innovation. The pressure from the bandwagon can both be institutional, where non-adopters fear being perceived as different from adopters, and competitive, where non-adopters fear the potential disadvantage in the market compared to the adopters (Abrahamsen & Rosenknopf, 1993).

Bandwagon effects can play an important role when trying to predict the adoption process of an innovation in a given population, and by using mathematical models like the one proposed by Abrahamsen and Rosenknopf (1993), one can examine how certain characteristics of organizations can determine whether such bandwagon effects will occur, how many organizations that are expected to be affected by this effect and how many of them will retain the innovation. Theories of bandwagons suggest that the strength of bandwagon pressure increases with the number of adopters. The level of ambiguity, however, moderates this main effect. According to Abrahamsen and Rosenknopf, ambiguity is the main factor moderating the impact of the number of adopters on the strength of bandwagon pressures, and is defined as the lack of clarity surrounding an organization's assessment of an innovation. The proposed mathematical model therefore models bandwagon pressure as the product of ambiguity and the number of adopters. In sum, to briefly explain the model proposed by Abrahamsen and Rosenknopf, assessed returns, ambiguity, and the number of adopters influence an organization's decision of whether to adopt an innovation according to the following equation:

$$B_{i,k} = I_i + (A_i * n_{k-1}),$$

Where $B_{i,k}$ is organization i's "bandwagon assessment" of the innovation, in bandwagon cycle k. I_i and A_i denote, respectively, organization i's individual assessment of the innovation and the ambiguity about this innovation. The bandwagon pressure during cycle k is denoted by the product of the level of ambiguity, A_i, and the proportion of adopters, n, after k - 1 cycles. The number of organizations in a collectivity that must adopt in order to prompt organization i's adoption is such that the bandwagon assessment, $B_{i,k}$ exceeds the adoption threshold (Abrahamsen & Rosenknopf, 1993).

In contrary to the theory of the bandwagon effect, some theories suggest that when the number of adopters is quite high, a so-called snob effects may occur. This means that certain organizations with the intent of standing out or appear different from the masses may feel increasing pressure to reject an innovation, as more and more organizations choose to adopt it (Abrahamson, 1986).

2.5.3 Market Adoption

The traditional literature on product life cycle has placed less importance on the role of the development of relevant infrastructure to support the given new product or innovation. However, the development of such associated infrastructure is often crucial when it comes to development of high technology innovations, as it reflects society's adoption of the potential of the new product. Such so-called market adoption process is defined as the "development, by other members or organizations in society, of supporting products or services to capitalize on the actual or potential adoption of some original innovation" (McIntyre, 1988).

The market adoption process has potentially strong implications when it comes to forecasting and predictions of the adoption and commercialization of new innovations. Failure to take the market adoption process into account can lead to forecasting errors that tend to overestimate short-run market potential, and underestimate long-run market potential. One reason for this might be that traditionally, market potential has been viewed as a statistic concept and thereby often considered to be fixed at a too high level for the initial period, and a too low level for the long run. In light of the market adoption perspective however, market potential is considered to be more dynamic, and focuses on the fact that not only does it take time to penetrate the market potential, it also takes time for the market potential itself to develop. This means that even though the market potential is fixed at any given point in time, the key aspect related to forecasting is that such potential will shift in predictable ways and for predictable reasons as the market adoption process develops itself (McIntyre, 1988).

3.0 Method

3.1 Source of data

The method to be used for this thesis will be a meta-analyses, which will involve computer based and manual methods. This method is appropriate when one is trying to broaden the base of studies in some way, expand the question, study the pattern of answers and combine data from several studies to estimate the common or mean effect (Borenstein et. al., 2009). A literature search should be conducted to identify published criterion-related validity studies of innovation (more precisely innovation within Smart Homes) for the time period 1970 - 2017. The following strategies should be used to search for relevant literature. First, a computer search should be done through Google Scholar, which will include published work that has undergone peer review. Second, a manual screening of the article should be done to check the sources cited in the literature review, books and articles. Lastly, contact in form of e-mails could be sent to researchers in the domain asking for their published and unpublished work or input on the subject.

Our research should generate a huge amount of published and unpublished studies, where we should evaluate the measures of the relationships among the variables researched. Some keywords that could be used in the search is: "Smart homes", "Smart Homes past present and future", "Smart Homes review", "innovation", "innovation prediction", "IoT", "Internet of Things" etc.

Studies should be included in the meta-analysis if they meet the following criteria: (1) the article/papers is about innovations preferable innovation within smart homes. (2) The articles/papers were published in a scholarly book or journal, or popular media which is quality checked. Using these criteria hopefully produced a group of several empirical studies, articles, popular media and books.

3.2 Proposed analysis of data

After having completed the meta-analysis and identified and mapped up the relevant factors, the researchers could use different statistical analysis as correlation on the data. After a correlation is calculated, the next step of the analysis should be to decide whether or not moderating variables should be introduced. This is a decision the authors need to make after having identified the source of data, before starting the analysis.

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