



Vaasan yliopisto
UNIVERSITY OF VAASA

Moritz Aalto-Setälä

**Innovations of the vehicle manufacturers and
diffusion of it on the basis of their annual reports**

School of technology and innovation
Master's thesis in Discipline
Industrial Management

VAASA 2020

UNIVERSITY OF VAASA**School of technology and innovation**

Author:	Moritz Aalto-Setälä		
Title of the Thesis:	Innovations of the vehicle manufacturers and diffusion of it on the basis of their annual reports		
Degree:	Master of Science in Economics		
Programme:	Industrial Management		
Supervisor:	Ville Tuomi		
Year:	2020	Pages:	72

ABSTRACT:

The automotive industry has changed significantly over the years, and is still facing major transition, due to the various driving forces associated with it. The biggest factors affecting the vehicle sector are the new, more environmentally friendly powertrain systems and intelligent technology. Vehicle companies are aware that concerning these changes, they need to bring ever better innovations to the market. As a result, they have begun to develop innovations, such as electric cars, and at the same time increasing the number of them in their production, to meet the regulations brought by climate change, and especially to create an unpolluted future mobility.

The aim of this research is to find out what different innovations vehicle companies are developing as well as have already brought to the market. In this context, the research examines how these emerging innovations have diffused in the automotive industry over the last 10 years. Two well-known vehicle companies, Toyota and BMW, have been selected as the case companies of this thesis, and the research has been carried out utilizing the annual reports of these two companies since 2009.

The theoretical framework of the research is based on the diffusion of innovations, and how innovations are adopted. An important feature of innovation is that its diffusion usually takes place gradually among different adopters. This supports the aim of the research and at the same time it highlights the significance of time in the diffusion of innovations, which is well reflected in the comparison of the annual reports for the 10-year period.

A considerable part of the data in the annual reports is in text form, so the main research method of this thesis is qualitative. However, to support qualitative research, the thesis will also use a slight amount quantitative research method, when comparing company figures with each other.

The research shows that vehicle manufacturers have developed innovations such as electric cars, and in particular different variations of them, connectivity, autonomous driving, and mobility services. Some of these innovations have been seen in a few cars in the past, but in recent years their importance in the automotive industry has grown remarkably. Case companies have taken these innovations pretty much in the same way into account in their development and operations, but few differences can be also found, such as the approach of electric car variations and how they see the future in that sector.

KEYWORDS: Innovation, adoption, diffusion & vehicle industry

Contents

1	Introduction	6
1.1	Research background.....	6
1.2	Aim of the research	8
1.3	Research questions.....	9
1.4	Structure of the research	10
2	Diffusion of innovations	11
2.1	History of diffusion	12
2.2	Innovation	15
2.2.1	Characteristics of innovations	17
2.2.2	Closed vs. open innovation.....	18
2.2.3	Research and development (R&D)	20
2.3	Communication channels	20
2.4	Innovation-Decision process.....	21
2.5	Adoption categories of innovations	24
2.5.1	Innovators.....	26
2.5.2	Early Adopters	27
2.5.3	Early Majority	28

2.5.4	Late Majority	29
2.5.5	Laggards.....	29
2.6	Summary of the theoretical background.....	31
3	Implementation of the research	33
3.1	Research method	33
3.2	Research material and its acquisition.....	34
4	Research results.....	37
4.1	Case companies	37
4.1.1	Toyota.....	37
4.1.2	BMW	38
4.2	R&D comparison.....	39
4.3	Research of annual reports	40
4.3.1	Toyota 2009-2019.....	41
4.3.2	BMW 2009-2019.....	46
4.4	Innovation findings and their comparison between companies....	52
4.5	Evaluation of the diffusion of innovations in the automotive industry	54
5	Conclusions	58
	References.....	62
	List on data used in the research	71

ABBREVIATIONS

BEV	Battery electric vehicle (100% electric powered vehicle)
EV	Electric vehicle
FCEV	Fuel-cell electric vehicle
HEV	Hybrid electric vehicle
ICT	Information and communications technology
IoT	Internet of Things
PHEV	Plug-in hybrid vehicle
R&D	Research and development

LIST OF FIGURES

Figure 1. Diffusion curve of innovations. Rogers (2003.)

Figure 2. The characteristics of innovations. (Rogers 2003.)

Figure 3. Closed vs. open innovation. (Bigliardi, Dormio & Galati 2012.)

Figure 4. Innovation decision-process. Rogers (2003.)

Figure 5. Innovation adoption categories. Rogers (2003.)

LIST OF TABLES

Table 1. R&D expenses and their share of total revenues.

Table 2. Diffusion of electric vehicles.

1 Introduction

1.1 Research background

History books show that the world has been afflicted by several crises, from wars to pestilences, and even to this day, the globe is facing crises on a regular basis, whether they affect the economy or human health. However, one of the most significant of the crisis is climate change, which has been on the table for a long time. The climate is warming at a steady pace and this is affecting everyone's lives as it causes changes in weather conditions such as heavier rainfall as well as increasing drought. Due to warming, glaciers are melting, raising sea levels and due to drought, forest fires are also becoming more common. (Baldwin and English 2020.)

The release of various gases, such as carbon dioxide, into the atmosphere is a major factor contributing to climate change. These gases let the sun's rays pass them to the ground, but don't let them return into space so easily. As a result, more heat radiation left in the atmosphere, which warms the climate. Industry is one the largest emitters of carbon dioxide, also known as CO₂, and covers up to a quarter of its emissions. The transport sector is also considered to be a fairly large consumer of fossil fuels, which generate harmful CO₂ emissions. (Hannappel 2017.)

To reduce the use of fossil fuels, many countries have joined various climate agreements aimed at reducing the use of fossil fuels and increasing the use of renewable "green" energy. This has led companies, such as vehicle manufacturers, to think more about low-emission traffic and, ultimately, a zero-emission future. Hannappel (2017) states in his article that car companies have therefore begun to develop and manufacture alternative powertrain choices for their vehicles, such as electric cars. As an innovation, the electric car is quite old, as already at the beginning of the 20th century, about 25% of vehicles

was powered by electricity. However, they disappeared from the market for decades due to their expensive manufacturing as well as short driving distance. (Hoyer 2008.)

The cityscape has changed over time as the population has grown and this has caused overcrowding in some of the big cities. The number of vehicles, and their ownership, has increased really much, increasing the beforementioned emissions, but also other problems such as traffic jams and parking difficulties. Studies show that up to half of urban mobility is done using private vehicles. These figures are expected to increase further due to the growth of cars in developing countries. Car manufacturers as well as many other companies have taken these issues into account in their operations, especially in the development process, and are trying to come up with ever better solutions to these problems. (Soltani 2017.)

The continuous progress of digitalisation is also one of the significant features in the development of vehicles and their use. The analog meters of cars have replaced to digital as well as more and more functions in today's vehicles are handled through large touch screens. Digitalisation has brought the functions of everyday life more into a network that has created connectivity in almost all industries. With connectivity, an increasing amount of information is transferred between various parties over the network, and nowadays, several things can be controlled and monitored via the Internet, which is also known as Internet of Things or IoT. (Marcu, Suciu, Balaceanu, Vulpe and Dragulinescu 2020.)

Marcu (2020) et al. states in their article that the IoT has increased the use of the "smart" prefix in front of several words, such as smartphone, smart city and smart home. These are thus able to interact via the Internet, creating different groupings with each other. Traffic and its vehicles are also increasingly integrated into a network that generates, above all, safety and the provision of many new services to people in traffic.

These previously mentioned factors affect greatly to the operations of today's car manufacturers. They need to take these into account when developing new vehicles as well as services for them. The market is facing a constant transformation as new technologies emerge, and the changing needs of consumers also play a major role in contemplating future mobility. Several vehicle brands are now investing more in the innovation and R&D activities, as they compete with each other, for who can develop better and safer cars, to meet the needs of a changing world, through various innovations. (Hardman, Steinberger-Wilckens & Horst 2013.)

1.2 Aim of the research

The aim of this master's thesis is to get acquainted with the innovations of vehicle manufacturers and to provide information on how the innovations have diffused to production and the market. Innovation is a major part of car brands' activities, as they create a competitive advantage over other companies. This research also takes into consideration how technological innovations are developed over a certain period, which in this case is ten years.

This research is an empirical case study that focuses on innovation, and the theoretical framework of the research consists of innovation theory, especially the diffusion of innovations. The research is carried out by examining the annual reports of car manufacturer companies, in which they report on their innovation activities in that specific year. In the theoretical part of the thesis, the term innovation as well as the diffusion of innovation are introduced in more detail so that the reader gets a clear understanding of the topic.

1.3 Research questions

The automotive industry is constantly facing changes, and it seems that in recent years, vehicle brands have taken great strides in matters related to the operation of cars. These operations include many various things, one of the most significant of which is innovation. Automakers are developing these innovations to respond to global changes, some related to climate change mitigation and some to digitalisation. Led by this, the thesis presents information on what innovations vehicle manufacturers are developing and bringing to the market, and therefore the main research question is:

- *What innovations does the vehicle manufacturers disclose in their annual reports and how innovations diffuse among car brands?*

The automotive industry has always been a great interest to me and the innovation courses I have taken at university have made me want to study these two subjects in the same context. Additional questions are:

- *What are the differences and similarities between vehicle brands in terms of their innovation?*
- *How the disclosed innovations have diffused to production and how has the innovations evolved during time?*

In order to get answers to these research questions, I will study reports and documents published by these three companies as well as articles published by other parties in this regard.

1.4 Structure of the research

The thesis begins with an introductory section, which reviews the background of the topic and presents the aim of the research. This section also presents research questions that will be answered at the end of the thesis. A small part of theoretical framework is also presented in the introduction. The second chapter comprises the theoretical part related to the research in its entirety. That chapter contains the diffusion theory of innovations, that is, how innovations spread. Diffusion is strongly associated with the adoption of innovations and is addressed in more depth in the theoretical part when the categories of adopters are explained in detail.

In the third chapter, the research method and the material used in the thesis are presented. The fourth chapter deals with research material, which means reviewing the annual reports from year to year and on the basis of them the research results are examined. This chapter also provides a better introduction to case companies and their technological innovations. The last chapter of the thesis is the conclusion, which state the research results and also consider their reliability, as well as ideas for further research.

2 Diffusion of innovations

Many may have heard the term diffusion used in some context, but still they may not fully understand what it means, so at first it is essential to have a glance at this term a little more closely. A word “diffusion” is usually seen used in chemistry or biology, and according to the Cambridge Dictionary, it is considered as the movement of spreading in many ways and as a process of spreading in which two substances mix with each other. In addition, the term diffusion is often associated with innovation.

The diffusion of innovation is considered one of the oldest scientific study theories of human beings and the guru of this theory can be considered to be a man named Everett Mitchell Rogers. Rogers grew up with his family on their farm in the State of Iowa and during his agricultural studies in high school and in the university, he had the opportunity to learn about various new technologies. Rogers then quickly realized that some of these new technologies would be a great help to farmers, but Rogers was left to marvel at one significant thing – his father or other neighbouring farmers didn’t adopt these new technologies. This aroused Rogers’ interest in further research and he wrote a university’s graduate dissertation on the diffusion of agricultural innovations in Iowa. (McGrath & Deone 2001.)

During in the process of writing his dissertation, Rogers found that the diffusion research was not only limited to farmers, as it had already been the subject of a few medical studies. McGrath & Deone (2001) write in their article that Rogers’ interest regarding in diffusion research grew more and more, and that led him to write a book called ‘Diffusion of Innovations’ which was published in 1962. The content of the book covers all the key factors regarding the diffusion theory of innovation and because it deals with a so-called new kind of study theory, its popularity increased a lot. A total of five editions of Rogers ‘Diffusion of Innovations’ book were published, and the latest edition was released to the market in 2003.

According to McGrath & Deone (2001) Rogers' innovation studies have greatly shaped people's thinking about diffusion, and thanks to it, many other researchers have also taken innovation diffusion studies as their research subject. Rogers himself defines diffusion as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers 1995: 5).

By exploiting the diffusion theory of innovations, commonalities with product life cycles can be observed. That is when a product enters the market, only a few will take advantage of it and finally, when most have adopted it, the product has reached the end of its life cycle. (Agarwal, Anand, Bansal & Pathak 2019.)

The diffusion of innovation is combined by four inherent factors which, together, enable the diffusion of innovations between other parties and individuals. Rogers (2003) clarifies that these four factors that create diffusion are: *innovation, communication channel, time* and *social system*. These factors are explored in more detail, but before that, a little more attention is paid to the history of diffusion.

2.1 History of diffusion

In his book 'Diffusion of Innovations', Rogers (1995) points out that one of the initial researchers of the diffusion of innovation study is Gabriel Tarde. Tarde (1843-1904) was a Frenchman and he worked as a lawyer by profession, but at the same time he was also known as a truly active sociologist. Tarde's interest towards diffusion originated when ethnologists as well as human scientists in Europe began to investigate the matter in more detail in the early 19th century. Gabriel Tarde found himself having a similar mind with these human scientists regarding ideas that they brought up. (Kinnunen 1996.)

At his work in the courtroom, Tarde had a habit to observe culture tendencies, and soon he noted that individual imitations had similar features to each other. The indicated

finding influenced him remarkably, which encourage Tarde to write a book “The Laws of imitation”. This ‘*laws of imitation*’ began to be better known as the diffusion of innovations, and nowadays the word *imitation* used by Tarde means the adoption of innovations. (Rogers 1995: 39-40.)

