Ma Din Jenny

Disruptive Technologies in Geospatial Industry

Master's thesis to achieve the university degree of

Diplom-Ingenieur

Master's degree programme: Geomatics Science

submitted to

Graz University of Technology

Supervisor

Ass.Prof. Dipl.-Ing. (FH) Dr.techn. Johannes Scholz
Institute of Geodesy

in cooperation with
Institute of General Management and Organisation

Graz, October 2017

AFFIDAVIT

I declare that I have authored this thesis independently, that I have not used other than the declared sources / resources, and that I have explicitly marked all material which has been quoted either literally or by content from the used sources. The text document uploaded to TUGRAZonline is identical to the present master thesis.

……………………………	………………………………………………..
date	signature

Acknowledgements

It is a pleasure to thank those who supported me throughout the process of the master thesis. But first of all, I am very grateful to be permitted to write this thesis on this very specific topic. Furthermore, I would like to express my gratitude to my advisor Dr. Johannes Scholz as well as Prof. Stefan Vorbach and DI Harald Wipfler who gave insightful comments and suggestions as well as assistance.

Abstract

Disruptive technologies are technologies that first underperform in a niche market but then overtake the mainstream market as a market leader. A common example therefore would be digital cameras. When digital cameras first came up, they were – compared to analog cameras – very expensive, bulky and had little memory storage so they were not appealing for the mainstream market. Digital cameras had started out with less performance than analog cameras but with rapid development in storage capacity they caught up quickly and entered the mainstream market. The development of digital photography was disruptive to producers of analog cameras. This master thesis deals with the identification of characteristics and detection of disruptive technologies in the field of geospatial technologies. The goal of this thesis is to gather the data and information available and to analyse them relating to disruption in order to develop a method to rate the disruptiveness of a technology. The approach to this topic is based on past examples of disruptive technologies described in academic journals, scholarly papers and books as well as experts' opinions. On the basis of the compiled characteristics a method will be used to integrate the characteristics into a prediction. Christensen's framework was used as a starting point and expanded by analyzing case studies of disruptive technologies. Based on the studies and various methods to identify disruption a new method was created. To test the method past examples were used. After approving the method is used on three present and future geospatial technologies to estimate their level of disruption.

Table of content

1 Introduction 1

1.1 Motivation 1

1.2 Goal and hypothesis 2

1.3 Approach and research design 2

1.4 Organization of the thesis 3

2 Theory 4

2.1 Definition of the term disruptive technology 5

2.2 Characteristics of disruptive technologies 7

2.2.1 Technology maturity 7

2.2.2 Market entry level and declining costs of technology 10

2.2.3 New Value Propositions 11

2.2.4 New entrants 12

2.2.5 New market 12

2.2.6 Overengineering 13

2.3 Criticism of the concept 15

3 Technology forecasting 16

3.1 Delphi Method 16

3.2 Extrapolation, Trend Analysis and Models 16

3.3 Scenarios and simulation 17

3.4 Patentometrics 18

3.5 Gartner Hype Cycle 18

3.6 Checklists 19

4 Case studies of disruptive technologies 21

4.1 A new approach for rating the disruption level of technology 21

4.2 Google Docs versus Microsoft Office 23

4.2.1 Technology maturity 23

4.2.2 Market entry level and declining costs of technology 23

4.2.3 New Value Propositions 23

4.2.4 New entrant 24

4.2.5 New markets 24

4.2.6 Summary 25

4.3 Digital cameras versus analog cameras 25

4.3.1 Technology maturity 26

4.3.2 Market entry level and declining costs of technology 27

4.3.3 New Value Propositions 27

4.3.4 New entrants 27

4.3.5 New market 27

4.3.6 Summary 28

5 Disruptive Technologies in geospatial industry 29
5.1 GNSS based system versus theodolite 29
5.1.1 Technology maturity 30
5.1.2 Market entry level and declining costs of technology 30
5.1.3 New Value Propositions 31
5.1.4 New entrants 31
5.1.5 New markets 31
5.1.6 Summary 32
5.2 Software as a service versus Desktop software 34
5.2.1 Technology maturity 34
5.2.2 Market entry level and declining costs of technology 35
5.2.3 New Value Propositions 35
5.2.4 New entrants 36
5.2.5 New markets 36
5.2.6 Summary 37
5.3 Open Street Map versus analog maps 38
5.3.1 Technology maturity 38
5.3.2 Market entry level and declining costs of technology 38
5.3.3 New Value Propositions 39
5.3.4 New entrants 40
5.3.5 New markets 40
5.3.6 Summary 42
6 Interviews 43
6.1 Results 44
6.2 Conclusion 45
7 Discussion and conclusion 46
8 Bibliography 48

1 Introduction

This chapter contains the motivation behind the thesis, research goals and assumptions as well as expected results. The introduction also includes the overview of the chapters.

1.1 Motivation

Digital cameras, iPods and DVDs have one thing in common: They are disruptive to analog cameras, the Walkman and VHS tapes. Disruptive technologies are technologies that first underperform in a niche market but then overtake the mainstream market as a market leader (Christensen, 1995). A common example therefore would be digital cameras. When digital cameras first came up, they were – compared to analog cameras – very expensive, bulky and had little memory storage so they were not appealing for the mainstream market. Digital cameras had started out with less performance than analog cameras but with rapid development in storage capacity they caught up quickly and entered the mainstream market outperforming analog cameras in many ways. Kodak, who was the market leader for analog photography at that time, did not see the digital photography as a future technology. The development of digital photography was disruptive to producers of analog cameras. Kodak, once a pioneer in the field of photography, went bankrupt (Lucas & Goh, 2009).

This master thesis deals with the identification of characteristics and detection of disruptive technologies in the field of geospatial technologies. The goal of this thesis is to gather the data and information available and to analyses them relating to disruption in order to develop a method to rate the disruptiveness of a technology.

The term „disruptive technologies“ was first used by Christensen in 1995, describing them as underperforming and with new value propositions. The concept of disruptive technologies is not to be mistaken for sustaining technologies. Sustaining technology improves the existing technology whereas disruptive technology underperforms. Furthermore, disruptive technology as opposed to sustaining technology starts out in a niche market.

To quote Amshoff: *„Sustaining technologies improve the performance of established products measured against criteria customers and competitors are used to assess. Examples of such criteria in the context of motor vehicles include engine power or range. Disruptive technologies underperform established products in terms of the traditional performance criteria. However, they provide other benefits (e.g., a car's CO_2 footprint). These features do generally not attract interest within the existing mainstream markets, but are valued by a few fringe customers*“ (Amshoff et al., 2015, p.2). Disruptive innovation can affect any company but *„something that is disruptive in one company can have a sustaining impact on another*“ (Christensen et al., 2011, p. 94).

A lot of research has been done on the field of disruption but especially on the field of geospatial technology. Further research and analysis has to be done on the causes of disruption and whether there are common factors for disruptions or if they differ from field to field. This thesis gives an overview of the theme and discloses an accessible method to detect the disruptive potential of technologies.

1.2 Goal and hypothesis

The goal of this thesis is to explore methods detecting disruption in geospatial industries. By starting out with Christensen's framework other approaches will be discussed and an effective way to rate the disruption of a technology is set up. The primary research question is:

Which technologies in geospatial industries are disruptive?

To answer this question a chosen method is used on three examples as follows:

- GNSS based systems compared to theodolites
- Software as a service products compared to Desktop software
- Open Street Map compared to analog maps

The hypothesis of the research is:

There are disruptions in geospatial industries which can be rated based on a selected method.

1.3 Approach and research design

The approach to this topic is based on past examples of disruptive technologies described in academic journals, scholarly papers and books as well as experts' opinions. On the basis of the compiled characteristics a method will be used to integrate the characteristics into a prediction. Christensen's framework was used as a starting point and expanded by analyzing case studies of disruptive technologies. Based on the studies and various methods to identify disruption a new method was created. To test the method past examples were used as the outcome is distinct. After approving the method is used on present and future geospatial technologies to estimate their level of disruption.
Figure 1 shows the research design of the thesis. Previously analyzed characteristics, methods, case studies and interviews are integrated into a new framework which is based on a checklist. After evaluating the checklist, a prediction regarding the level of disruption is made.