Tarde was particularly amazed why only a tenth of innovations will spread and the rest are forgotten by people. Examining the amount of coffee people drink, Tarde found out that its diffusion follows a S-shaped curve. Kinnunen (1996) writes in his article that Gabriel Tarde was able to explain this resulted diffusion curve by the fact that first the wealthy people are able to consume coffee, mostly because of the high price. Over time, raw materials become cheaper and this makes coffee more common, so other consumers will also adopt the use of coffee.

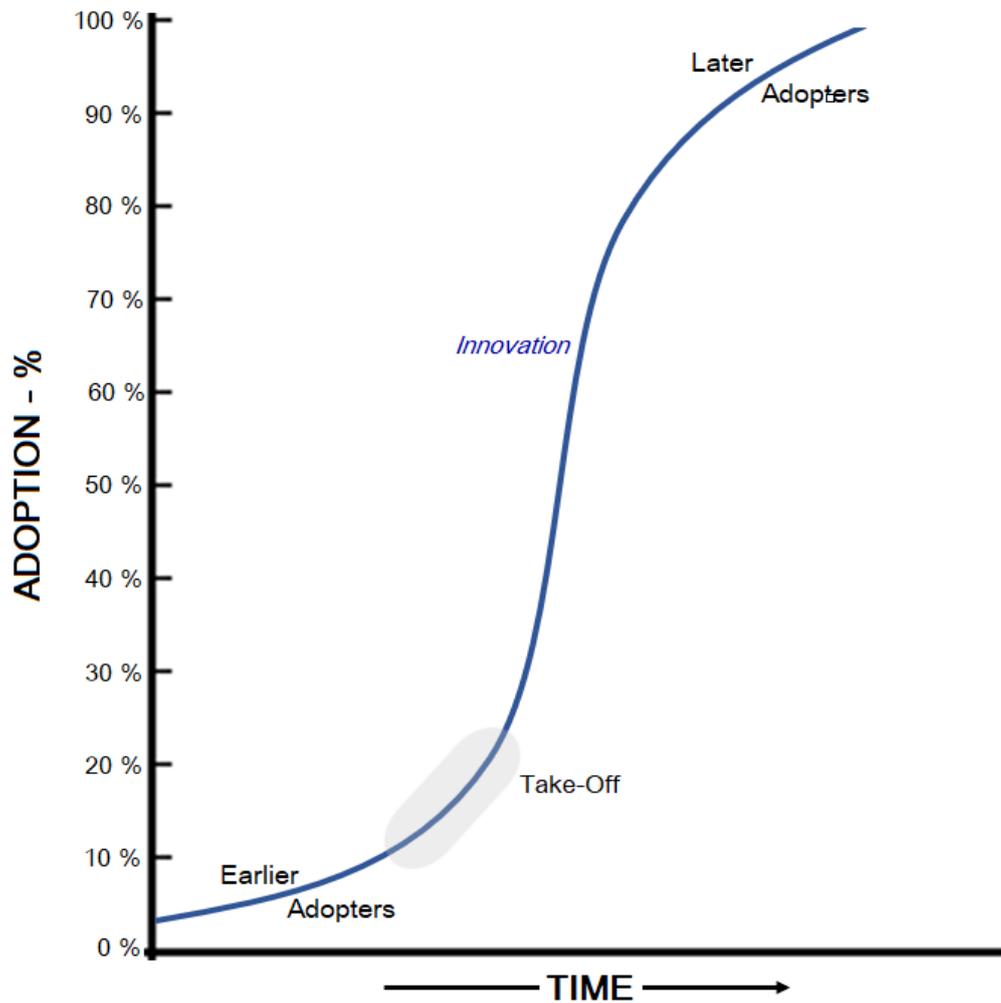


Figure 1. Diffusion curve of innovations.

At the beginning of diffusion studies, researchers focused on examining a specific branch of science. According to Rogers (1995), this means for example, that researchers whose field of study is education, explored the diffusion of new teaching methods among school teachers. Researchers from these studies also noticed that the diffusion curve of innovation was following the S-shaped curve. Rogers explains that the S-shaped diffusion curve is formed when initially only a few people adopt a new thing or idea,

making the spread rate slow, but over time the adoption increases rapidly when a large proportion of members of society put the innovation in use, after which the adoption rate slows down.

Examining the diffusion curve of innovations, Gabriel Tarde noticed at the beginning of the curve the so-called Take-Off part, where the growth starts to rise. This happens when the leaders of different organizations began to take advantage of the new idea. The adoption rate of innovation takes-off usually between 10 to 25 % in the curve. Tarde figured out that the innovation is first adopted by individuals who are socially closest to the source of this new idea, and after that it begins to gradually spread from a higher position to lower classes. (Rogers 1995.) The adoption categories of innovation will be presented in more detail later in this thesis.

In Figure 1, the diffusion curve that appears is only an illustrative graph of a specific innovation, as it is important to realize that the S-shaped curve may be steeper or more gently sloping at different points depending on the innovation.

2.2 Innovation

Innovation – a familiar concept to many, but what exactly is it. Part of individuals might explain it to be some kind of invention, while others interpret it with R&D (research and development), and they are partly right (Hawkins, Blind & Page 2017). Invention and innovation are commonly seen as the same thing mixed with each other in various contexts, but the two can be distinguished. An invention emerges when, and only when, a new idea is created. Innovation, on the other hand, is more encompassing, because it consists of the whole process of developing the new idea and its implementation. (Van de Ven, Polley, Garud & Venkataraman 1999.)

There are many definitions of the term innovation, which Everett M. Rogers (2003) defines as something that a person or other unit of the adoption group considers to be new, while Van de Ven (2017) defines it to be “unique new ideas that are implemented”. It can be thought of as an item, idea, technology and in addition to these also teaching method, practice and even an information. Factors affecting to innovations are its novelty in time and how people and individuals discern it. When an individual considers a thing, idea etc. as new, it can be recognized as an innovation. Thus, innovations can be said to be quite complex, as they are difficult to measure, and because of their definition may also depend on the individual’s thoughts (Kline & Rodenberg 2010).

New knowledge in an innovation is not always directly linked to its novelty, as some people may have been aware of the innovation for a long time, but at the same time they have not shown any opinions towards it. Rogers (2003) writes in his book that persuasion, knowledge and determination to accept innovation can often indicate its novelty.

When talking about innovations, one might think only of some technological innovations, that is, as the name implies, new type of technology, product, process or service. In his book, Rogers (2003) even uses terms innovation and technology as synonymous with each other. But as stated earlier, innovations can also be divided into so-called intangible innovations, which are also known as administrative innovations. This category includes innovations that are symbolic and verbal, such as new method, arrangement and practice. (Van de Ven, Angle & Poole 2000.)

Some researchers believe that during the innovation process, these administrative and technological innovations should be kept separate from each other. However, according to Van de Ven et al. (1999) several innovations contain elements from both innovation groups, such a separation of administrative and technological innovations could even violate the innovation process. It is important to be able to understand the close boundary between administrative and technological innovation in order to manage

innovation process properly. Studies have also shown the dangers of keeping these two groups separate, as many technical innovations would not have taken place without administrative innovations.

2.2.1 Characteristics of innovations

Later in this thesis will become acquainted with the fact that innovations are often adopted at different times among various consumers. Due to the diversity of innovations, it is also clear that they also differ a lot from each other. It causes that, due to the nature of the innovation, its broad adoption may generally happen fast pace, as in the case of telephones, while with other innovations it may stretch over several years, like for example in the case of some car safety features. This is also known as a rate of adoption. (Rogers 2003.)

There are five different characteristics for innovations, which according to Rogers (2003) are *relative advantage*, *compatibility*, *complexity*, *trialability* and *observability*. The relative advantage describes how much improved and better the innovation is compared to the old, replaceable one. Compatibility examines the coherence of an innovation with adopters' former background, current values and demands. Complexity means whether an innovation is simple or troublesome to exploit and catch on, for if it is easy to relate and understand then its adoption will be faster. Trialability refers to the ability to test an innovation limitedly before full adoption. The last characteristic of innovation, observability, comprises how the introduction of an innovation appears to others. Thus, if an innovation can dispense more of these five characteristics than others, so then, in general, that exact innovation is adopted more quickly. However, in addition to this, characteristics related to technological innovations, can be categorized as its novelty, development phase, intricacy and the quantity of technical operation it contains (Senyolo, Long, Blok & Omta 2018).

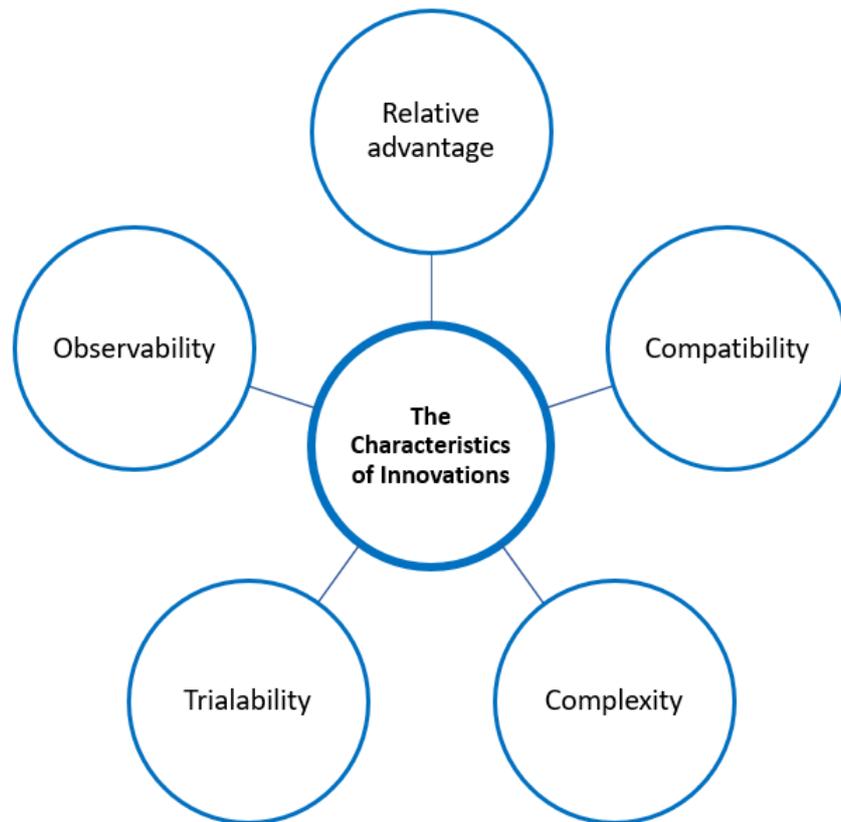


Figure 2. The characteristics of innovations.

2.2.2 Closed vs. open innovation

Various specific concepts have been stapled around the concept of innovation, and one of the most recent and important is open innovation. The concept of open innovation was brought up in the early 2000s by an American professor named Henry Chesbrough. Chesbrough talks about the way companies try to find new, more effective practices for their innovation policies. One powerful way to improve innovation processes is to utilize the company's external theories and ideas, as well as company's internal concepts and ideas. In this way, the company searches and leverages the best existing external ways to enhance its competitive advantage in the marketplace. (Vanhaverbeke & Chesbrough 2014.)

Open innovation helps corporations to expedite their innovation processes and identify new opportunities to develop their technologies. Vanhaverbeke & Chesbrough (2014) write that in this way, they can bring innovations faster into the hands of consumers, as many often think of this as a competition, where the first bringing the innovation to the market, is the winner. Thus, the company usually sees the innovations coming from outside of its operation as just as significant, if not more significant, than innovations which are generated internally. Above all, this increases the performance of the company's operations. (Ahmed, Halim & Ahmad 2018.)

When talking about open innovation and its advantages, it is good to point out its opposite, that is closed innovation. As the name implies, closed innovation means that company's entire innovation process is carried out internally, so third parties are not involved in innovation at all. Vanhaverbeke & Chesbrough (2014) say that such closed innovation activities may slow down and weaken the development of creative thinking. and at the same time, it usually is more expensive. At the same time, closed innovation can also be a more expensive way of working for a firm, because they need to hire the best employees in its field to bring new perspectives on the company's operations, in order to be able to match, and outpace, the technologies of its competitors.

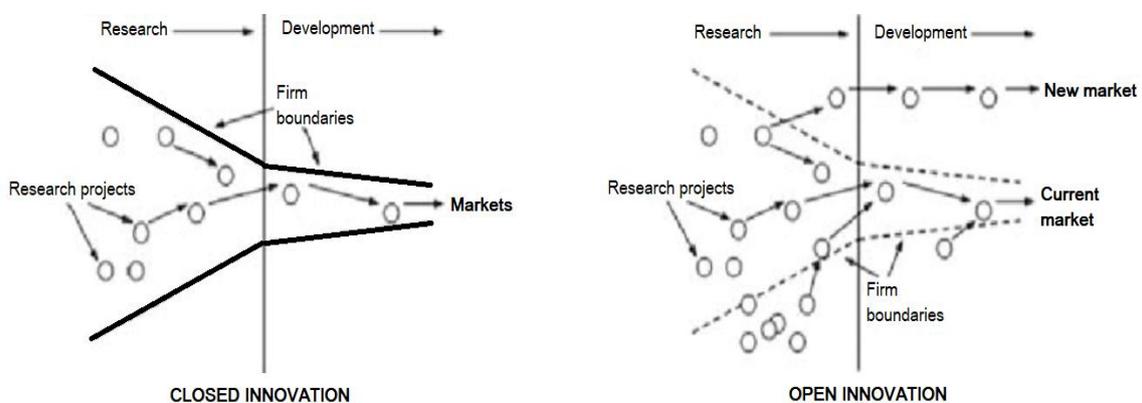


Figure 3. Closed vs. open innovation.

2.2.3 Research and development (R&D)

Technology seems to be constantly evolving at a faster pace than before, which is partly due to the fact that companies are investing more and more their resources in research and development, also known as R&D. Innovations and R&D can be said to contribute to each other, because when innovations emerge, many of them happen by accident, but still some of them originate due to company's strong R&D activities as well as risky experimentation. (Vasara 2013.)

R&D can be considered a vital condition for companies to maintain their sustainable competitive advantage, because without investing in R&D, it will be almost impossible to bring new innovative products to market. Although R&D activities can cost a lot of money, the development of knowledge and technology is often worth it. Studies have shown that companies' active commitment to research and development enable the growth of new innovative products and technologies. (Chamsuk, Fongsuwan & Takala 2017.)

2.3 Communication channels

In his book, Everett Rogers (1995) describes communication as a process where individuals come to consensus by discovering and sharing information with each other. This kind of communication can take place through different channels, such as people-to-people communication, also known as interpersonal communication, or through the mass media. Diffusion can be considered as one specific kind of communication, where the transfer of information between individuals contains some kind of new idea. One of the most important factors in the diffusion process is exactly the transmission of information among individuals. That being said, a communication channel is a process between individuals, where information is transferred to another party. (Sundstrom 2016.)

The process of communication channel in its simplicity includes four factors, which are:

1. Innovation
2. Individual who is familiar with the innovation
3. Individual who is NOT familiar with the innovation
4. Communication channel between the individuals

Rogers (1995) points out a remarkable issue related to communication in the diffusion of innovations, which occurs when the counterparts in the communication channel are too different from each other. By this, Rogers means that the parties can, for example, speak a different language and therefore do not understand each other, nor the information that would be desired to transfer to another. However, it is also important to realize that if the transmitting individual and the receiving individual are too similar to each other, the diffusion do not occur, because the individuals share exactly the same things, so the information will not be transmitted.

The best possible perspective for the diffusion of innovations in a communication channel would be if opposing individuals shared some similarities in education and social status, but in addition to these, it is important that they also share some differences with each other so that diffusion can best occur. Different communication channels can also be used to achieve different results, as Sundstrom (2016) states in his article. According to him, the mass media reaches a larger audience, but still the interpersonal communication serves as a more convincing factor in diffusion.

2.4 Innovation-Decision process

Time plays a major role in the diffusion process of innovations, as it is a common part of any communication process. However, Rogers (2003) says in his book that the determination of time in the diffusion process is often castigated, but time is also one

of the key forces of the process. Although time occurs in the diffusion process, it is notable that when doing research in other human sciences, the time variable does not usually occur in them.

At the core of the diffusion process is a preference for innovation, whether the individual adopts the innovation or not. This is one part of the so-called innovation-decision process, which is measured over time. Rogers (2003) explains the innovation-decision process as a gradual series of events, where an individual progress from the initial cognizance of the innovation to form an opinion towards it. After that, an individual decides the aforementioned question, whether to adopt or repudiate the innovation, which is followed by the execution of the new idea and the verification of this decision.

Everett M. Rogers (2003) determines the innovation-decision process into five different parts, which are *knowledge, persuasion, decision, implementation* and *confirmation*. The first step in the decision process, knowledge, is accomplished when the individual is aware of the innovation and learns to understand even part of its operation. Persuasion occurs when an individual develops a mindset toward innovation, whether positive or negative.

The third phase of the decision-process includes the decision itself, which appears, when one makes acts in relation to the approval or rejection of the innovation. Implementation, as the name implies, emerges when an individual begins to use and take advantage of innovation. During the innovation decision-process, the individual may have received anomalous information related to the exact innovation, so in the final stage of the process, one seeks confirmation to his or her previous innovation decision. At his stage, the decision maker can still change the choice made regarding innovation. (Rogers 2003.)

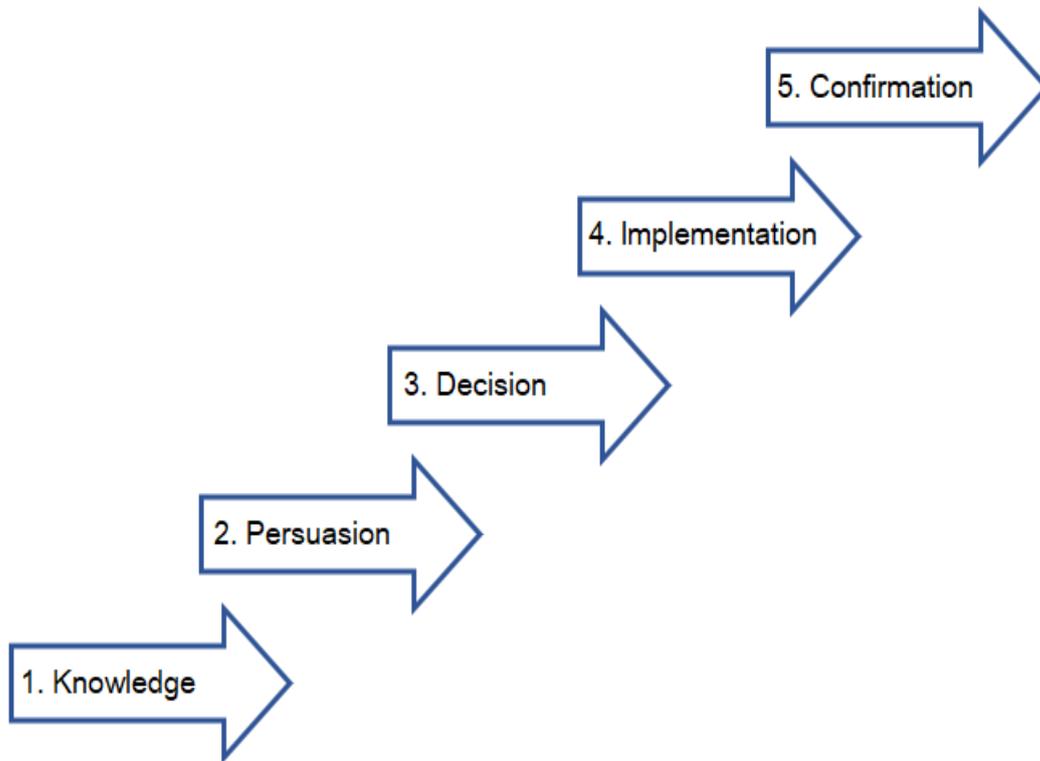


Figure 4. Innovation-decision process.

As stated, the innovation decision-process helps the individual to obtain and gather information concerning about the innovation, which ultimately leads to either the adoption of the innovation or its rejection. Rogers (2003) explains this whole decision-process chain including a time variable with it, as the five-step decision-process takes place in chronological order. In its simplicity, the period of the innovation decision-process is the time that elapses from the beginning to the end of the whole decision-process. It may take years to complete this process by others, while some individuals move rapidly from one stage of the decision-process to the next.

2.5 Adoption categories of innovations

A new product, process, practice or idea, in other words an innovation, is characterized by the fact that it is adopted at different times. This is often because individuals, organizations, or other parties have access to innovations at different times (Voiovich 2019). We already noted this in Gabriel Tarde's study on coffee consumption, in which he noted that individuals with higher wealth and social status began to consume coffee before others, as it was considered a deluxe victual.

Robert A. Peterson is considered a well-known professor of theology and he noted that three important factors need to be explored in relation to the management of adoption categories when studying the diffusion of innovation. These three factors are conviction of the number of the different groups who adopt the innovation, measuring the proportion of adopters in different innovation groups and conviction of the refinement mechanism between individual innovation adoption groups. (Peterson 1973.)

Peterson (1973) writes in his article that Rogers began to study the matter in more detail, allowing various communication, learning and analytic theoretical studies to determine and identify the primary idea for the diffusion theory of innovation. Rogers made remarks on that a diagram curve showing the sum of adopters of an innovation per unit time, produces a bell-shaped diffusion curve and to exploit of this information as well as a few other variables, Rogers was able to classify innovation adopters into their own categories.

In his book, Rogers (2003) divides the adopters of the innovations into five groups of their own, which are *innovators*, *early adopters*, *early majority*, *late majority* and *laggards*. The members of these five groups go through the innovation decision-process mentioned in the previous chapter and its duration can vary greatly between the groups (Voiovich 2019).

As can be seen from the figure below, the diagram appears symmetric, but the uneven distribution of adopter categories abrogates its symmetry. When the adoption curve reaches its peak, the curve has achieved its halfway and it is noticeable that there are three adopter categories on the left side of the midpoint and the two remaining categories on the right side. In his book, Rogers (2003) explains that the symmetry of the diagram category could be achieved if, for example, the first two – innovators and early adopters – were combined into one separate category. However, he does not fully favour that option, as the two first categories share quite some differences.

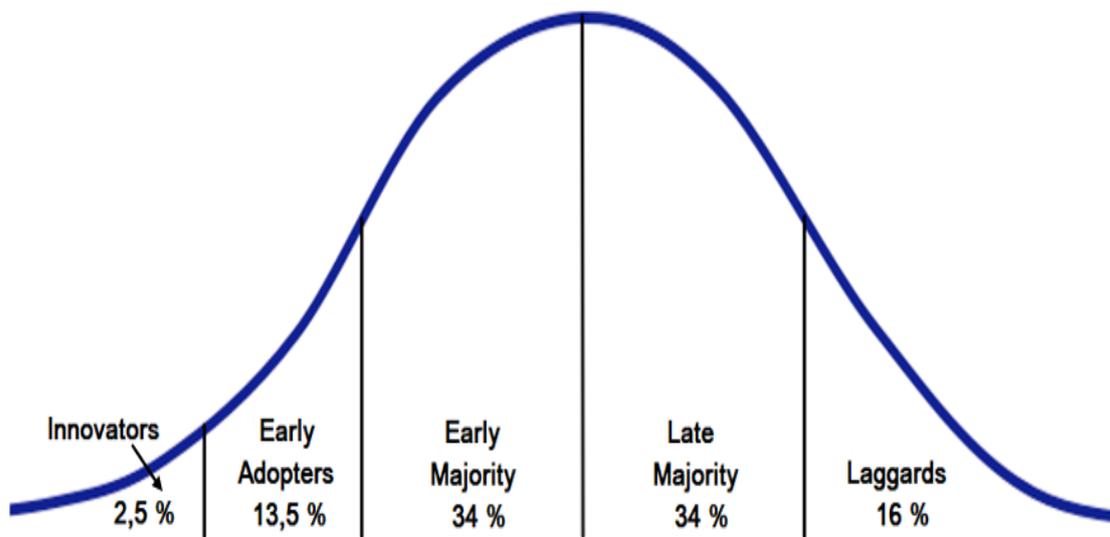


Figure 5. Innovation adoption categories.

This adoption of Everett M. Rogers theory of diffusion and its separation into five different classes is very well-known in the scientific world, but it still has some weaknesses. One of them is that, in many cases, members belonging to different categories are considered to be mere purchasers of innovation, even though the adoption of innovation also takes place other than on the basis of purchase. In addition,

in Rogers' theory, innovations are considered unchanged throughout the process, although innovations are characterized by the fact that they change and develop during the whole adoption process. (Noel, Sovacool, Kester & Zarazua de Rubens 2019.) Next, these five categories of innovation adopters will be explored and explained in more detail.

2.5.1 Innovators

The first group of adopters may not come as a surprise by name, as it is called innovators. The members of this group, known as innovators, are usually seen as very brave and daring, because they don't tend to feel afraid to try new things and ideas, or putting them into use. However, Rogers (2003) says that being an innovator involves several presuppositions, such as comprehending and utilizing different complicated technical information and safeguarding one's own financial situation, as innovations usually tend to fail. This leads to the risk that if the innovation does not succeed then the innovators may incur significant financial losses. In other words, the innovator must therefore be able to cope with the great uncertainty of the innovation in its early stages.

The characteristics of innovators are that those in this group love challenges as well as risk-taking, but at the same time high risks bring a lot of uncertainty. According to Rogers (2003), they also must accept the occasional setbacks and obstacles that may occur along the way.

Members of innovators group are often known as a financially stable, educated young people (Ainamo 2009). Innovators are the first to adopt innovations and at the same time a crucially significant part of the diffusion process, as the members of this group bring these innovations from outside the social system to others. Innovators are generally considered to be a relatively separate group from other users, as they do and

create so many new and own things, but at the same time this is the cluster, which causes new ideas to be launched within the social system. (Rogers 2003.)

The fact that many of the innovations come into existence accidentally, is often due to individuals or companies not knowing what kind of new product, idea or service they want or need. It is recognized that they commonly realize their needs right away when someone has introduced the innovation to them. However, there are companies and users who already know in advance what product or service they need and, on this basis, start to develop the desired end commodity. This grouping is known as user innovators. (Ogawa & Pongtanalert 2013.)