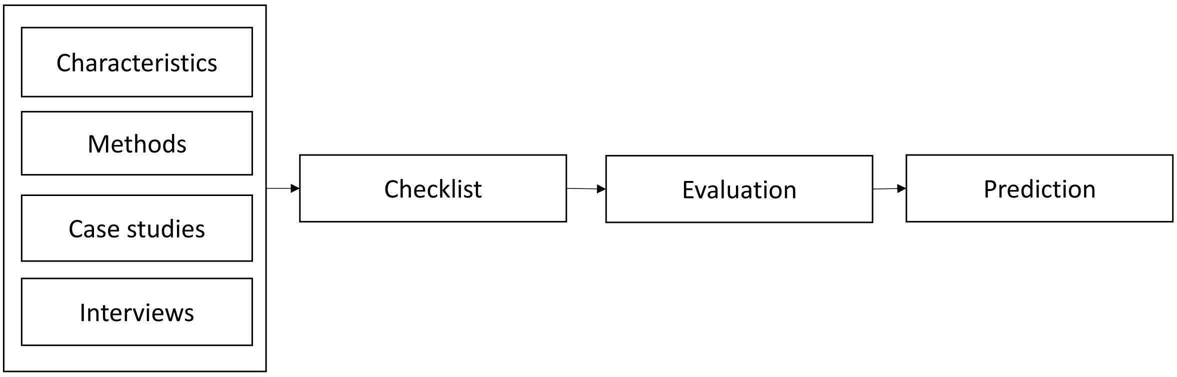


Figure 1: Research design

1.4 **Organization of the thesis**

The thesis consists of two parts: Part one is the theoretical part starting from chapter 2 to 3 and part two is the empirical part continuing on with chapter 4, 5 and 6. Chapter 2 starts off with a brief overview of the important points leading up to today's technology, then going to the different explanations of the term disruptive technologies. The characteristics of disruptive technologies are determined for future analysis.

In chapter 3 methods to identify disruptive technologies are discussed. Cases of disruptive technologies have to be analyzed and interpreted in order to collect data for predictions. Past cases of disruptive technologies were analyzed in order to distinguish the patterns and to predict disruption. In chapter 4 examples of disruptive technologies are analyzed and characterized based on selected methods. Examples include Google Docs versus Microsoft Word and digital cameras versus analog cameras.

Chapter 5 is about disruptive technologies in the geospatial sector starting with GNSS which was a cornerstone for a lot of upcoming developments in the sector, then Software as a service in comparison to Desktop software and Open Street Map versus analog maps. A checklist method was applied on the examples to rate their disruption level. In chapter six four experts from the geospatial sector are interviewed about their opinion on disruptive and upcoming technologies. Chapter 7 finishes up with the discussion and conclusion.

2 Theory

The first mention of the term „disruptive technologies“ was used to describe a technology that causes unpredictable life cycles (Christensen, 1995). In the beginning the phenomenon involved the technological aspect but the definition later included not only technology but also disruptive innovations (Christensen, 2003). In this chapter different specifications of the term disruptive technologies/innovations will be provided and determined. Furthermore, there will be an overview of characteristics for disruptions and critical comments on this field.

Today's technology plays a big role in our life and we cannot imagine one without it since big parts of our life involves and are surrounded by it. Economist Nikolai Kondratiev discovered that the development of technology comes in waves. Figure 2 shows Kondratiev waves consisting of cycles with a duration of 50-60 years and a reoccurring pattern. As seen in the figure below the main technology during the 1st wave was steam engines, then came steel and oil followed by information technology which has been the 4th and last wave so far. According to the graphic we are currently in the 5th wave which will enfold in the next decade (Linstone, 2011). Inventions up to now have relied on existing inventions, for example if steam engines had not have been invented, railroads could not be developed leading to the transportation of steel and oil and the flourishing industry. Having satisfied the technology on a grand scale, technology in the small scale like information technology arose. This development created the basis for modern technology. To find out which disruptive technology is waiting ahead, the term will be explained first.

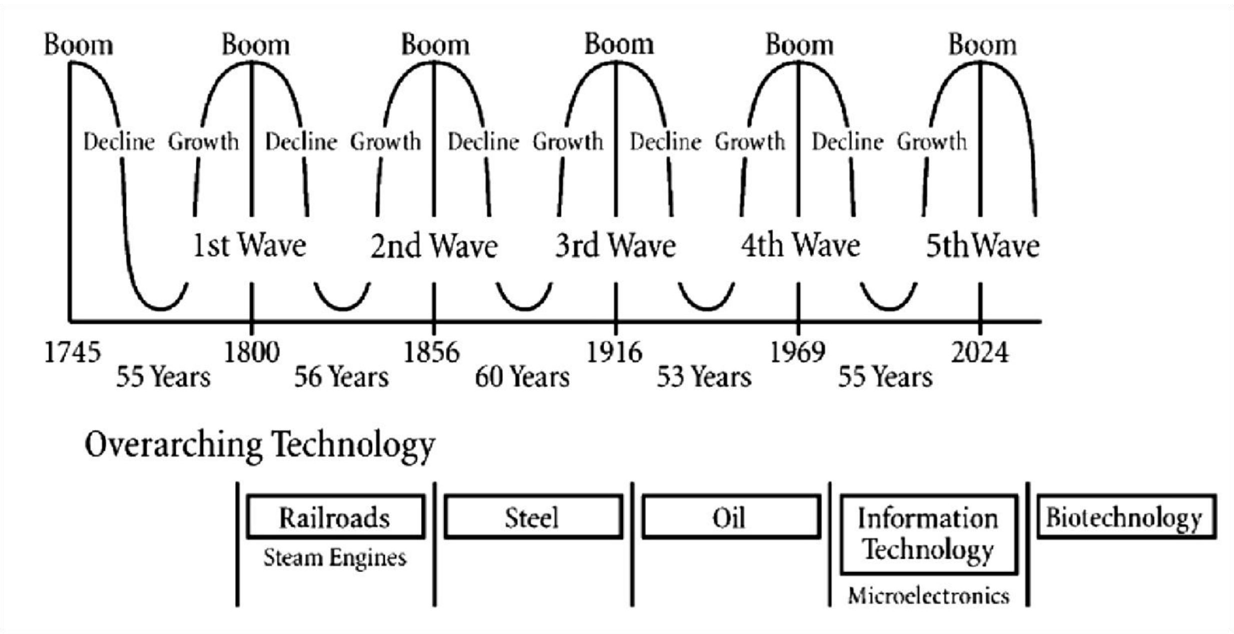


Figure 2: Long waves or K wave cycles
(Linstone, 2011)

2.1 Definition of the term disruptive technology

The term „disruptive technology“ was first established in 1995 by Christensen. Years later he replaced the term „disruptive technology“ by „disruptive innovation“ using the term „technology“ synonymously with „innovation“ (Christensen, 2003). Christensen (2011, p. xviii) describes disruptive technologies as following: *„Generally, disruptive technologies underperform established products in mainstream markets. But they have other features that a few fringe (and generally new) customers value. Products based on disruptive technologies are typically cheaper, simpler, smaller, and, frequently more convenient to use*“. With this specification 3 characteristics can be spotted: (a) underperformance (in relation to existing products), (b) new value proposition and (c) declining costs in technology. The detailed classification of characteristics is discussed in the next chapter. More definitions of disruptive technologies can be found in Table 1.

The most used characteristics are new value propositions and market entry level with a mention of 6 and 4 times out of 9 definitions. Govindaraj & Kopalle's (a) and Tellis' (b) definition of the term in Table 1 show a number of 5 disruptive characteristics and can be taken into account as a proper definition.

(a) „A disruptive innovation is described as introducing a different set of features and performance attributes relative to the existing products and being offered at a lower price, a combination unattractive to mainstream customers at the time the product is introduced due to inferior performance on the attributes mainstream customers value. However, a new customer segment (or the more price-sensitive mainstream market) sees value in the innovation's new attributes and the lower price. Over time, subsequent developments raise the new product's attributes to a level sufficient to satisfy mainstream customers, thus potentially attracting more of the mainstream market.“ (Govindaraj & Kopalle, 2006, p.13)

(b) „A new disruptive technology initially underperforms the dominant one along the dimensions mainstream customers in major markets have historically valued. But the disruptive technology has other features a few fringe (and generally new) customers value. Products based on disruptive technologies are typically cheaper, simpler, smaller, or more convenient than those established on the dominant technology. The leading firms' most profitable customers generally do not want and indeed initially cannot use products based on disruptive technologies. So disruptive technologies are first commercialized in emerging or insignificant markets. Incumbents conclude that investing in disruptive technologies is not a rational financial decision for them. The new disruptive technology steadily improves in performance until it meets the standards of performance demanded by the mainstream market. At that point, the new (disruptive) technology displaces the dominant one and the new entrant displaces the dominant incumbent(s) in the mainstream market.“ (Tellis, 2006, p. 35).

Author (year)	Definition	Characteristics
Christensen (1997)	Generally, disruptive technologies underperform established products in mainstream markets. But they have other features that a few fringe (and generally new) customers value. Products based on disruptive technologies are typically cheaper, simpler, smaller, and frequently more convenient to use.	New Value Propositions, Market entry level, Simplification, overengineering
Danneels (2004)	A disruptive technology is a technology that changes the bases of competition by changing the performance metrics along which firms compete.	New Value Propositions
Danneels (2010)	A disruptive technology is a specific type of technological innovation. In essence, a disruptive technology initially appeals only to a marginal market segment, but because of its improvement over time it can eventually satisfy the mainstream market. As a consequence, entrant firms that supported the disruptive technology displace incumbent firms that supported the prior technology.	New entrants
Downes & Nunes (2014)	There are four types of disruptive innovation. First, one with lower price, second better performance, but not cheaper, then third feature enhancement and same price and fourth, the Big Bang disruption which is better and cheaper.	New Value Propositions, Market entry level, declining costs
Govindaraj & Kopalle (2006)	A disruptive innovation is described as introducing a different set of features and performance attributes relative to the existing products and being offered at a lower price, a combination unattractive to mainstream customers at the time the product is introduced due to inferior performance on the attributes mainstream customers value. However, a new customer segment (or the more price-sensitive mainstream market) sees value in the innovation's new attributes and the lower price. Over time, subsequent developments raise the new product's attributes to a level sufficient to satisfy mainstream customers, thus potentially attracting more of the mainstream market.	New Value Propositions, New Market, Technology maturity, Declining costs, market entry level
Hüsig et al. (2005)	[A disruptive technology] describes a specific type of innovation that has the potential to alter substantially the basis of competition in an industry to the disadvantage of the incumbent firms.	New Value Propositions
Gilbert (2012)	[Disruptive technology is] a new technology that unexpectedly displaces an established one.	New entrant
Tellis (2006)	A new disruptive technology initially underperforms the dominant one along the dimensions mainstream customers in major markets have historically valued. But the disruptive technology has other features a few fringe (and generally new) customers value. Products based on disruptive technologies are typically cheaper, simpler, smaller, or more convenient than those established on the dominant technology. The leading firms' most profitable customers generally do not want and indeed initially cannot use products based on disruptive technologies. So disruptive technologies are first commercialized in emerging or insignificant markets. Incumbents conclude that investing in disruptive technologies is not a rational financial decision for them. The new disruptive technology steadily improves in performance until it meets the standards of performance demanded by the mainstream market. At that point, the new (disruptive) technology displaces the dominant one and the new entrant displaces the dominant incumbent(s) in the mainstream market.	New Market, Simplification, Technology maturity, market level entry
Yu & Hang (2011)	Innovation [is] not only in technology, but also in product, process and service.	New Value Proposition

Table 1: Definitions of disruptive technologies

2.2 Characteristics of disruptive technologies

Although some characteristics of disruptive technologies can be determined from the definitions in the previous chapter, a deeper explanation of the characteristics of disruptive technologies including examples will be given.

2.2.1 Technology maturity

Technology is based on the technology life cycle which depicts the maturity level of a technology over time. According to Little (1981) technology is classified into packing technology in the beginning, then key technology and base technology at the end of the technology life cycle which can be evaluated by key indicators in Table 2.
Eversheim's (2003) 10 key indicators are listed to determine a technologies' maturity stage. Uncertainty of technical performance/efficiency can be classified into high, medium, low and very low. It indicates how robust the technology is and how big the chance of a blackout could be or how often stoppages might occur. In the beginning investment in technology development is medium until it is at its maximum. Afterwards, the investments decrease to low and very low. Extent of potential application range is the sum of all fields where the technology can or might be applied to starting from unknown, where its use is indistinct. Once its use is found, the technology can be applied to a variety of fields resulting in a big application range. As a leading technology in a field gets replaced by another technology, its status changes to established. At the end the application range is decreasing. Scientific research forms the basis for development of a technology. As a key and base technology the focus lies on application orientation meaning that for further development the target is on practical usage. The aging base technology is cost oriented which means that improvement of technology only can be raised through more costs resulting in an unproportioned growth.
As a key technology the impact on cost-performance-ratio of products is maximized, meaning that the best performance can be achieved at the paid (lowest) price compared to a base technology where the ratio is low hence a worse performance would be attained for the same amount of money.
Type of patents shows in which stage the technology is: concept-related for packing, product-related for key and process-related for base technology. The number of patent filings typically is increasing in the beginning, hits its high as a key technology and decreases thereafter to low. Barriers to accessing markets in packing technology are R&D potential, in packing technology personnel, in mature base technology know how and licenses and in aging base technology application-know-how. The availability of packing technology is restricted since it is under development, as a key technology adapting and market oriented as mature base technology and high availability as it is on the market. Primary the duration of competitive advantage is big when the technology is new on the market. As other competitors catch up, the advantage

is at medium level and as an aging base technology the advantage is minimal or the technology is obsolete.

	Packing Technology	Key Technology	Base Technology	
Indicators	**Embryonic**	**Growth**	**Mature**	**Aging**
Uncertainty of technical performance/efficiency	High	Medium	Low	Very low
Investment in technology development	Medium	Maximum	Low	Very low
Extent of potential application range	Unknown	Big	Established	Decreasing
Requirement for development of the technology	Scientific	Application - oriented	Application - oriented	Cost - oriented
Impact on cost-performance-ratio of products	Secondarily	Maximum	Low	Low
Number of patent filings	Increasing	High	Decreasing	None
Type of patents	Concept - related	Product - related	Process - related	--
Barriers to accessing markets	R &D - potential	Personnel	Know-how, licenses	Application - know - how
Availability	Very restricted	Restructuring	Market - oriented	High
Duration of competitive advantage	Long	Medium	Medium	Short

Table 2: Indicators of maturity stages of disruptive technologies according to Little (Eversheim, 2003)

The maturity stages of technology can be visually depicted. Christensen's sigmoid curve or better known as the s-curve depicts the correlation between time and performance of a product of conventional (sustaining) technology where one technology gets replaced by another at the intersection of the curves (see Figure 3). In the early stage the advancement rate of the first technology is low. As soon as the technology is researched, the rate goes up and in the maturity stage the rate reaches its natural limit and more advancements can only be reached with much more effort which is disproportionate to the outcome. As this point is reached, the second technology which is more efficient, emerges and the cycle goes on. Usually disruptive technology starts out in a niche market as well as often simpler, cheaper and with lower profit margins than incumbent products. Besides the conventional s-curve there is a s-curve for disruptive technologies too. Disruptive technologies develop in their own value systems. As they are underperforming the incumbents do not recognize or ignore the threat until the performance can keep up with conventional products and they start entering the mainstream market as seen in Figure 4, pushing the incumbents aside and overtaking their leading position (Christensen, 1997). Danneels (2004) agrees with Christensen's characteristics such as lower performance for the mainstream market in the beginning which over time leads to satisfying performance.

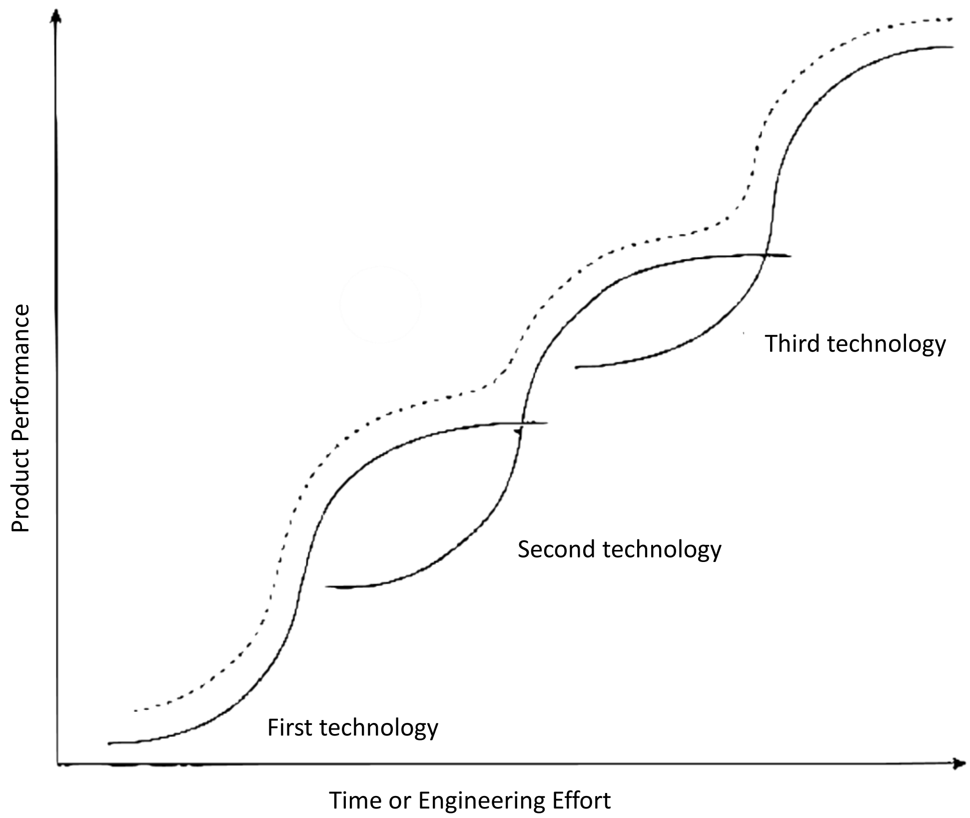


Figure 3: The conventional technology S-curve
(Christensen, 1997)