Products developed by user innovators are often based on the main features of blue ocean ideas and are more likely to eventually spread among other users in different adopter categories, than other innovations. This brings many companies a big competitive advantage when user innovators work for them as a source of new ingenious concepts and ideas.

User innovators are generally perceived as self-acting or solving an individual type of problem, while many other innovators work in a community where its members seek to help each other as well as share important information related to innovation with each other. Ogawa & Pongtanalert (2013) state in their article that these innovators who work together for a common goal are also known as community innovators and as noted, there are thus noticeable differences between these two types of innovators.

2.5.2 Early Adopters

The second adopter category is called early adopters. Members of this adopter group are accustomed to examining the new idea before using it or sharing their opinions with other groups. When early adopters utilise an innovation, it is common that the members

of a subsequent adopter categories will follow from the side and wait for tips and instructions concerning about the exact innovation. (Rogers 2003.)

Early adopters receive a lot of appreciation from others in the adopter categories, and according to Rogers (2003) when innovators were seen as an almost separate part of the social system, early adopters are classified as well adapted to the community. The great gratitude and assistance to other categories in matters related to innovations, early adopters are even seen as paragons for some members of different adopter categories.

Early adopters are characterized by the fact that its group members often spread the innovation among family members and inner circle friends. The diffusion of this category can even be described as the spread of some sort of a disease, because when one close relative becomes ill, the probability that others in the family will get ill increases significantly. Thus, innovation diffuses from the early adopter to their close relatives, because they form their first contact with the innovation, for example, from a family member. This accelerates the diffusion process of innovation considerably. (Seebauer 2015.)

2.5.3 Early Majority

The next adopter category is known as early majority. This class is one of the biggest of all the adopter categories, and its position right between the early adopters and later adopters increases its relevance, so that innovation diffuses more effortfully to later categories as well. The early majority spends time quite a bit more on the decision phase than the previous categories, because according to Rogers (2003), this group wants to make sure that the innovation is usable and beneficial. For this reason, it takes a little longer to adopt within early majority.

Early majority often cooperates within the members of its own group, as well as others to assist ordinary members of the community to gain knowledge of the innovation and later to benefit from it. Rogers (2003) explains that it is common for this group not to be seen as leading the way forward in innovation, as the early majority tend to observe and spend time implementing innovation. The saying of this category can be considered that do not be at the extremities of the adopters.

2.5.4 Late Majority

As the adoption of an innovation increases among members of adopter categories, it often augments pressure on those who have not yet applied or utilized the innovation. This can be considered as one of the main reasons for late adoption of the fourth category, which is called late majority. The financial position of the members of this group also has a significant effect on the later adoption of the innovation, as it is clear that over time and as technology evolves, prices usually drop significantly compared to the price of the product just launched. Rogers (2003) notes that the late majority often accepts an innovation after most of the adopters have adopted it.

The late majority are accustomed to get acquainted with innovations rather cautiously and doubtfully, so those in the group often protract their time pondering about decision-making about innovation. This results in a long-lasting innovation decision-process within the group, which according to Rogers (2003), also includes as many members as the previous group, early majority, 34 %.

2.5.5 Laggards

After the late majority in the adopter category becomes laggards, which is the fifth and thus the last adopter group. Decisions on innovation issues often depend on what

members from other categories have done, how innovation has affected them and also what are the benefits that it has brought. Rogers (2003) points out in his book that laggards, like the late majority, are often suspicious concerning about new things as well as the laggards being quite old-fashioned, this leads to an extremely slow pace of innovation decision-process.

As laggards begin to understand as well as become more interested in things related to innovation, time may have taken a really long time, even years. According to Rogers (2003) during that time, innovators have been able to test and implement an entirely new idea to replace the previous innovation, which is now being adopted by later users. This group can therefore be considered as adopters of old technology (Diederer, Meijl, Wolters & Bijak 2003).

The limited resources of laggards are often the main reason why they utilize innovation so late, if at all. It can also be seen as a positive thing for them, as the members of this category must be absolutely certain that the innovation cannot fail, because otherwise they would lose even their meagre funds. Rogers (2003) writes that laggards are usually rather distant from others, and he also mentions that when most of the adopters look forward, laggards are stuck looking behind.

Rogers' research shows that the number of laggards in the innovation adoption process is 16 %, but some researchers disagree with this number. Few of them consider the number of laggards to be even higher than Rogers have stated, but it is important to keep in mind that due to differences in innovation, the proportions of adopter categories may also vary. However, it is clear that the proportion of laggards is significantly large, and this can even be seen as a burdensome deployment to innovation, as its adoption extends so long. (Jahanmir & Lages 2015.)

According to Rogers (2003), laggards do not see themselves as innovative or an important part of the social system, but however Rogers says that it would be quite

important to involve them more profoundly in innovation. This would be an enormous benefit for companies, as it would help them to better understand the reasons for late adoption of innovations and at the same time help them to get through the barriers of adoption that lie ahead. This would speed up the time taken to adopt the innovation and thus abbreviate the diffusion curve of the various technologies and products. (Jahanmir & Lages 2015.)

Several think that laggards title carriers a bad reputation, because they are not seen in a very respectable position by others (Rogers 2003). According to Jahanmir and Lages (2015) the life cycle of a product could even be lengthened if companies became more familiar and analysed laggard practices. This would provide them with more information on the consumption behaviour of subsequent adopters and thus enable companies to better meet the needs of each adopter category. However, it is important to be aware of the fact that the diffusion process can take several years and achieving a full adoption, meaning that each member of the social system adopts a certain innovation, happens only rarely.

2.6 Summary of the theoretical background

The diffusion that emerges in this theoretical part simply means how an innovation, which can be, for example, a new idea, product or practice that has been implemented spreads among individuals. The factors influencing this diffusion and its pace are the innovation itself as well as the communication channels through which the information spreads and the innovation-decision process, that tells the time spent on it.

One of the main factors in the diffusion of innovation can be considered whether the individual even adopts the whole innovation. This supports the fact that most innovations do not spread widely, or at all, but they simply fail. This process where an

innovation is either adopted or rejected is called the innovation-decision process that progresses over time.

Diffusion theory has its roots in the early 1900s and because of its long history, it is thus one of the best-known research topics in innovation theory. Everett M. Rogers is considered a major scholar of this theory and his work “Diffusion of innovations” is used in several diffusion studies. Some researches still consider Rogers’ research to be insufficient, as it does not take into account the evolution of innovation over time. However, I believe that almost every research theory has several perspectives among different researchers, because they may study the issue from different angles.

It is clear that innovations do not reach to individuals at the same time, and that is one reason why they are not adopted at the same time. Thus, the adoption of an innovation often occurs at different times and can therefore be divided into five categories. These categories are innovators, early adopters, early majority, late majority and laggards. Upstream adoption groups, as their name implies, put innovations to use before the majority of others, and later groups adopt innovations later, even years after innovators.

Innovations are often created by accident, but it is vital for the development and growth of companies that they are able to bring innovations to market. This is strongly linked to the R&D activities of companies, which are receiving more and more attention nowadays. These above-mentioned concepts, such as diffusion, innovation and R&D will thus play a major part as this thesis proceeds.

3 Implementation of the research

3.1 Research method

In this master's thesis, I will make particular use of the texts published by the company, most of which will consist of the companies' annual reports. Other articles and reports will be used in the thesis as well, which are both texts published by the company itself and those published by other parties. Based on this, the research method of my thesis is qualitative, because the information I research that appears in the articles as well as in the reports is in text form. This thesis contains a comparison between two companies, so the research is qualitative case study. The research material is collected through companies' document collection. To support qualitative research, I will also make use of quantitative research. It will appear as an observation of different figures for companies, such as annual comparisons of research and development expenses. Thus, my thesis will use both a qualitative and quantitative research method, but for the most part it will consist of qualitative research.

When doing a research, like this thesis, it is essential to be aware of what kind of research methods exist and what their main purpose is. The writer must recognize of what research method one intends to utilize in his or her empirical research and to get started with that, it is worthwhile to examine research material that one is referring to as well as research questions. This gives the author a perspective on how to gather the necessary data. The use and exploitation of data is based on quantitative and qualitative analysis. (Lo, Rey-Marti & Botella-Carrubi 2020.)

There are notable differences between quantitative and qualitative research. Quantitative research includes occasions where research is approached numerically. The data it contains is mostly numerical and that is why it need to be studied especially

mathematically as well as from a statistical point of view. Qualitative research is more difficult to determine, but it can be said to cover all data other than numerical. The information based on this is usually in textual form, which is intended to gather more understanding of, for example, assumptions and logics. The research can utilize, among other things, interviews and perceptions. (Yilmaz 2013.)

Researchers often have their own views on whether it is worthwhile to utilize different research methods, which in this case are quantitative and qualitative, or whether it is best to focus on only one research method. The way of utilizing both research methods has increased its popularity in recent years and in studies it is better known as a mixed-methods research. Indeed, several scholars believe that it is desirable to use both research methods in the same dissertation, as they often complement each other. This may usually clarify some of the conclusions and at the same time help to see the desired issue from a different perspective. (Lund 2012; Kajamaa, Mattick & de la Croix 2020.)

Although the mixed methods research has grown its popularity, some researchers still discern some weaknesses in it. When using both quantitative and qualitative research method at the same time, it is possible that the researcher may even omit important available data, as well as the results of mixed methods may even be unrelated to each other. Studies have also shown that many of the research papers are often presented as using only one research method, but when taking a closer look at the paper, it can usually be noted that it has used both quantitative and qualitative research. (Bryman 2007.)

3.2 Research material and its acquisition

Communication between companies and their shareholders is necessary, as it tends to increase particularly the trustworthiness of owners towards the exact enterprise. One of the most important factors enabling such communication between these two is

considered to be the annual reports published by the company. There are some differences between countries in what a company must prepare and publish, such as its financial statements and annual reports (Pacios & Serna 2020). For example, in Finland, all large companies are required to publish financial statements and an annual report, which shows, among other things, the company's financial situation, the development of operations, and also, the uncertainties affecting its operations. (Kirjanpitolaki 1997/1336.)

Pacios and Serna (2020) states, that the structure of the annual report is usually a summary, containing both qualitative and quantitative information, but for the most part it consists of textual data. Companies often submit their annual reports in the spring or early summer, covering the necessary documentation of its previous fiscal year. Although the annual reports are intended mostly for investors and stockholders, it is important to remember that when a company publishes its annual report in its website, it becomes public information for everyone. Therefore, the company's competitors can also get acquainted with it, as well as anyone else. For this reason, companies' annual reports are often superficial in that they do not share detailed information that is crucial to their operations with competitors, as it could jeopardize the company's competitive advantage.

As in any published text, there are also variabilities in the readability of the annual reports. Readability is affected by, among other things, the logic, comprehensibility and accessibility of the published text, which in this case indicates whether the annual reports are easily readable and accessible. It is sometimes difficult for shareholders to understand the industry-specific concepts in company's documents. For this reason, companies should use simple vocabulary, as well as clear and short sentences in their publications. The use of difficult-to-interpret language in the annual report may also indicate that the company is trying to conceal harmful information from shareholders and investors. (Li 2005.)

Due to the above, the decision to choose these two specific automotive companies comes precisely because they are effortlessly accessible and consistent. It is also notable that the lengths of companies' annual reports vary and often there is a clear repetition in the annual reports of the same company. The major reason for this is that it is easier for companies to take advantage of unchanged data from previous years in their latest annual reports. By doing so, the company therefore saves considerable time and money. (Davison 2008.) My choice to exploit companies' annual reports over a ten-year period, gives a broader picture of how innovations have evolved over time. Both of the companies still had annual reports in their websites for a period of ten years, so that is also the reason for my choice.

The acquisition of information needed, is done by going through companies' annual reports one by one, starting in 2009. Therefore, year 2009 is used as a benchmark for what has happened in the following years. Toyota's annual reports are generally less than 100 pages long, while BMW's annual reports are more than 250 pages long. This means that some of the information used may be overlooked by the researcher. By minimizing this to happen, I have taken advantage the tables of contents of annual reports, as well as the use of keywords.

4 Research results

4.1 Case companies

I chose these companies because I wanted to examine as well as adduce the technical innovations of large and reputable companies in the automotive industry. The selection criteria for the case companies were that they had to be well-known and significant operators in terms of production volumes. In addition to these, I wanted to make sure that they aren't too similar, so the target companies are from continents, but both of their markets are still divided around the world.

The companies that were selected for this thesis are Toyota and BMW. My choice was focused at these exact companies, because their annual reports are quite clear as well as consistent. An important factor in this selection was also that the annual reports of the companies can be found online, as my study covers their annual reports all the way from 2009 to 2019. I had initially thought that one of my choice company would have been an American car manufacturer, but their annual reports are quite confusing, and the availability of their older reports is bad. Next, the case companies in the thesis, Toyota and BMW, will be presented in more detail.

4.1.1 Toyota

Toyota, or as well-known Toyota Motor Company, is a Japanese car brand that is also the world's largest vehicle manufacturer. The company's annual vehicle production volume has been more than 10 million cars a year for several years. Toyota was originally largely a family business and to this day, the same family business values can be seen in its daily operations. (Magee 2007.)