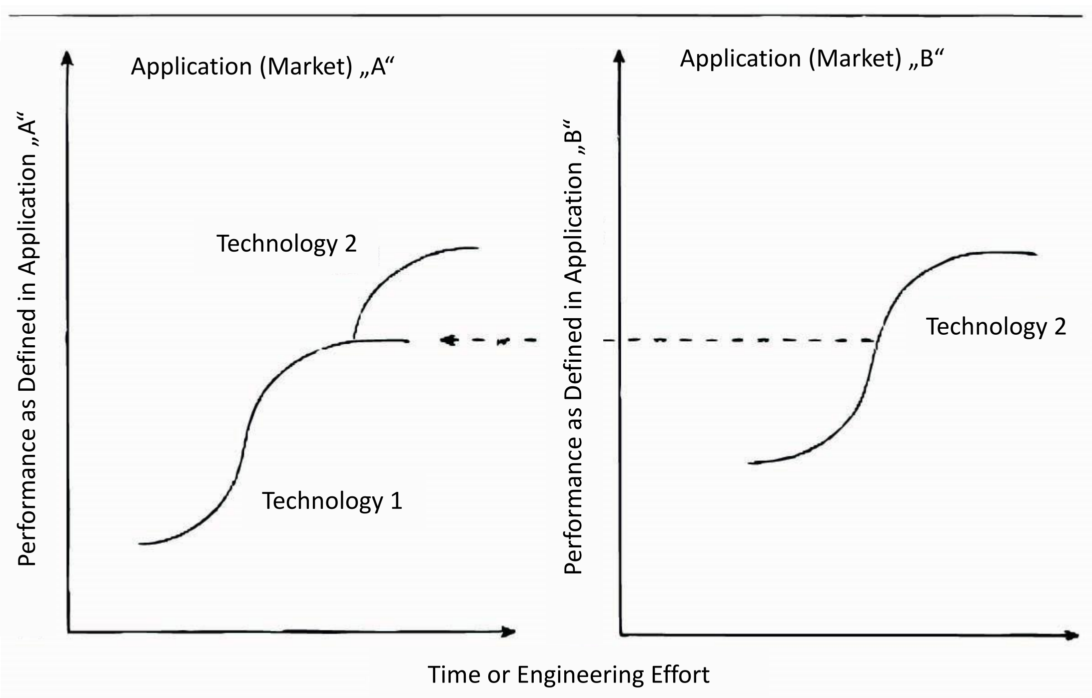


Figure 4: Disruptive technology S-curve
(Christensen, 1997)

2.2.2 Market entry level and declining costs of technology

There are two strategies to enter a market: „bottom up“ meaning low price segment and „top down“ which is starting in the more expensive segment. To enter the low price segment, two assumptions have to be made: First, the business model has to be low cost based and second, the products' performance level on the market has to be above the price which a customer is willing to pay (Christensen et al., 2002). The high end solution enters the market with a price that lies above the average price, an example is the iPod (Govindaraj & Kopalle, 2006). The first iPod with 5 GB storage entered the market in 2001 and was sold in Europe for € 500, comparable products were sold between € 200 and € 300, such as the Rave MP2200 with 64 MB storage from Sensory Science. Storagewise the iPod has a better MB/€ ratio but pricewise it cost as twice as much as other available MP3 Players (Focus, 2017; Miller, 2001).
Normally cheap products entering the market are outperformed by incumbent's products but there are Big Bang Disruptions which not only operate on the low end customer segment but also show a high performance level such as Google Maps compared to analog maps. Google Maps was not only free, but also had more features than an analog map could offer contradicting the argument that a disruptive innovation can only be cheap and have a bad performance or expensive with a better performance (Downes & Nunes, 2013).

According to Treacy & Wiersema (1995), businesses should stick to either low cost, constant innovation or customized offerings, but Big Bang Disruptions are creating a cheaper product that are not only better but also customized because of technology deflation like Google Maps and GPS tracking features on smartphones. So nowadays Big Bang Disruptions do not stick to one strategy but all at once (Downes & Nunes, 2013). The main advantages of Google Maps compared to analog maps are the costs, the availability and special features like routing or position reckoning.
Figure 5 shows the time/cost relation between conventional and Big Bang products and that before technology was either better, but expensive or cheaper, but had worse performance. The factors that lead to the rapid developments and sinking costs are connected with progresses that are made in computing power, software development, the Internet and standardized interfaces which allow global access. The declining costs in technologies are related with declining costs in experimentation, information and innovation (Downes & Nunes, 2014).

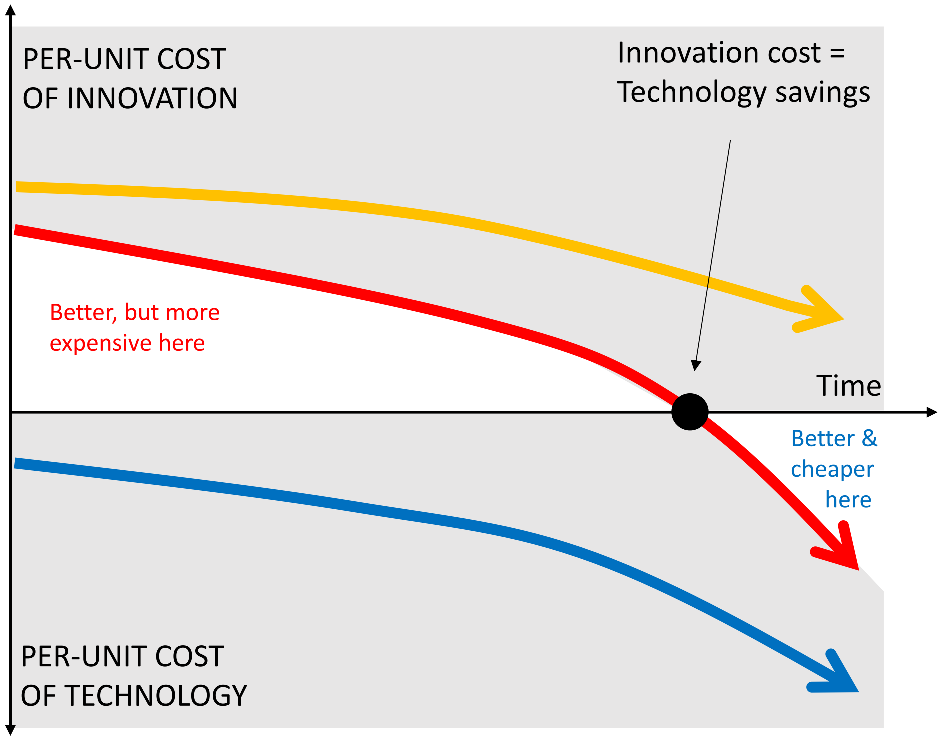


Figure 5: Declining costs in technology
(Downes & Nunes, 2014)

2.2.3 New Value Propositions

New value propositions can be seen as added values to the attributes of existing technology. They are a decisive reason for customers to buy goods based on the price. A new business model also counts as a new value proposition. Google Maps serves as an example as it is simpler and cheaper compared to a navigation system and it is also a cloud based system so it is not dependant on downloaded maps.
A simplification of a product is also known as reverse innovation. International companies develop simple and cheap solutions for emerging and developing countries. General electric for example produced a cardiogram machine for just $ 2500 destined for the rural Indian landside which cost less than 80% of comparable models that were on the market at that time. Siemens paired up with Somatom Spirit and created a computer tomography scanner which cost € 150 000 instead of € 1 000 000. In China an ultrasound device was created just costing € 40 000 instead of € 100 000 and only 5 years later dropping to € 15 000 (Christensen & Matzler, 2015).
Yu & Hang enlisted several categories of new value propositions in disruptive innovations which can be summed up in miniaturization, simplification, augmentation and exploitation for another application. After analyzing 37 case studies, simplification was the most used strategy (40.8%), followed by miniaturization (28.6 %). The authors noted that these strategies only

apply for disruptive innovation and not radical innovation and to disruptionwise consider the technology to develop as affordable, with good performance, new features, time and resources (Yu & Hang, 2011).
There is a linkage between disruptiveness and business model concept: A disruptive business model innovation redefines the concept of the product so the new business model has to increase profit, either through new customers or increased consumption. Disruptive technologies have the potential to overtake the market whereas disruptive business model innovations only increase their market share (Markides, 2006).
An example for that would be the digital camera, which in comparison with an analog camera is in fact more expensive in buying but comes with advantages such as instantly seeing the taken photos or deleting them, taking as many photos as you want (as long as memory card is capable of). With instant photography, you can transfer the photos right onto the computer and share them with the world.