The roots of Toyota's history go back to the 1930s when a man named Sakichi Toyoda produced Japan's first electric weaving machine. This made the company (formerly called Toyoda) one of the largest textile manufacturers in Japan. Sakichi's son Kiichiro Toyoda took over the management of the company and he was particularly interested in Henry Ford's way of mass-producing vehicles. Kiichiro Toyoda and his team built their first prototype car in 1935 under the model name AA, which was heavily influenced by American car brands such as Ford, Chevrolet and Chrysler. Over time, Toyota's popularity and market share increased among vehicle manufacturers, largely due to Toyota Production System. (Magee 2007.)

Last year, Toyota employed just over 370,000 people, which was second highest number of employees after Volkswagen Group. Today the company has a total of more than 50 factories around the world where Toyota vehicles and its parts are manufactured. Today, Toyota Motor Company is led by Akio Toyoda. Akio Toyoda states on Toyota's website that Toyota's goal is to further strengthen continuous growth and sustainable development by producing high-quality and innovative products and services. (Toyota 2020.)

4.1.2 BMW

BMW is a German company based on car manufacturing and its acronym comes from the words Bayerische Motoren Werke GmbH, which translated into English means Bavarian Engine Works Company. BMW is one of the world's best-selling premium car brand and its annual car production volume is around 2,5 million units. The BMW Group also includes the car brands MINI and the luxury Rolls Royce. (BMW Group 2020.)

The history of BMW goes back to 1916, when a company focused on aircraft engines called Rapp Motorenwerke and Bayerische Flugzeug-Werke merged into one company, known as BMW. In addition to aircraft engines, the company began manufacturing

vehicles, and in 1932, the company's first car, AM-model, came on the market. The war affected BMW's operations majorly and the company switched its production back to airplane engines, but in 1951 BMW released its 501-model vehicle, which challenged its competitors with its luxury finish. From the 1960s onwards, BMW grew in popularity among the people and the company began to expand its vehicle fleet. During the 1990s, Rolls Royce and MINI were acquired by the BMW Group. (Leppänen 2020.)

Today, BMW Group employs more than 120,000 workers and has a total of 31 production plants around the world. The company has extended its regular vehicle models in previous years and offers passenger cars all the way from 1 series to 8 series and SUV's between X1 and X7. BMW Group's goal is to maintain its leading position in the manufacturer of premium vehicles and as a developer of mobility services. Sustainability is important to the company and enables BMW to create advanced solutions for individual mobility. (BMW Group 2020.)

4.2 R&D comparison

Quantitative data regarding innovations, such as research and development expenses, can be found in the annual reports published by vehicle companies. R&D expenses play a significant role in the economy of vehicle companies. An example of this is the three largest sectors in Europe that spend the most of their funds on research and development, which are automotive, ICT and health sectors. (European Commission 2019.)

The R&D expenses of companies in the automotive industry are, as usual, quite high, largely due to their ability to respond to growing competition in the market. These expenditures have been seen to increase since the 1970s, when car manufacturers began to invest more in the development of lower-emission vehicles. The growth and

importance of lower-emission vehicles originated in the climate change discussions and their development has continued to this day. (Frenken, Hekkert & Godfroij 2004.)

The table below shows the annual research and development expenses of the two companies and its share of the company's total revenue in the same year. The R&D expenditures shown in the table is presented in millions of euros.

Year	Toyota		BMW	
	m€	% of total revenue	m€	% of total revenue
2009	7315	4,4	2448	4,8
2010	5869	3,8	2773	4,6
2011	5910	3,8	3373	4,9
2012	6310	4,2	3952	5,1
2013	6534	3,7	4792	6,3
2014	7368	3,5	4566	5,7
2015	8129	3,7	5169	5,6
2016	8542	3,7	5164	5,5
2017	8396	3,8	6108	6,2
2018	8617	3,6	6890	7,1
2019	8487	3,5	6419	6,2

Table 1. R&D expenditures and their share of total revenues.

4.3 Research of annual reports

The financial crisis that arose in the United States in 2008 quickly escalated into a global crisis, and thus affected almost every business. This led to difficulties in the automotive

industry, as vehicle sales collapsed and some supplier companies even went bankrupt. Vehicle manufacturers in the United States still suffered the biggest losses compared to the global automotive industry, driving some of them even to the brink of bankruptcy. (Rosenfeld 2009.)

This thesis reviews the annual reports of companies over a period of 10 years and the first year studied is precisely 2009, during which companies were still struggling with the obstacles brought by the financial crisis. It can be directly reflected in the poor financial results of the target companies and even in staff reductions, but over time, vehicle brands have gotten their operations back on track.

As mentioned earlier, the thesis goes through the technological innovations in the annual reports and how they have spread among car manufacturers. The purpose is to present the company's innovation activities year by year, so that one paragraph corresponds one year. For some reason Toyota's 2015 annual report could not be found anywhere, so I wasn't able to editorialise on it, but fortunately their financial results have been published for that year, so I was able to get the necessary quantitative data.

4.3.1 Toyota 2009-2019

In 2009, Toyota spent ¥904 billion (yen) on R&D, which is about 50 billion yen less than the previous fiscal year. Toyota faced challenges in 2009, mainly due to the financial crisis, which led to the company's second year of operating losses in its history. The company considers safety, excitement, clean energy and the environment as the main themes of its product development and innovation activities, and as its core technology, Toyota has settled hybrid technology, due to environmental concerns. In 2009, Toyota introduced seven new hybrid vehicles, four of which were aimed at the Japanese market and the rest across the seas. As an innovation, the company has developed a safety system (Pre-crash Safety System) that detects pedestrians in front of the car as well as

vehicles coming from behind. Toyota's new petrol-powered vehicles introduced an economical start-stop system that automatically shuts off the engine when the car stops and starts it when a driver touches clutch or gas pedal. The company has also developed fully bioethanol-powered vehicles that will coexist with hybrid technology to create cleaner future mobility. (Toyota 2010.)

The financial crisis still reflected in Toyota's operations in 2010, however the company performed better than last year. The growing popularity of small-sized eco-friendly vehicles, Toyota announced a specific focus on their development. The company will continue to make great strides with hybrid models as well as the launch of plug-in hybrids (PHEV) in a few years. In the development of the fully electric vehicle (EV), Toyota began working with Tesla Motors, which focuses exclusively on electric cars. (Toyota 2011.)

Toyota's 2011 annual report focuses primarily on the safety systems that they have created, which are originated by innovative technologies. Toyota claims that it has also been able to shorten the production lines of some of its factories with the help of new technologies, which speeds up production while saving energy. R&D expenditures remained more or less the same as last year, but the company still calls for strong development in its hybrid technologies. As a result of these development phases, Toyota plans to introduce as much as 10 new hybrid vehicles by 2015. (Toyota 2012.)

In 2012, Toyota released "Toyota Global Vision" with the intention of showing others what kind of company it aspires to be. Related activities include a focus on continuous innovations as well as increasing collaboration with other companies, enabling open innovation and more efficient product development. The long-term growth development of Toyota Global Vision divides the company's car manufacturing into four different categories, one of which is the green vehicles of the future. The development of this category requires innovations and one part of the Global Vision is innovation in production technology. Advanced innovations in production technology require,

according to Toyota, simplicity and flexibility to new production methods and components. In addition to this, the skills and competencies of the firm's employees should be adopted by these technological improvements, which would allow for even better innovations. (Toyota 2013.)

Toyota believes that many of the eco-cars of the future will use plug-in hybrid technology, which in addition to the petrol engine has an electric motor that the users can charge, even from their own yard. To increase environmental friendliness, Toyota is also aiming to get consumers to charge plug-in hybrids (PHEV's) using solar-generated electricity. The company's R&D includes green electricity storage operations at home, which would always provide enough electricity to charge PHEV's. The 2013 annual report shows that the company believes that future electric vehicles (EV's) will be small, and with this EV development, Toyota wants to bring relief to combining car and human life. (Toyota 2014.)

As technology continues to evolve, Toyota is more devoted to the origins of new technologies, innovation and future developments. In 2014, Toyota released a small two-seater i-ROAD electric car concept and right away started a three-year shared driving project with it in Grenoble, France. With this project, Toyota wants to make life easier for city dwellers, enabling them to enjoy the shared driving experience. Up to 70 i-ROAD EV's will be brought to the city and about 30 charging points will be installed there. Toyota's project brings the two innovations together as those in the city can take advantage of the ease of a compact electric car as well as shared driving. The company believes in the growth of shared driving, because users do not have to worry about its cost of ownership, as its payment is based on the distance the user drives. After driving, the user parks it, from where the new user can start their own journey again, making i-ROAD available to everyone. Toyota has expanded its hybrid electric vehicle (HEV) collection and now has at least one hybrid option available in each of its vehicle categories. This makes a total of 27 hybrid electric vehicles as well as one plug-in hybrid. The company also released its first fuel cell car called Mirai, which operates on electricity

generated by the chemical reaction of oxygen as well as hydrogen, and therefore is an emission-free vehicle. Thanks to significant R&D, Toyota was able to create a way for its gasoline engines to improve their thermal efficiency. Thus, the new gasoline engines are up to 10 % more economical than the previous internal combustion engines, and Toyota plans to bring consumers 14 new economical gasoline engines with this technology in the same year. (Toyota 2015.)

The 2016 annual report highlights Toyota's trend toward a society of the future where intelligent mobility will bring relief to people's daily lives. To achieve this, the company defines three functions, which are: *(1.) enjoyment of mobility for all, (2.) the development of even better vehicles, (3.) achieve an environmentally friendly society of the future.* The innovations related to the first activity are the development of an autonomous car that utilizes AI technology and the connectivity technology integrated into vehicles. Toyota will continue its strong R&D toward these innovations and will constantly strive to promote autonomous driving through open innovation. Toyota unveiled an autonomous demonstration vehicle, which can operate on the highway independently, with the aim of bringing its associated functions, such as independent lane changes and motorway entry and exit, into its post-2020 car models. Utilizing the big data collected through car connectivity, Toyota is able to anticipate driver actions, provide services and software updates remotely, and thus create superior and safer driving pleasure for its users. The innovations for the second function are related to Toyota's production, where it works with various suppliers to reduce emissions, waste and unnecessary operations. Innovations related to Toyota's third function concern the environment, such as the emission-free development, production and charging of electric vehicles. The company has set a goal for 2050 to reduce all its emissions to zero and to create a positive impact on the environment with its presence. (Toyota 2017.)

Toyota emphasizes in its 2017 annual report that innovations are becoming increasingly more meaningful in their operations, as they are now generating even faster technological advances, especially in the fields of artificial intelligence (AI), information,

robotics and internet of things (IoT). These will enable Toyota to connect people, vehicles and social infrastructure more closely in the future. Toyota reports that the diffusion of hybrid vehicles is constantly increasing and is no longer a rare product in the streetscape. However, in order to achieve zero emissions throughout the vehicle's life cycle, Toyota is increasingly focusing on the production of battery electric and fuel cell cars. The diffusion of these two innovative powertrains is greatly affected by the fact that the charging infrastructure for EV's is already well advanced, especially in cities, while the charging system infrastructure for fuel cell cars is not widespread. To speed up the launch of electric vehicles in a short time frame, the company established a separate EV Business Planning unit, and also collaborated with Mazda Motor Company, allowing them to combine their electric car technology developments. Toyota aims to bring EV's to the mass market within a few years. (Toyota 2018.)

Due to technological developments and innovations, the automotive industry is undergoing major changes. Therefore, in 2018, Toyota decided to change its corporate image from a car manufacturing company to a mobility company that aims to offer diverse mobility services for all people. In the 2018 annual report, Toyota highlights its assumed main technological innovations for future mobility, which include electrification, autonomous vehicle, connectivity and shared driving. By bringing these innovations to consumers, it requires large investments in the company's R&D as well as the adoption of innovations. Toyota says its R&D expenses are over a trillion yen, so they can create a better future with the help of these innovations. To enhance the functions and systems that enable autonomous driving, the Toyota Research Institute - Advanced Development (TRI-AD) was founded. In this regard, Toyota launched an international project called "call for innovation", which aims to get ambitious start-up companies to collaborate with TRI-AD. Toyota is aware that more advanced battery technology is needed to increase the diffusion of electric vehicles, and inspired by that, Toyota began to examine, together with Panasonic, the use of prismatic batteries in vehicles, making the batteries more efficient and smaller, and believe they will have this new battery technology in their EV's in the early 2020s. (Toyota 2019.)

Toyota recognizes that developing and selling the company's vehicle fleet alone is not a sufficient way to get these advanced technologies to spread among consumers. Therefore, Toyota states in its 2019 annual report that it intends to work with more companies to accelerate the adoption of these new era technological innovations. The company even made its own patents related to its hybrid technology available to others, to ensure the wider spread of vehicle electrification to reduce traffic emissions. The company also established the Toyota ZEV factory in 2019, which aims to improve the development and productions of zero-emission vehicles, like BEV's and FCEV's. Toyota is confident about the future of FCEV's and intends to launch a second-generation Mirai in 2020, but according to it, governments should also put more effort into it, such as allowing them charging infrastructure. The company states that the price of hydrogen should also be cheaper in order to reach the take-off point in the adoption curve of fuel cell vehicles. The share driving innovation also increased its share when the company unveiled Toyota Share service, which allows Toyota cars to be easily and quickly rented to customers. (Toyota 2020.)