2.2.4 New entrants

Disruptive technologies are often introduced by new entrants (Bower and Christensen, 1995). But incumbents do not see them as a threat due to their little market share. As the new entrants take over the mainstream market it is often already too late for incumbents to take action. The reason for the success often lies in their new business models (Christensen, 2006) and new value networks (Rosenbloom & Christensen, 1994). An example for a new entrant is Amazon. Amazon started as an online bookseller in 1995, rapidly transforming into the world's biggest book retailer. They did not invent a new product, but a new business model based on the Internet and added values such as low return rates, big selection and cheaper prices. Later on, the company introduced Kindle, an e-book, which became a bestseller and Amazon Web Services, a cloud based solution (Ritala et al., 2014).

2.2.5 New market

Two types of disruptive technologies can be distinguished: One takes up the incumbents' technology while customers gradually embrace the new technology gradually. An example thereof would be the replacement of the horse by the horse drawn carriage and later by the automobile. The second type is disruptive technology fabricating a new market like the personal computer (NRC, 2010).
Often the change of market or generally creating a new market causes a product to be disruptive in the new market. An example therefore is Honda. Honda had manufactured a bike for short distances and wanted to conquer the American market with a specifically altered bike

that could compete with Harley Davidson but their efforts seemed to be in vain. One day the negotiators sent from Japan discovered that the bikes were suited for off road challenges and wanted to promote the bikes for this terrain. At first Honda did not want to agree because they did not want to change the image and the use of the bikes but in the end Honda was persuaded and Honda as an off-road bike manufacturer was established (Christensen, 1997). New markets offer disruptive technologies the possibility to gain a foothold in niche markets to then take over the mainstream market.

2.2.6 Overengineering

A performance oversupply is a promotor for disruptive technologies because it usually leads to simpler and cheaper alternatives (Christensen, 1997). The same goes for overengineering. Overengineering is taking a lot of resources to improve the performance of a product slightly thus representing a small cost performance ratio.

As shown in the cases of insulin or Microsoft Word, when functions are working way above the market demands, it is most likely a disruptive technology will develop. In 1922 the first time insulin from animals could be extracted to help battle diabetes. The first insulin from a company named Eli Lilly in 1925 contained 50 000 ppm (parts per million) of impurity, in 1950 it could be decreased to 10 000 ppm and in 1980 it came down to 10 ppm which was the highest purity that can be achieved. As some diabetics were resistant to the animal based insulin, the company decided to produce a human based insulin that should also be highest purity. The product named Humulin cost one billion dollars in development and the price of sale was 25% higher than animal based insulin but the product failed due to overengineering, there simply was no need for insulin this pure. At the same time Novo developed an insulin pen, which reduced the time, effort and treatment of diabetics. Up to that time every diabetic had to carry a syringe with which the exact amount of insulin hat to be drawn from a vial that contained several doses. The whole process lasted at least one to two minutes. The NovoPen on the other hand is an injection system with exchangeable cartridges. The whole injection process was reduced to 10 seconds or less and the dosing was precise so all in all the NovoPen not only brought a reduction in time and effort, but also an increase in precision (Christensen & Matzler, 2015).

Also the case of Microsoft Word and Google Docs serves as an example: Microsoft Word launched its first version in 1983 and continuously added more functions – all in all there are more than 1000 functions which could be executed in Word, compared to nearly 200 of Google Docs which is also available online. It is estimated that users only use about 10 % of all available functions so Google Docs meets the needs of the users whereas Microsoft Word exceeds the demands (Christensen & Matzler, 2015).

Keller & Hüsig's characteristics of a disruptive innovation are shown by the performance and price trajectories which intersects with the market demand. High end disruptions have high performance and also high prices at first but then due to technology advantages the price declines over time and meets with market demands. On the other hand, the low end disruptions start out later than the sustaining innovations but are lower in price and performance but as time progresses, also meets the market demands (see Figure 6).

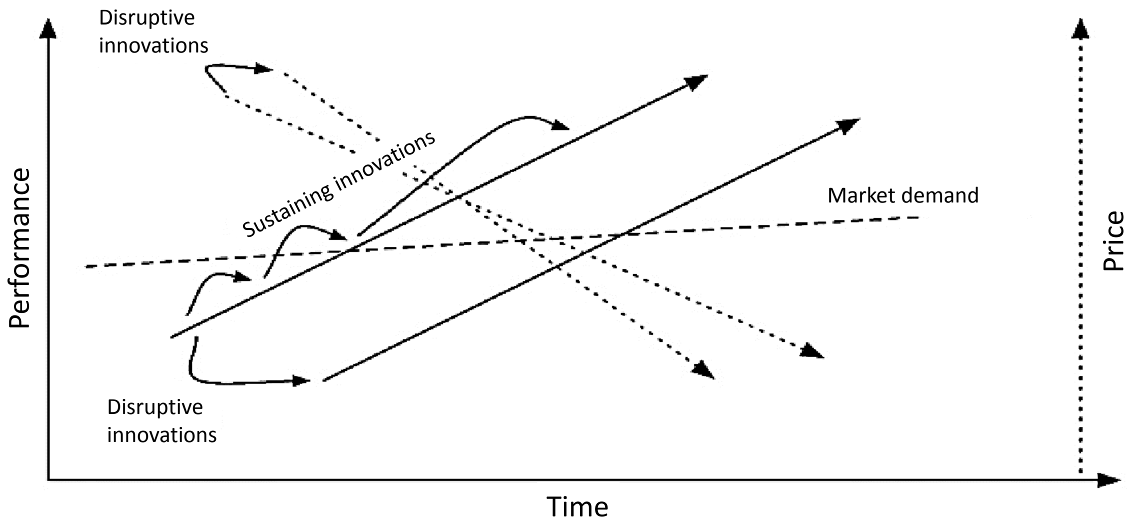


Figure *6:* Disruptive innovations create a new performance and price trajectory. Sustaining innovations, in contrast, move a new product or service along its existing trajectory
(Keller & Hüsig, 2009)

The definitions of disruptive technologies from Table 1 are used to classify characteristics in Table 3. The characteristics were divided into seven categories. Each definition was assigned to one or more correlating characteristics. Most mentioned characteristics were added values and simpler and cheaper technology compared to the existing ones.

Author (year)	**Characteristics**						
	Underper-formance in the beginning	Simpler, cheaper	Niche market	Over-engineering	New entrants	Added values	Declining costs
Amshoff et al. (2015)	x			x			
Christensen (1997)	x	x	x	x	x		
Danneels (2004)	x		x				
Downes&Nunes (2014)		x				x	x
Govindaraj&Kopalle (2006)	x	x				x	
Hardman (2013)			x			x	
Hüsig et al. (2005)			x			x	
Kostoff et al. (2004)		x				x	
Yu & Hang (2011)		x				x	
Total	4	5	4	2	1	6	1

Table 3: Characteristics of disruptive technologies

2.3 Criticism of the concept

As Christensen was the first one to introduce the concept of disruptive technologies and build the framework, he formed the basis for consecutive research in this area. But his work is also criticized. In the following Danneels (2004) and Downes & Nunes (2014) express their criticism. Danneels criticizes Christensens term of „disruptive technologies“. It would not have concrete criteria to rate them. Other points are that the ambiguity of the statement that a technology can be disruptive to one company but sustaining to another and the point in time when it becomes disruptive. In Christensen's opinion, one way to detect disruptive technologies is when the performance demanded by the mainstream market intersects with the performance provided by the disruptive technology. But there are more than one criteria when it comes to performance factors so the decision parameters are more than two dimensional. Danneels also criticizes that Christensen's characteristics such as „simpler, cheaper, more reliable and convenient“ are typical but not necessary ones for disruptive technologies. Given examples in Christensen's book only include successful case studies and focused more on arguments why companies failed instead of what to do to remain successful. All characteristics from disruptive technologies are made ex post which raised the question if it is possible to detect them ex ante. A problem to be faced is that disruptive technologies often enter a new market, hence there are no data available to predict them. In order to predict disruptive technologies ex ante, one could do a historical study albeit time consuming. Also the attention should not only be focused on how not to fail. For prediction one can use the Delphi techniques or try shifting their marketing strategy.
Following points from Christensen are also criticized:

- Despite companies in the USA having troubles competing against disruptive technologies, Japanese companies did not have these kind of troubles. It is unclear why one technology is disruptive in one country but not in another one.
- In the software industry, network effects occur. One innovation is dependent on or pushes/drags another innovation/technology so it is impossible to only look into one industry without disregarding another. So the uprise of a technology can depend on another one.
- The so called truth teller is often mentioned. Companies should seek a person who has insights in the industry but the problem is to know whom to listen to und when to listen.

3 Technology forecasting

Technology forecasting is used to predict possible new technologies and technologies that could replace an existing one. In this chapter methods for forecasting are presented which can be used to identify disruptive technology. This field of research is quite young and arose after the Second World War. One of the first methods was the Delphi method which was developed by the Research and Development (RAND) Organization as well as gaming and scenario planning. With the upcoming of computers and increasing power of data processing large data sets could be analyzed. Also the Internet and networking increased the amount of data to work with (NRC, 2010). In the following methods to forecast technologies are introduced as well as a checklist method to distinguish whether to rate a technology disruptive or sustainable.

3.1 Delphi Method

The Delphi method is a multilevel procedure based on experts' opinions. A group of experts anonymously take part in a survey. The individual responses are analyzed and put into a median response. Having been notified of first rounds' answer the experts can rethink their answers and the same questionnaire is taken again. This cycle lasts at least for two rounds until the results reach a predefined stop criterion (NRC, 2010) which can be the number of rounds, the achievement or the stability of consensus (Rowe & Wright, 1999). The goal of this method is to decrease the range of answers (Linstone, 2010). The advantage of this method is that the feedback is controlled and it can be used on a wide variety of topics. Furthermore, it does not involve the participants to meet physically so it is spatially independent, inexpensive and quick to use (NRC, 2010). A disadvantage could be that important individual information is left out in order to show a group opinion (Stewart, 1987).

3.2 Extrapolation, Trend Analysis and Models

Extrapolation and trend analysis are based on historical data to predict future trends. This method of forecasting presumes that the future is an extension of the past and trends can be predicted using gathered data. Trend extrapolation, substitution analysis, analogies and morphological analysis are forecasting methods based on extrapolation and analysis. Trend extrapolation is used to predict a future pattern of data gathered over time. The Gompertz and Fisher-Pry substitution analysis relies on the growth or S-curve for predicting trends. Analogies use patterns of past situations or technologies alike for forecasting (NRC, 2010).
In theory models are based on an equation like in mathematics where on one side information is given and processed and on the other side is the outcome. In the days of increasing

computer power and the ability to process large amount of data, the only crucial point is the lack of theory characterizing the socioeconomic change; it is difficult to create a model which considers all aspects and relations between given factors. Examples of model based methods are the Theory of Increasing Returns, influence diagrams and Chaos theory and artificial neural networks.

However the Theory of Increasing Returns signifies that especially in the knowledge based industries the returns do not decrease but increase tremendously – often involved with a „lock in“ like Google, Facebook or Apple's IPhone where customers once using the product have to stick to the product. A change to another product comes with information costs.

The main statement of the Chaos theory and artificial neural networks is that technology evolution is very similar to the chaos theory. It is due to nonlinear development and follows a complex pattern which seems to be illogical. In order to set up a mathematical model a neural network is used to run pattern recognition on already existing data sets. This kind of forecasting technique needs a big set of validated data to get good results. In order to process these large sets of data equal computational power is required. Biases could occur during the automated approaches and multiply. Also patterns can be falsely established where there are none which can cause unwanted correlations and pattern identifications when in reality none existed. To prevent such cases, it is recommended to review the data and algorithm frequently (Wang et al., 1999).

3.3 Scenarios and simulation

Scenario planning was one of the first forecasting methods used. It started out with depicting a surprise-free scenario, but soon all development paths of a scenario were tracked and analyzed. In order to create scenarios, it is fundamental to know the potential of the technology and how it could be applied as well as its fundamental science (NRC, 2010). Another scenario planning technique is called „backcasting“ which starts at future scenarios leading back to the present and analyzing which steps and considerations have to be taken leading to the favored end. The military utilizes simulation and war games for their purpose of creating and testing scenarios. The main factor in these simulations are human based and focuses on the action each individual take, their communication with each other and their distinct use of technology (NRC, 2010).

3.4 Patentometrics

Momeni and Rost's methods in exposing disruptive innovation is through patent development paths, k-core analysis and topic modeling of past and current trends of technological development. Patentometrics is a strong method to detect disruptiveness ex ante. A submitted patent most likely contains some kind of new invention or invention on a new technology basis so it can give a hint for future technologies. But not all patents are easy to read as most of them are written in a complicated manner or it is impossible to determine which technology is behind each patent. Also not all inventions are patented and the method is restricted to a certain amount and class of patents. This analysis was made based on patents in the photovoltaic industry only and has yet has to be tested in other categories. The analyzed patents contained patents that were registered worldwide which means the study does not account regional patents (Momeni&Rost, 2015). Bibliometrics such as patentometrics is an area of scientometrics and its purpose is to determine the relationships between patents and papers, but not more. It measures the quantitative aspect of research and the development of science and network, for example ranking lists of how many articles a university or a scholar had published. As already stated, bibliometrics does not conclude measurements about the quality of scientific publications but their quantity.

3.5 Gartner Hype Cycle

The Gartner Hype Cycle is - as the name already reveals – developed by an American research company named Gartner and it is a graphical display of the maturity state of technologies. As shown in Figure 7 the cycle is divided into five phases categorizing technology into Innovation trigger, Peak of inflated expectations, Trough of Disillusionment, Slope of Enlightenment and Plateau of Productivity. The Hype Cycle resembles a shifted s-curve, the difference is that after starting out there is a hype of the technology which flattens out slowly regaining market shares. In the graphic representation the technologies are put into time periods of their predicted emergence. For example, according to Gartner, Virtual Reality will be in the slope of enlightenment in the next 2 to 5 years.

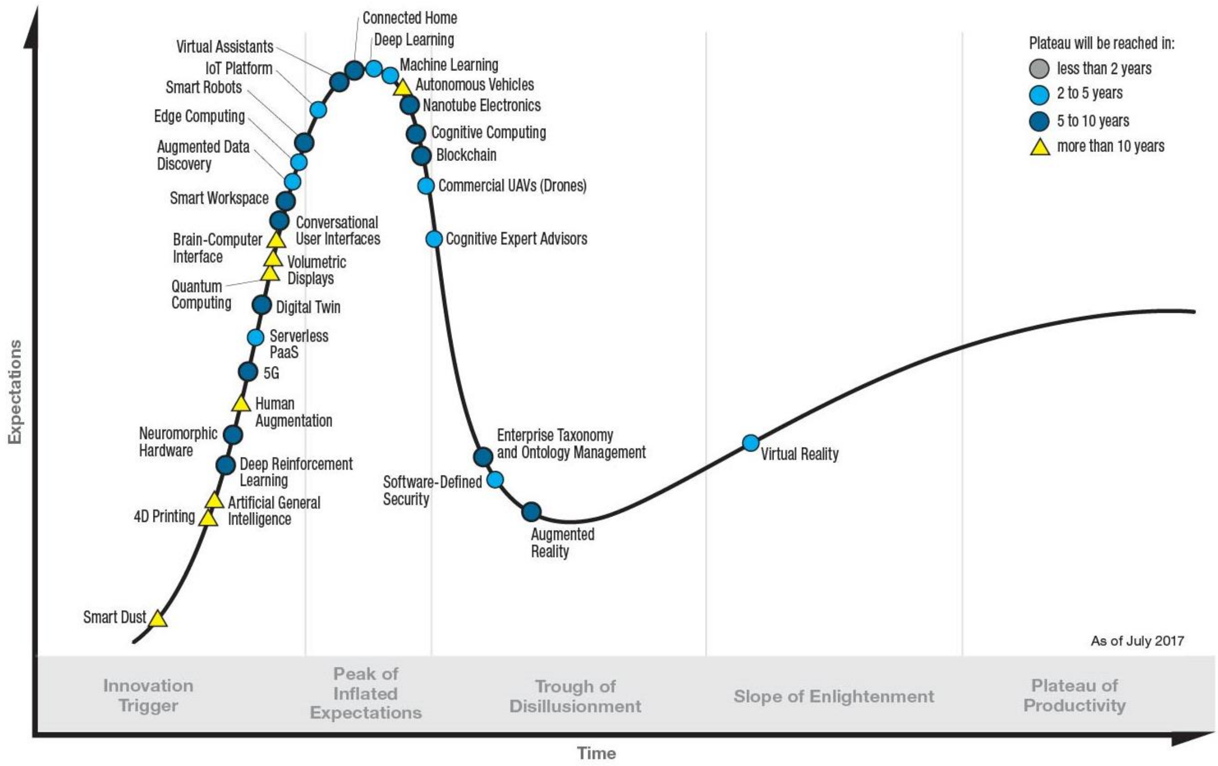


Figure 7: Gartner Hype Cycle
(Gartner, 2017)

Many use the consensus or Delphi method to predict trends but they are just based on subjective opinions and it is also very time consuming and costly collecting these amount of data for this type of analysis. Structural models do not explain all relationships within the factors used as forecast in macrolevel. Disadvantages of scenarios and technological vigilance are that they are also subjective, cognitive and costly because of the collected data quantity. Rolling cluster algorithms and blog analysis fail to depict the process of technological development, furthermore quantitative procedures make them costly and the analysis is subjective depending on experts' opinions. As of now methods can only give a trend on upcoming technologies.