4.3.2 BMW 2009-2019

Like most companies. BMW suffered from the global financial crisis in 2009, which was clearly reflected in reduced revenues. Due to the crisis, the company had to cut R&D expenses by 14,5 % compared to the previous fiscal year. However, the difficulties will not discourage the company, but will continue the development plan it has created, which takes consumers and the climate better into account. This development plan consists mainly of BMW's Efficient Dynamics innovations, which aims to increase the amount of lighter and more streamlined body styles as well as more economical cars, such as low-emission engines and start-stop systems to company's vehicle fleet. BMW unveiled its first hybrid car models at the 2009 car show, reducing consumption by more than 20 % and is also developing its first hydrogen vehicle. BMW also points out in its annual report that it is working on "Project i" aimed at creating a new kind of vehicle

concept, consisting of innovative powertrains and, above all, enabling a new kind of mobility. (BMW 2010.)

In its 2010 annual report, BMW emphasizes the importance of electric cars in enhancing environmental friendliness, but also calls to produce energy needed in cars using renewable energy. Population density is increasing in big cities, due to the urbanization and in that scene, BMW is developing a new version of vehicle for mobility, which is known as, Megacity Vehicle. Its function is based on BEV and a truly compact size, enabling emission-free as well as effortless mobility in the cities of the future. BMW disclosed its first test version of the FCEV and believes that with the help of R&D, fuel cell vehicles will become a big part of the BMW's vehicle fleet in the future. The company aims to improve its connectivity innovation – Connected Drive – which will share real-time information to its driver, for example about weather conditions and traffic jams, making driving safer. BMW believes that Connected Drive innovation will enable new software updates to be downloaded to cars in the future, which will reduce fuel consumption. (BMW 2011.)

The co-operation is a big part of BMW's operation and the company opened a new manufacturing plant in the United States, where it was able to develop with SGL Group an innovative way to produce lighter body parts, which improves the fuel economy and lowers CO₂ emissions of the car. By utilizing innovative carbon-fibre strengthened plastic parts in its body panels, BMW enables a significant difference in weight compared to other car structures, thus considers itself the technologically best manufacturer of lightweight body structure. The company points out in 2011 that it has recovered from the financial crisis, but in order to continue to grow, the company needs to make a greater effort on technological innovations. One of the biggest innovation releases in 2011 was the company's concept cars i3 and i8, which are BMW's masterpiece for the innovative vehicles of the future. The i3 reflects the company's Megacity Vehicle project, which is a tiny electric car suitable for urban use, while the i8 is an aerodynamic

sportscar with a lightweight chassis that utilizes PHEV technology. BMW plans to launch these i-series vehicles in a few years. (BMW 2012.)

The 2012 annual report highlights that the automotive sector is facing changes and the company intends to restructure its operation towards more sustainable mobility, which will require technological innovations. Despite the new changes, BMW sees that combustion engines will be popular with the consumers for a long time to come. For this reason, the company aims to further develop its internal combustion engines to be more environmentally friendly, which will eventually be utilized together with hybrid technology innovation. BMW has expanded its hybrid powertrain range and now offers a hybrid option for its 3, 5 and 7 series vehicles. R&D expenses in 2012 increased quite a lot due to the vehicle electrification of the company's fleet. As a technological innovation, connectivity has been well established by BMW and it is the only manufacturer with a high-speed internet in the car. However, BMW's Connected Drive is under constant development and in 2012 this innovation allowed driver to dictate the messages that the car sends to the desired recipient. (BMW 2013.)

Launched in 2013, the new-age innovative BMW i3 for urban mobility opened the company to a trailblazer role in the future automotive sector. This trend can be called as an urban e-mobility and the company sees a clear future in it. The electric motor of the first version BMW i3 achieves a range of up to 130-160 kilometres, which is considered to be good for city driving. In response to market changes, BMW will continue its collaborations with important partners, enabling successful R&D as well as rapid innovations. However, in vehicle electrification, the company relies mostly on in-house development and has not established cooperation with other vehicle manufacturers. The company's commitment to reducing emissions from its cars was also better integrated into the production of the i-series, as the plant in Leipzig received four wind turbines on its site to give their production the most ecological label possible. By bringing connectivity to cars more widely, BMW plans to install a SIM-card in many of

its new models, aiming to connect millions of BMW's together with Connected Drive. (BMW 2014.)

BMW discusses about the future of vehicle sector and states in its 2014 annual report that connectivity will change this sector significantly more than, for example, the vehicle electrification. Both technologies are constantly evolving, and BMW's connectivity now provides its users location-related information, such as accidents and entertainment, through cars location system. As a new mobility innovation, BMW introduces its own shared driving service called DriveNow. Shared driving has been seen as a successful mobility service and DriveNow users in 2014 were just under 400,000 people. As of next year, BMW plans to expand its shared driving service outside Germany. BMW also set up another service related to the same concept for use by employees of various companies, called AlphaCity. As a technological innovation, in 2014 the company introduced its test car, which includes advanced autonomous driving functions such as acceleration, braking and lane changes. In addition, BMW is in the final stages of development with an autonomous safety system that detects a deterioration or cessation of the driver's reaction, after which the car independently drives to the side of the road and calls for emergency. (BMW 2015.)

Technological developments allow for a closer link between vehicles and their environment. BMW points out in its 2015 annual report that, by contributing this development, the company has partnered more broadly with innovative companies in its R&D, bringing advanced innovations to the market, such as connected, autonomous and electric vehicles. BMW has brought some highly autonomous driving functions to some of its cars, but they still require control from the driver. The company intends to bring more of these highly autonomous functions to people for adoption, after which BMW will aim for fully autonomous driving where the driver becomes the passenger. This requires cameras, laser sensors, radars as well as advanced map services. BMW continues to develop innovative lightweight body structures as well as alternative powertrains PHEV's, BEV's and FCEV's. In 2015, BMW produced the first plug-in hybrid

to its regular series vehicle X5. The shared driving service offered by BMW also increased the number of electric vehicles and now every fifth car is a battery electric i3 on DriveNow service. (BMW 2016.)

BMW will strive for a leading position in the field of autonomous driving and to achieve this, the company began in 2016 to work with Intel and Mobileye to enhance the development of a self-driving car. BMW announces in the annual report from 2016 that it has started tests for autonomous urban driving, as most of the development work has been done on the track or on the motorway. Transition to full autonomy (5th step), where people are just passengers, the company created a five-step model. The first step is Driver Assistance, which allows for partial autonomous driving, such as speed control according to the vehicle ahead. In the fourth step, Fully Automated Driving, the car driver for the most part itself, but the driver must also be ready to drive if needed. BMW plans to launch its fully autonomous car in 2030. Driver-vehicle interaction was enhanced by the introduction of the innovative AirTouch accessory in the BMW 5- and 7-series, allowing the information system to be controlled with just the movement of the hands. The shared driving innovation, DriveNow, expanded to the US as well as many European cities. The company gave a peek at its future VISION VEHICLES, which are scheduled to enter the market in 2030 and their operations are based solely on evolving innovations such as electric, connected and autonomous driving, and their interaction with people and the environment will be revolutionary. (BMW 2017.)

The mobility of the future is divided by BMW into autonomous and electric driving as well as digitalisation. In these areas, BMW wants to be at the forefront of the market, and this can be reflected in 2017 R&D expenses, which exceeded six billion euros. The progress of autonomous driving innovation was intensified when the company opened a new development center in Munich, which will increase the number of employees working on autonomous driving from 600 to more than 2000. There have also been autonomous test vehicles in traffic, which are collecting information about traffic and roads that BMW can take advantage of. The annual report shows that e-mobility is a

priority strategic target for the company, and they sold over 100,000 electrified vehicles in 2017. BMW began working with several companies, including Siemens, to create a fast-electric charging system that would significantly reduce the car's charging time. The digitalisation of cars covers connectivity as well as services and in 2017, more than 10 million BMW's are already connected via ConnectedDrive, which has increased safety and brought comfort. BMW aspires to be a brand leader as a service provider, and it requires them to have user friendly mobility services that help people move effortlessly to different places. Some of these have already been widely adopted, such as the DriveNow, which already has a total of one million users. (BMW 2018.)

Innovation is a major part of BMW's operations and philosophy, and in 2018 they added a design to the company's previously linked future innovation trends, such as autonomous driving, electrification, connectivity and services. Design can be seen as a mix of the style and shapes of the whole car and its comprehensive technology, and this will be seen in the BMW of the future with their even futuristic essences. In 2021, BMW plans to launch iNext, which is bursting with these innovations, and at the same time takes the next step of BMW's autonomous driving model. iNext will be a paragon of innovation and at the same a significant highlight for the company, as it will, like i3, give a new future mobility direction to the world. BMW is constantly developing its battery technology and states in its 2018 annual report that with a single charge, the iNext can drive over 700km. To achieve this, BMW will open a modern Battery Cell Competence factory, in order to cooperate with two major battery technology companies to advance the power source for its electric cars. BMW has made its production lines more flexible, as well as the chassis of its cars, so that soon they will be able to install any drivetrain system in the assembly phase. As a result, the division of production between combustion engine cars and electric cars will be simplified, enabling BMW to launch more than 10 electric versions of its current models by the end of 2020. (BMW 2019.)

As connectivity increases, BMW states in the 2019 annual report that cars will be sources of digital services that will become commonplace for its users. The driver-vehicle

connectivity will be created even before the ownership, as the user can get to know the desired car and its services interactively, for example via virtual reality, and thus get a deeper impression of the vehicle. ConnectedDrive also allows you to maintain your own driver profile, so that when you change cars, driver information, such as services used, is automatically transferred to another BMW. This is a facilitating factor in shared driving services. The car's software system can be updated in the future, just like a smartphone and with connectivity, the driver is able to modify some of the vehicle's accessories. Therefore, if the owner did not choose, for example Driver Assistance package at the time of purchase, it is possible to be bought and downloaded later to the car. Electric driving is being further developed and in 2019, there are 11 different electric car versions in BMW's fleet and at the same time, the number of the company's electric cars exceeded the 500,000 mark. BMW believes that it cannot compete with just one powertrain, consequently it wants to offer its consumers a wide range of low-emission powertrain options. This supports the decision that next year BMW X3 is available in BEV, PHEV, petrol or diesel alternative.

4.4 Innovation findings and their comparison between companies

The results show that innovations in Toyota and BMW vehicles are mainly focused on the development of alternative, low-emission powertrain technologies. These include hybrids, plug-in hybrids, battery electric and fuel cell electric vehicles, which are reckoned as electric cars. For a low-emission future, innovations in lighter vehicle components and materials have been utilized, and manufacturers have developed more compact and lightweight vehicles, enabling lower consumption and reduced emissions.

In addition to electric car innovations, the results disclose the connectivity of vehicles made possible by digitalisation and the wide range of services it creates. The Internet of Things brings unlimited opportunities for new vehicles, such as enabling communication between a car and your own "smart" home. With connectivity, the number of these

services will increase tremendously in cars, making the daily lives of car users easier. With an aim for safer mobility, car manufacturers have also strongly involved the development of autonomous driving in their own operations.

Examining the innovations in the annual reports for a period of ten years, the results reveal that the innovations of Toyota and BMW go practically hand in hand. In 2009, both Toyota and BMW had 11 R&D facilities scattered around the world, but at the same time R&D expenses, presented in table 1, shows that Toyota spent significantly more, about three times as much, on R&D activities than BMW. Both manufacturers opened factories for the production of innovative compact vehicles and their lightweight body parts in 2011 and they also launched their shared driving innovation service at the same time in 2014.

The companies' annual reports reveal that Toyota and BMW are making significant technological advances to increase the number of electric vehicle models in their car selection. Every year, annual reports emphasize that progress in all of these electric powertrain technologies are being made, but Toyota and BMW have also taken some different approaches in this area. Toyota is approaching the electrification of cars, especially with hybrid technology, as the company believes that the adoption of hybrid and plug-in hybrids will be faster, and therefore broader, compared to full-electric vehicles (BEV). Toyota has also expressed in its actions that it believes hydrogen cars (FCEV) will be the main solution for zero-emission mobility in the future, as its refuelling time as well as driving range correspond to the readings of a normal internal combustion engine vehicle.

BMW's approach to electric cars is also largely hybrid-focused, but the company sees the future faster in full-electric vehicles. This is evident when the company launched its first full-electric BMW i3 in 2013. i3 brought BMW more reputation, based on EV's, when in 2014 it was the world's third best-selling full-electric vehicle. The results show that the company's first hybrid came on the market in 2009 and BMW has since brought

some hybrid options to a part of its vehicle models. Compared to Toyota, BMW relies more on full-electric cars than fuel cell hydrogen cars, and the company has not released a hydrogen car on the market. However, BMW has said that the company's first FCEV to hit the market will be in 2022 at the earliest.

According to the results, the companies also spend large sums on the development of innovations such as connectivity and autonomous driving. In terms of research and development expenses, the results show that there was a significant difference in expenses between companies in 2009, but over the years BMW has increased its R&D expenditures significantly in its own operations. The R&D expense table reveals that in ten years, Toyota's expenses has grown by just over € 1 billion, while BMW's expenses has risen by around € 4 billion over the same period. Although BMW's expenses are not yet quite at Toyota's level, compared to companies' total revenue, BMW's R&D expenses covered 6,2% of total revenue in 2019, while Toyota's R&D expenses was 3,5% of total revenue.