3.6 Checklists

In order to determine the disruption level of a technology, studies on checklists from following authors are used:

(a) Keller & Hüsig (2009)
(b) Momeni & Rost (2015)
(c) Yu & Hang (2011)
(d) Govindaraj & Kopalle (2006)
(e) Sainio & Puumalainen (2006)
(f) Hüsig et al. (2005)

Keller & Hüsig (2009) base their method on previous studies by Rafii & Kampas (2002), Christensen et al. (2004) and Hüsig et al. (2005) which all are based on Christensen's original theory. Keller & Hüsig identified five characteristics for a disruptive innovation and set up a criteria sheet. This sheet contains three phases: foothold market entry, main market entry and failure of incumbents. They did not only set up a checklist for incumbents but also a separate checklist for entrants to determine whether the disruptive potential is high. Each question can be answered with „Fulfilled“, „Not Fulfilled“ or „Unknown“. The answers for each category are added together and displayed in a bar chart. Moreover, they picked two significant performance attributes to compare the trajectory maps. The method was tested on Google Docs and Microsoft Word.

Momeni & Rost (2015) focus on patents and patents citation as well as linkages between patents. Their method combines path identification based on a forward citation node pair algorithm, k-core analysis, topic modeling and academic literature research. Their forward citation node pair algorithm is based on Choi & Park (2009). Forward citation is the linkage between patents that are referred to from other patents (the opposite is backward citation when the patents refer to other patents). K-core analysis classifies subgroups of patents and topic modeling analyzes the occurring of words and meanings in text bodies in relation to each other. All of the above mentioned methods were applied on the photovoltaic industry.

Yu & Hang's (2011) method of detecting disruption involves four steps: identification, abstraction, postulation and demonstration. They extracted the new value propositions of each case study and categorized them into miniaturization, simplification, augmentation and exploitation for another application.

Govindaraj & Kopalle (2006) analyzed seven papers and extracted five common characteristics disruptive innovations contained on which they determine the probability of a technology to be disruptive.

Sainio & Puumalainen's (2006) framework is based on disruptive characteristics. They extracted six propositions, each with corresponding questions which can be answered with confirmed, partly confirmed or not confirmed. In group discussions representatives of different companies and working positions developed answers to the propositions.

Hüsig et al. (2005) developed a questionnaire with 64 questions based on disruptive characteristics. If more answers are 'no', then a disruption is unlikely.

Based on these six studies a new checklist was created to be applied on past, present and future technologies.

4 Case studies of disruptive technologies

As in the previous chapters’ characteristics and methods of forecasting disruptive technologies have been presented, this chapter is about creating a checklist method based on the previous ones to determine the disruptive potential of technological developments. In addition, the method is applied on two examples as a preparation for using it on technology in the geospatial industry.

4.1 A new approach for rating the disruption level of technology

Based on the acquired characteristics of disruptive technology a checklist was created in order to determine whether a technology has a high disruptive potential or is sustainable. Christensen's framework, disruptive characteristics and articles from the previous chapter 3.6 were used for the questionnaire. The checklist is divided into 5 categories and consists of 13 questions altogether (see Table 4) which equals the number of main characteristics of disruptive technologies (the chapter overengineering is included in technology maturity in the question „Does the technology perform worse based on established attributes?“). To each chapter one to four corresponding questions are elaborated and classified with high, medium or low. If a question in a chapter cannot be answered, the question will be dismissed depending on the prioritization of the other questions within the chapter and in relation to the other chapters.
Four questions about switching costs, new markets and new entrants derive from characteristics that occur within disruptive technologies. They were chosen because the data can be accessed easily and depicts an effective way to estimate the disruptive potential of a technology.

Characteristics	Question	Reference
Technology maturity	Is the number of patents high?	Momeni & Rost (2015)
	Does the technology perform worse based on established attributes?	Keller & Hüsig (2009) Govindaraj & Kopalle (2006)
	Does the technology start out in a niche market?	Keller & Hüsig (2009)
	Is the technology based on standard components?	Keller & Hüsig (2009) Hüsig et al. (2005)
Market entry level and declining costs of technology	Was the technology at market entrance more expensive than existing technology? And declined over time?	Keller & Hüsig (2009)
	Is the technology in the low price segment?	Govindaraj & Kopalle (2006) Hüsig et al. (2005)
	Are the switching costs low?	
New Value Propositions	Is the technology cheaper, simpler, more comfortable or more reliable than the existing technology?	Keller & Hüsig (2009) Sainio & Puumalainen (2006) Govindaraj & Kopalle (2006) Yu & Hang (2011) Keller & Hüsig (2009)
	Does the technology address current non-consumers?	Govindaraj & Kopalle (2006) Keller & Hüsig (2009)
	Is there a new business model behind the technology?	Keller & Hüsig (2009)
New entrants	Are there many new entrants?	
New markets	Is there a new market for the potential disruptive product?	
	Is the extent of potential application range big?	

Table 4: Checklist method to identify disruptive technologies

The new checklist is first tested on two afore discussed examples before it is applied on three more examples from the geospatial industry.

4.2 Google Docs versus Microsoft Office

In order to prove whether Google Docs (GD), compared to Microsoft Word (MW), is a disruptive innovation or not, the checklist is applied. This example is based on Keller & Hüsig (2009) with a few additions.

4.2.1 Technology maturity

At the beginning Google performed worse than Microsoft because the program had less number of operations (see Figure 8) but with time the numbers increased and satisfied customers. It did start out in a niche market because the capacity of the software was limited but the advantage was that the documents could be shared and edited online. The technology is based on standard components since a computer or laptop with an Internet access is required.

4.2.2 Market entry level and declining costs of technology

Google Docs is free of cost so it is cheaper to use than Microsoft Word which you have to buy a license for (starting at € 69/year). Therefore, Google Docs entered the market in the low price segment, resulting in low switching costs.

4.2.3 New Value Propositions

As Google Doc documents are accessible online and is designed for multiple users as well as simultaneous use, its potential application range is big. It addresses non consumers because it is easy and free to use. It is a new business model because Microsoft Word is based on paid Desktop software while Google Docs is a free online program stored in a cloud. Customers were oversatisfied with MW because the number of operations were exceeding the upper demand (see Figure 8). Google is a new entrant in the text editing sector, starting in the year 2006. It is simpler than existing technology because the documents are not stored locally but in a cloud and can be accessed from anywhere in the world via Internet. MW documents easily can be up- and downloaded via internet but the main advantage within GD is that the document itself is stored, edited and saved online whereas MW docs have to save and uploaded first in order to be stored online.

4.2.4 **New entrant**

Microsoft Word was first introduced in 1989 whereas Google Docs was released in 2007. Three years later, in 2010, Microsoft also launched an online version of its text editing program. OpenOffice, launched in 2002, can be seen as a new entrant or a competitor to Microsoft Word. It offers the same functionalities as Microsoft Office such as Writer (Word), Calc (Excel), Impress (PowerPoint) or Base (Access).

4.2.5 **New markets**

According to a study published by Gartner in 2013 the market for cloud office systems will rise from 8 % to 33 % by 2017. Microsoft currently has 1,2 billion 'Office' users. Approximately over 21 % of Internet users work with OpenOffice while 72 % with Microsoft Office (Webmasterpro, 2010). Cloud office systems like Google Docs do have the potential to catch up on market share and users as Microsoft launched Azure around the same time Google Docs did. The extent of potential application range for cloud based systems is very wide considering the increasing data amount and the hereby combined efforts to store them.

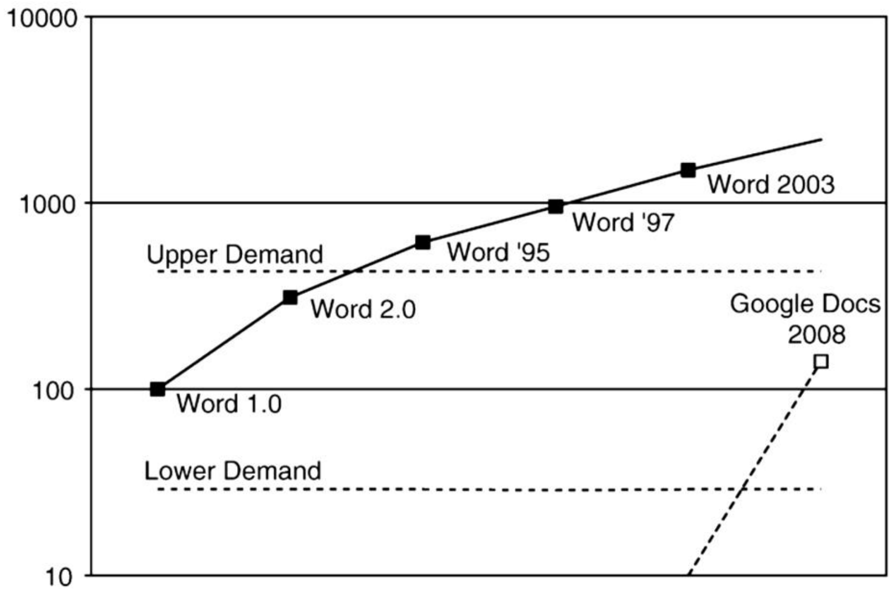


Figure 8: Number of operations in text editing software
(Keller & Hüsig, 2009)

4.2.6 **Summary**

Although both programs, Microsoft Word and Google Docs, are based on the same technology and infrastructure, they do not share the same business model. When Google Docs started out, their product only had few functions to work with compared to Microsoft Word and did not meet the demand line. Over time the number of operations of GD increased and soon met the customers' demands. MW has started with much more operations than GD and also increased during time but only a small percentage of the functions are used which is an example for performance overshooting. GD comes with additional values such as being free of charge whereas using MW requires buying the software for a limited period of time. Other added values include the cloud based solution to store documents online which enables users to access and share it instantly from anywhere in the world with anyone. In contrast, MW requires the document to be saved locally and also manually, GD saves the document automatically as soon as something is changed. In 2012, Gartner estimated that Office had a market share of 90 % but GD's shares could be rising up to 50 % in the next 10 years. All categories of the checklist are rated high, leading to the conclusion that Google Docs is disruptive compared to Microsoft Word (see Table 5). More about cloud computing and Software as a service can be found in chapter 34.