BMW's increased R&D expenses are evidence that the company is investing significantly in future automotive trends and wants to be a pioneer relating innovations, such as car connectivity and autonomous driving. Results show that both of these companies have increased the number of R&D facilities from 11 to 16 in ten years, indicating that these new trends really require more effort in companies' innovation and development operations.

4.5 Evaluation of the diffusion of innovations in the automotive industry

Toyota is considered one of the pioneers of hybrid technology, as the company released its first HEV, Toyota Prius, back in 1997. As a result, Toyota has had hybrid cars on the market for more than 20 years. This has boosted it bringing new hybrid versions of different car models to market for a longer period of time, and in 2009, Toyota brand

vehicles were available in 16 different hybrid versions in its whole collection. Comparing these figures with BMW, the results show that BMW's first hybrid electric vehicle was not launched until 2009. The spread of electrified vehicles of these two car manufacturers to the market between 2009 and 2019 is presented in the table below.

	TOYOTA				BMW			
	HEV	PHEV	BEV	FCEV	HEV	PHEV	BEV	FCEV
2009	16	0	0	0	1	0	0	0
2010	2	0	0	0	1	0	0	0
2011	3	0	0	0	0	0	0	0
2012	6	1	0	0	2	0	0	0
2013	1	1	0	0	0	0	1	0
2014	27	1	0	0	4	1	1	0
2015	3	0	0	1	2	2	0	0
2016	2	2	0	0	2	1	0	0
2017	1	0	0	0	1	0	0	0
2018	1	1	0	0	0	0	0	0
2019	2	0	0	0	2	1	0	0

Table 2. Diffusion of electrified vehicles.

The table reveals the numbers of all the different electric powertrain options, which are HEV, PHEV, BEV and FCEV, in the car manufacturer's model fleet. The years 2009 and 2014 in the table show the total number of EV versions for companies, while the other years reflect the introduction of new electrical models to the market. This confirms Toyota's dominance in hybrid vehicles, and the fact that in 2019 Toyota was the world leader in electrified vehicle sales. As Toyota considers hybrid technology to be a key

factor in its operations, the number of PHEV's is relatively small compared to the company's HEV's. The table also highlights the fact that Toyota has considered full-electric vehicles to be fairly distant idea in future driving. This can be reflected in the number of BEV's on the market, which is zero. However, Toyota has released one fuel cell car to the market, but its adoption has remained relatively low, with sales of that car at around 10,000 units worldwide.

The launch of BMW electric vehicles started in 2009 and the company has been able to introduce more of them quite well. However, the number of hybrid models has remained quite small, which can be partly explained by the fact that BMW invested significantly in its first BEV, which was launched in 2013. The numbers of BMW plug-in hybrids are pretty much in line with Toyota's when examining their annual diffusion. The table also shows that BMW has not yet launched its first fuel cell car to market, although it has been developing this technology for years.

The table notes that there are clearly more hybrid electric vehicles than other electric cars on the market. In 2019, more than 30 different electrified vehicle models were available from the Toyota brand fleet, while in the same year BMW had 11 different electrified versions available in its entire vehicle fleet. For 10 years, Toyota has increased the selection of its electric cars from 16 to over 30, while BMW increased its EV's from 1 to 11. Toyota's electric vehicle sales exceeded more than 14 million units in 2019, and BMW's electric car sales in the same year exceeded the 500,000 mark. This shows that as an innovation, electric vehicles have been adopted quite well by consumers. However, it is clear that Toyota's car production volumes and model fleet are higher than those of BMW, so this helps to explain some of the differences that emerge.

Innovations related to connectivity have clearly gone further and diffused more widely in BMW cars than in Toyota. The results show that BMW wants to offer its car owners high-quality accessories and services. This can be reflected in the fact that the company was the first to enable high-speed internet connectivity in its cars, and BMW has brought

connectivity to its cars faster than many other car brands. In terms of autonomous driving, both companies have developed their operations far, but BMW offers more autonomy to its vehicles than Toyota. Here, however, it must be noted that even if a self-driving car has already been developed for the market, its use may not be fully legal in some places. As an innovation, this is quite new, so legislation and traffic in many countries have not yet progressed to the adoption of autonomous driving.

5 Conclusions

In this master's thesis, I examined the innovations of two different car manufacturers and their diffusion over a ten-year period. In the thesis I used the annual reports of the companies, which showed that the automotive industry today is constantly facing some changes, due to various factors such as increased competition from new trends in the sector as well as changing regulations and policies. The development of vehicle technology is now having an even greater impact on business growth and success. To answer this, vehicle manufacturers need to bring ever better innovations to the market.

The aim of this research was to find answers to the questions *“What innovations does the vehicle manufacturers disclose in their annual reports and how innovations diffuse among car brands?”* Additional questions were *“What are the differences and similarities between vehicle brands in terms of their innovation?”* and *“How the disclosed innovations have diffused to production?”*

The research results reveal that the most important innovations of car manufacturers during 2009-2019 are strongly related to the electrification of vehicles, connectivity and the services it creates, as well as autonomous driving. These innovations have clearly emerged in the annual reports of both Toyota and BMW, and they approach these trends pretty much the same way.

Connectivity has become widespread in cars and nowadays more than 90% of new cars are somehow connected to its environment through various technologies. This and the use of information technology in vehicles will open a wide range of opportunities for car manufacturers to produce many services in their future development work that will make life easier and better for vehicle users. In the past, it was remarkable to be able to listen to the music you want in the car from your own device via Bluetooth, but now new cars can even handle the functions of your own home remotely, such as turning electrical devices on and off. Even the software updates of vehicles can be done totally

remotely nowadays, which is already an indication of how much connectivity has spread in the automotive sector.

Both companies have also launched a mobility innovation, which is based on a car sharing service. Toyota's own sharing service still only operates in Tokyo, while BMW's DriveNow shared driving service has already spread to many different cities. Autonomous driving has evolved considerably among manufacturers, and in 2009 some vehicles may have been equipped with driver-assistance functions, such as lane departure warning and adaptive cruise control, but in 2019 some vehicles already was able to drive autonomously. However, the driver still has to give some commands to the car, like touch occasionally the steering wheel, to let the car know that driver is able to take control of it.

The constant development of technology and the growing investment of companies R&D operations have evolved these innovations considerably forward in development. The results show that the number of electric vehicles has increased remarkably since 2009 and there has also been a progress in battery technology. As a result, electric vehicle batteries have become more efficient and lighter, allowing electric cars to have longer driving range and at the same time increase their reliability.

Although both BMW and Toyota have invested in electric vehicle development, there are still some differences to be seen in that innovation area. It is strongly related to the version of electric cars that will be used the most in the future. Toyota has attached importance to the future of the FCEV's, while BMW's perspective on an emission-free future has relied heavily on the development of BEV's. This is also seen in the fact that during 2009-2019, Toyota developed and launched one FCEV, while BMW introduced one BEV. To add to this, Toyota has unveiled documents and procedures related to its hybrid technology to enable other manufacturers to produce hybrids more easily and quickly, so that car emissions can be reduced faster. BMW, on the other hand, strictly considers its electric vehicle technologies to be its own knowledge.

Electric vehicle sale at Toyota by 2009 were just over two million units, when at the end of 2019, Toyota brand electric vehicle sale worldwide exceeded 14 million units. BMW's electric vehicle production and sales volumes from 2009 to 2019 have grown from a few thousand to over 500 thousand units. In relative terms, production of Toyota's electric vehicles has grown more compared to BMW. These production and sales volumes reflect to Everett Rogers' theory of diffusion of innovations, which states that the adoption and diffusion of innovation increases over time.

The companies' annual reports also show that the adoption and diffusion of these future innovations is greatly influenced by the actions of various nations and governments. They need to make faster determinations in order to be able to increase innovations such as autonomous driving, car sharing services and, for example, fuel cell vehicles. Regarding FCEV's, their diffusion really depends on its required charging infrastructure, which is quite scarce in the cityscape. Generating and increasing the hydrogen refuelling stations amount is also largely the responsibility of cities and states, and thus car companies would most likely bring more hydrogen vehicles to market. Governments should seek to encourage and reward more the use of such innovations to reduce emissions and bring more safety to traffic. Diffusion here may not have had enough time yet, when the infrastructure has not yet been built. It may also be that the importance between climate change and electric vehicles is not yet seen as very great.

The research results indicate a clear direction in which the automotive industry is heading. However, it must be kept in mind that the research material of this thesis consists mainly of companies' own annual reports, so it is sometimes desirable to be rather sceptical about some of the information contained there. This is largely due to the fact that companies publish these reports mainly to their shareholders, in which case the company tends to emphasize positive things that increase owners' reliability and loyalty for the company's future.

The content of the annual reports is based entirely on the company's own published text, making it sometimes difficult to determine their veracity. A good example of a distortion of reality is case Volkswagen, which was caught in an emission fraud. The company used illegal software to help with the emission measurements, which kept the emissions lower than they actually were. This has certainly increased the scrutiny and questioning of the content of the annual reports for many people, but I still feel and believe that their content is in line with the company's operations as well as their intentions to develop technologies to create a more sustainable and environmentally friendly future. As a result, I find the research result reliable and valid.

The research findings can be generalizable among other vehicle companies, as the case companies in this thesis, Toyota and BMW, may be considered by some metrics in different categories of automakers. BMW focuses primarily on producing premium-class vehicles, while Toyota produces vehicles from side to side for all consumers. However, the innovation activities and development of these manufacturers is quite similar, and the market has proved that almost every vehicle company is also on the same levels with these innovations as well as their diffusion.

I have noticed how much more vehicle companies advertise their new electric vehicles now in 2020. BMW and Toyota have highlighted in their 2019 annual reports how many electric vehicles they are planning to bring to market in the 2020s, so for future research, it would be great to see when electric vehicle production exceeds diesel and petrol vehicle production, as well as research on how the prices of electric vehicles will drop as their production is increased. In the field on connectivity, it will be interesting to see what kind of innovations the cars of the future will include.

References

- Agarwal, M., Anand, A., Bansal, G. & J.P. Pathak (2019.) Innovation Diffusion Process Based on Market Coverage Under Dynamic Environment. *Nonlinear Studies*. Vol. 26, No. 3. Available from Internet: <URL: <http://web.a.ebscohost.com.proxy.uwasa.fi/ehost/pdfviewer/pdfviewer?vid=3&sid=af16d434-b73d-45ac-ae4d-9aed01f3129d%40sdc-v-sessmgr03>
- Ahmed, S., Halim, H. & N. Ahmad (2018.) Open and Closed Innovation and Enhanced Performance of SME Hospitals – A Conceptual Model. *Business Perspectives and Research*. Vol 6, Issue 1. Available from Internet: <URL: <https://doi.org/10.1177/2278533717722661>
- Ainamo, Antti (2009.) Building the Innovation Factory: The People Dimension. *Knowledge, Technology & Policy*. Vol. 22(4). Available from Internet: <URL: <http://doi.org/10.1007/s12130-009-9092-x>
- Baldwin, C. & K. English (2020.) Learning from Dual Global Crises: COVID-19 and climate change. *Social Alternatives*. Vol 39. Issue 2. p. 43-49. Available from Internet: <URL: <http://web.a.ebscohost.com.proxy.uwasa.fi/ehost/pdfviewer/pdfviewer?vid=3&sid=39bd57e8-6fd5-4ec9-b171-54f7821d5c22%40sessionmgr4007>
- Bigliardi, B., Dormio, A. & F. Galati (2012.) The Adoption of Open Innovation within the Telecommunication Industry. *European Journal of Innovation Management*. Vol 15. Available from Internet: <URL: <https://doi.org/10.1108/14601061211192825>
- BMW Group (2020.) Company overview. Available from Internet: <URL: <https://www.bmwgroup.com/en/company.html>

BMW Group (2020.) Downloadcenter, Annual reports. Available from Internet: <URL: <https://www.bmwgroup.com/en/download-centre.html>

BMW Group (2020.) Responsibility. Sustainability at the BMW Group. Available from Internet: <URL: <https://www.bmwgroup.com/en/responsibility/sustainability-at-the-bmw-group.html>

Bryman, A. (2007.) Barriers to Integrating Quantitative and Qualitative Research. *Journal of Mixed Methods Research*, Vol. 1. No. 1. Available from Internet: <URL: <https://doi-org.proxy.uwasa.fi/10.1177/1558689806290531>

Chamsuk, W., Fongsuwan, W. & J. Takala (2017.) The Effects of R&D and Innovation Capabilities on the Thai Automotive Industry Part's Competitive Advantage: A SEM Approach. *Management and Production Engineering Review*. Vol 8. No 1. Available from Internet: <URL: <http://journals.pan.pl/dlibra/publication/121935/edition/106278/content>

Davison, J. (2008.) Rhetoric, repetition, reporting and the "dot.com" era: words, pictures, intangibles. *Accounting, Auditing & Accountability Journal*, Vol. 21(6). Available from Internet: <URL: <https://www-emerald-com.proxy.uwasa.fi/insight/content/doi/10.1108/09513570810893254/full/pdf?title=rhetoric-repetition-reporting-and-the-dotcom-era-words-pictures-intangibles>

Diederer, P., Meijl, H., Wolters, A. & K. Bijak (2003.) *Innovation Adoption in Agriculture: Innovators, Early Adopters and Laggards*. Cahiers d'Economie et de Sociologie Rurales, INRA Editions, 67. Available from Internet: <URL: <https://hal.archives-ouvertes.fr/hal-01201041/document>

European Commission (2019.) 2019 Industrial Research and Development Scoreboard: EU companies increase investment amidst stiff global competition. News, Research and Innovation. Available from Internet: <URL: https://ec.europa.eu/info/news/2019-industrial-research-and-development-scoreboard-eu-companies-increase-investment-amidst-stiff-global-competition-2019-dec-18_en

Frenken, K., Hekkert, M. & P. Godfroij (2004.) R&D portfolios in environmentally friendly automotive propulsion: Variety, competition and policy implications. Technological Forecasting & Social Change, Vol. 71. Available from Internet: <URL: [https://doi.org/10.1016/S0040-1625\(03\)00010-6](https://doi.org/10.1016/S0040-1625(03)00010-6)

Hannappel, R. (2017.) The Impact of Global Warming on the Automotive Industry. American Institute of Physics. Available from Internet: <URL: <https://sci-hub.tw/10.1063/1.4996530#>

Hardman, S., Steinberger-Wilckens, R. & D. Horst (2013.) Disruptive Innovations: The case for hydrogen fuel cells and battery electric vehicles. International Journal of Hydrogen Energy. Vol. 38, Issue 35. Available from Internet: <URL: <https://doi.org/10.1016/j.ijhydene.2013.09.088>

Hawkins, R., Blind, K. & R. Page (2017.) Handbook of Innovations and Standards. Edward Elgar Publishing Limited. ISBN 9781783470082. 439 p. Available from Internet: <URL:https://books.google.fi/books?id=AXkvDwAAQBAJ&pg=PA395&lpg=PA395&dq=the+innovation+journey+pdf&source=bl&ots=GZDB3V9VP-&sig=ACfU3U1apOrf7NUf6OBGadQH5FLiBpF5cw&hl=fi&sa=X&ved=2ahUKEwiyw_Plpb3pAhUll4sKHYYMcDIs4FBDoATADegQICRAB#v=onepage&q=the%20innovation%20journey%20pdf&f=false>

Hoyer, K. G. (2008.) The History of Alternative Fuels in Transportation: The Case of Electric and Hybrid Cars. Utilities Policy. Vol. 16, Issue 2. p. 63-71. Available from Internet: <URL: <https://doi.org/10.1016/j.jup.2007.11.001>>

Jahanmir, S. F. & L. F. Lages (2015.) The Lag-User Method: Using laggards as a source of innovative ideas. Journal of Engineering and Technology Management. Vol 37. Available from online: <URL: <https://doi.org/10.1016/j.jengtecman.2015.08.002>>

Kajamaa, A., Mattick, K. & A. de la Croix (2020.) How to ... do mixed-methods research. The Clinical Teacher, Vol. 17(3). Association for the Study of Medical Education and John Wiley & Sons Ltd. Available from Internet: <URL:<https://doi-org.proxy.uwasa.fi/10.1111/tct.13145>>

Kinnunen, Jussi (1996.) Gabriel Tarde as a Founding Father of Innovation Diffusion Research. Acta Sociologica (Taylor & Francis Ltd). University of Turku, Department of Political Science. Available from Internet: <URL: <https://doi-org.proxy.uwasa.fi/10.1177/000169939603900404>>

Kirjanpitolaki 1997/1336. Toimintakertomus (30.12.205/1620.) Available from Internet: <URL: <https://finlex.fi/fi/laki/ajantasa/1997/19971336>>

- Kline, S. J. & N. Rosenberg (2010.) An Overview of Innovation. Studies on Science and the Innovation Process. Available from Internet: <URL: <https://pdfs.semanticscholar.org/335e/d947244672fd0d5f854f1ca06ba7342d6b00.pdf>
- Leppänen, T. (2020.) Automerkkien historia: BMW – lentokoneiden moottoritehtaasta premium-brändiksi. Tyyliniekka. Available from Internet: <URL: <https://tyyliniekka.fi/automerkkien-historia-bmw-lentokonemoottoritehtaasta-premium-brandiksi/>
- Li, F. (2008.) Annual Report Readability, Current Earnings, and Earnings Persistence. Journal of Accounting and Economics, Vol. 45, Issues 2-3. Available from Internet: <URL:<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.145.9133&rep=rep1&type=pdf>
- Lo, F., Rey-Marti, A. & D. Botella-Carrubi (2020.) Research Methods in Business: Quantitative and Qualitative Comparative Analysis. Journal of Business Research. Vol 115. Available from Internet: <URL: <https://doi.org/10.1016/j.jbusres.2020.05.003>
- Lund, T. (2012.) Combining Qualitative and Quantitative Approaches: Some Arguments for Mixed Methods Research. Scandinavian Journal of Educational Research, Vol. 56, No. 2. University of Oslo. Available from Internet: <URL: <https://doi-org.proxy.uwasa.fi/10.1080/00313831.2011.568674>
- Magee, David (2007.) How Toyota Became #1: Leadership Lessons from the World's Greatest Car Company. Portfolio Hardcover. 256 p. Available from Internet: <URL: <https://books.google.fi/books?hl=fi&lr=&id=Sz--bPE5iVMC&oi=fnd&pg=PP13&dq=toyota+company&ots=vla0McCg3K&sig=86p>

PJYoDkndUGp7Kgy4CaQl1vQ4&redir_esc=y#v=onepage&q=toyota%20company&f=false

Marcu, I., Suci, G., Balaceanu, C., Vulpe, A. & A. Dragulinescu (2020.) Arrowhead Technology for Digitalization and Automation Solution: Smart Cities and Smart Agriculture. *Sensors* (Basel). Vol. 20, Issue 5. Available from Internet: <URL:<https://doi.org/10.3390/s20051464>

McGrath, C. & Z. Deone (2001.) The Future of Innovation Diffusion Research and Its Implications for Management: A Conversation with Everett Rogers. *Journal of Management Inquiry*. Vol. 10, Iss. 4. Available from Internet: <URL: <https://doi-org.proxy.uwasa.fi/10.1177/1056492601104012>

Noel, L., Sovacool, B., Kester, J. & G. Zarazua de Rubens (2019.) Conspicuous Diffusion: Theorizing How Status Drives Innovation in Electric Mobility. *Environmental Innovation and Social Transitions* 31. 154-169. Elsevier B.V. Available from Internet: <URL: <https://doi.org/10.1016/j.eist.2018.11.007>

Ogawa, S. & K. Pongtanalert (2013.) Exploring Characteristics and Motives of Consumer Innovators – Community Innovators vs. Independent Innovators. *Research Technology Management: User Innovation*. Vol.56 (3). Available from Internet: <URL: <https://doi-org.proxy.uwasa.fi/10.5437/08956308X5603088>

Pacios, A. & I. Serna (2020.) The Annual Report, Indicator of Library Transparency. *International Information & Library Review*. Taylor & Francis Group. Available from Internet: <URL: <https://www.tandfonline.com/doi/full/10.1080/10572317.2020.1728176>

Peterson, Robert (1973.) *A Note on Optimal Adopter Category Determination*. *Journal of Marketing Research*. ed 9. [Online]. Available from Internet: <URL:

<http://web.a.ebscohost.com.proxy.uwasa.fi/ehost/pdfviewer/pdfviewer?vid=4&sid=3e8f3856-1504-4def-8a2e-00e1064b55e4%40sessionmgr4007>

Rogers, E. M. (2003.) *Diffusion of Innovations*. The Free Press. A Division of Simon & Schuster Inc. New York. 5th edition. 550 p. ISBN 0-7432-2209-1.

Rosenfeld, H. (2009.) *The North American Auto Industry in Crisis*. *Monthly Review: An Independent Socialist Magazine*. Vol.63, Issue 3. p.18-36. Available from Internet: <URL: https://doi.org/10.14452/MR-061-02-2009-06_2

Seebauer, S. (2015.) *Why Early Adopters Engage in Interpersonal Diffusion of Technological Innovations: An Empirical Study on Electric Bicycles and Electric Scooters*. *Transportation Research. Part A* 78. Available from Internet: <URL: <https://www.sciencedirect-com.proxy.uwasa.fi/science/article/pii/S0965856415001032?via%3Dihub>

Senyolo, M., Long, T., Blok, V. & O. Omta (2018.) *How the Characteristics of Innovations Impact Their Adoption: An Exploration of Climate-smart Agricultural Innovations in South Africa*. *Journal of Cleaner Production*. Vol 172. Available from Internet: <URL: <https://doi.org/10.1016/j.jclepro.2017.06.019>

Soltani, A. (2017.) *Social and Urban Form Determinants of Vehicle Ownership; evidence from a developing country*. *Transportation Research Part A*. Vol. 96. p. 90-100. Available from Internet: <URL: <https://doi.org/10.1016/j.tra.2016.12.010>

Sundstrom, B. (2016.) *Mothers “Google It Up:” Extending Communication Channel Behaviour in Diffusion of Innovations Theory*. *Health Communication*. Vol 31. Available from Internet: <URL: <https://doi.org/10.1080/10410236.2014.936339>

Toyota (2020.) Toyota Global. Available from Internet: <URL: <https://global.toyota/en/company/profile/>

Van de Ven, A. (2017.) The Innovation Journey: you can't control it, but you can learn to maneuver it. *Innovation: Organization & Management*. VOL 19. NO. 1. Available from Internet: <URL: <https://doi.org/10.1080/14479338.2016.1256780>

Van de Ven, A. H., Polley, D. E., Garud, R. & S. Venkataraman (1999). *The Innovation Journey*. New York: Oxford University Press. 422 p. ISBN: 0-19-513307-2.

Van de Ven, A., Angle, H. & M. Poole (2000.) *Research on the Management of Innovation. The Minnesota Studies*. Oxford University Press. New York. Available from Internet: <URL: <https://ebookcentral-proquest-com.proxy.uwasa.fi/lib/tritonia-ebooks/reader.action?docID=430336>

Vanhaverbeke, W. & H. Chesbrough (2014.) *New Frontiers in Open Innovation: A Classification of Open Innovation and Open Business Models*. Oxford University Press. 344 p. Available from Internet: <URL: https://www.researchgate.net/profile/Wim_Vanhaverbeke/publication/266737917_A_Classification_of_Open_Innovation_and_Open_Business_Models/links/543a344c0cf2d6698be1730e.pdf

Vasara, A. (2013.) *Tutkimus ja tuotekehitys rakentavat paremman tulevaisuuden. Talouselämä*. Alma Talent Oy. Available from Internet: <URL: <https://www.talouselama.fi/kumppaniblogit/tutkimus-ja-tuotekehitys-rakentavat-paremmat-tulevaisuuden/1164c09a-3369-3aad-88e6-5332e0564ead>

Voiovich, J. T. (2019.) *Innovations Diffuse, but People Adopt Behaviors: How to Use Misinterpretations of Diffusion of Innovations to Your Advantage*. Medium - The

Startup. Available from Internet: <URL: <https://medium.com/swlh/innovations-diffuse-but-people-adopt-behaviors-f729f75ab2c4>

Yilmaz, K. (2013.) Comparison of Quantitative and Qualitative Research Traditions: epistemological, theoretical and methodological differences. *European Journal of Education*, Vol. 48, No. 2. Available from Internet: <URL: <http://doi.org/10.1111/ejed.12014>

List on data used in the research

BMW

2009:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2009/2009-BMW-Group-Annual-Report.pdf

2010:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2010/2010-BMW-Group-Annual-Report.pdf

2011:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2011/2011-BMW-Group-Annual-Report.pdf

2012:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2012/2012-BMW-Group-Annual-Report.pdf

2013:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2013/2013-BMW-Group-Annual-Report.pdf

2014:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2014/2014-BMW-Group-Annual-Report.pdf

2015:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2015/12784_GB_2015_engl_Finanzbericht_Online.pdf

2016:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2016/BMW_GB16_en_Finanzbericht.pdf

2017:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2018/gb/BMW-GB17_en_Finanzbericht_ONLINE.pdf

2018:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2019/gb/BMW-GB18_en_Finanzbericht_190315_ONLINE.pdf

2019:

https://www.bmwgroup.com/content/dam/grpw/websites/bmwgroup_com/ir/downloads/en/2020/gb/BMW-GB19_en_Finanzbericht.pdf

Toyota

2009:

<https://content.presspage.com/uploads/1523/annual-report-2009.pdf?10000>

2010:

https://www.annualreports.com/HostedData/AnnualReportArchive/t/NYSE_TM_2010.pdf

2011:

https://www.annualreports.com/HostedData/AnnualReportArchive/t/NYSE_TM_2011.pdf

2012:

https://www.annualreports.com/HostedData/AnnualReportArchive/t/NYSE_TM_2012.pdf

2013:

https://www.annualreports.com/HostedData/AnnualReportArchive/t/NYSE_TM_2013.pdf

2014:

https://www.annualreports.com/HostedData/AnnualReportArchive/t/NYSE_TM_2014.pdf

2015:

Page could not be found

2016:

<https://global.toyota/en/ir/library/annual/archives/>

2017

https://www.annualreports.com/HostedData/AnnualReportArchive/t/NYSE_TM_2017.pdf

2018:

https://www.annualreports.com/HostedData/AnnualReportArchive/t/NYSE_TM_2018.pdf

2019:

https://www.annualreports.com/HostedData/AnnualReports/PDF/NYSE_TM_2019.pdf