	Disruptive potential	Notes
Technology maturity	high	Underperformance in the beginning, niche market
Market entry level and declining costs of technology	high	Free software
New value propositions	high	Free, worldwide online access
New entrant	high	
New market	high	Cloud storage

Table 5: Checklist for Google Docs

4.3 **Digital cameras versus analog cameras**

Digital camera versus analog cameras is the second case study on disruptive technologies. It is based on Lucas & Goh (2009) and extended with data from the new checklist.
The first ever camera ever was the „camera obscura“, which produced an upside-down photo when light came through a tiny hole. At the end of the 19th century George Eastman fabricated the first Kodak Box which was nearly as big as a brick and the company took over the film development so the user just had to take photos. With the beginning of the 20th century Oskar Barnack invented the Leica Camera which already had the shape as the analog cameras we are

familiar with. Cameras supported photo journalism, especially during war (Steffof, 2007).
The first ever digital camera ever was introduced in 1975 but it was not until the beginning of the early 1990s that it was available for purchase for the mainstream market. The very first digital camera weighed 4 kg and it took 23 seconds to save photo. Furthermore, the resolution was only 0.01 Megapixel (for comparison smartphone cameras can take photos with a resolution of 20 Megapixel). After the year 2000 sales in analog cameras began to decline constantly whereas digital cameras increased theirs (Lucas & Goh, 2009, see Figure 9).
In the year 1990 the price for an analog camera was $ 135, the price for a digital one was $ 995 which was unaffordable by normal standards and therefore access was restricted only to a small percentage of people. With declining costs in technology digital cameras entered the mainstream market replacing the analog camera. In 2016, 73.6 % of German households owned a digital camera (Statistisches Bundesamt Deutschland, 2016).

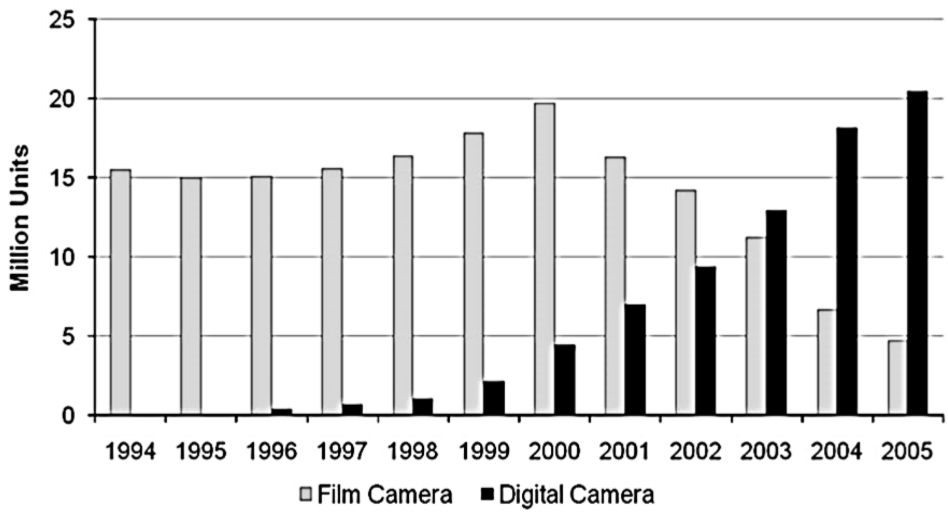


Figure 9: Comparison of sales numbers of analog and digital cameras 1994-2005 (Lucas & Goh, 2009)

4.3.1 Technology maturity

The technology maturity of the digital camera in the beginning was low: the number of patents was increasing until the year 2005 (1990: 20 000, 1995: 110 000, 2000: 760 000, 2005-2016: 1 million, accumulated, via Google patents). At first the technology performed worse based on established attributes because digital cameras were very expensive and bulky and had little memory storage. Only professional photographers were able to afford them so they started out in a niche market. Back then the camera's components (e.g. memory card) were not based on standard components but they later became standard.

4.3.2 Market entry level and declining costs of technology

The digital camera started out as a very expensive tool to take photographs, it cost $ 20 000, and could store 70 photos with a resolution of 1.3 megapixel so it was not in the low price segment (Zhang, 2015). But by 2003 when sales of digital cameras passed sales of analog ones, they were affordable, so the costs declined over time. Nowadays digital cameras cost as little as € 50 on Amazon. The switching costs from analog to digital camera were initially higher but with time they amortized since buying film rolls and developing photos were not needed for digital cameras.

4.3.3 New Value Propositions

The afore discussed technology comes with new value propositions: It is simpler as well as more convenient and reliable than analog photography. A new business model is involved since films do not have to be developed anymore and a digital image can be shared endlessly without additional costs. More advantages are that the photos can be transferred and edited on the computer and as well as be displayed instantly. Also in the same amount of time more photos can be taken with the digital camera with the analog one. The technology addresses non-consumers because the digital camera is easy to handle and does not require much knowledge for usage; it became affordable for everyone.

4.3.4 New entrants

The digital camera market was not dominated by new entrants, all of the companies that started developing digital cameras as Canon (1937), Nikon (1917), Konica (1873), Minolta (1928) or Fujifilm (1934) had been existing for at least 50 years, some even before the 1900s (data via homepages).

4.3.5 New market

Digital photography came at a time when it was more convenient to buy a digital camera than an analog one. The range of potential application range is big as is it easier to exchange photos on the computer through the Internet and as the changing of a film role is no needed anymore, much more photographs can be taken in the same amount of time.

4.3.6 **Summary**

The digital camera shows many characteristics of disruption. One is that they started in a niche market because they were expensive and only photographers were able afford them. Another characteristics is underperformance in the beginning resulting in little memory, low resolution, image noises and a bad color perception as well as the high price and the size of the camera. The price dropped over time as components became standard and therefore cheaper leading to affordable cameras. Digital photography enabled new possibilties of taking photos without additional costs. Digital photos can be saved, edited, sent or deleted and most of all be viewed in an instant instead of having to wait for them to be developed. It is simpler, cheaper and more convenient to take photos with a digital camera since little to no previous knowledge is required. The evaluation of the checklist results in digital cameras being a disruption in comparison to the analog camera both for private users and the industry (see Table 6).

	Disruptive potential	Notes
Technology maturity	medium	At the beginning underperforming, bulky, expensive
Market entry level and declining costs of technology	high	Costs declined over time, expensive in the beginning
New value propositions	high	Simpler, more convenient
New entrants	low	
New market	high	Big application range, growth rate

Table 6: Checklist for digital camera

5 Disruptive Technologies in geospatial industry

In this chapter three innovations in the geospatial industry are analyzed whether they are disruptive or not based on the checklist in chapter 3.6. The examples chosen are GNSS/theodolite, Software as a service (Saas)/Desktop software and Open Street Map/analog maps. At the end of every example the technology will be evaluated as disruptive or not disruptive. The evaluation time is the technology at present.

5.1 GNSS based system versus theodolite

GNSS stands for „each global navigation satellite-based systemes well as the combination or augmentation of these systems“(Hofmann – Wellenhoff et al., 2008, p.3). Global navigation systems involve the American positioning system GPS, the European GALILEO, Russian GLONASS and Chinese Beidou. Augmentation systems include the wide-area augmentation system (WAAS) as used in the US or the European geostationary overlay service (EGNOS). For further information, please refer to Hofmann-Wellenhoff et al. (2008, 420 ff). GPS was the first system to fully operate and be supported by all receivers. It was founded in the 1970s by the US military and is a space based satellite system. In the '90s it has reached its full functionality. GPS was used for military purposes, users in the civil segment could not achieve the same precision due to Selective Availability (SA), the accuracy of the output position was more than 100 meters and therefore unsuitable for precise measurements. In 1995 former president Bill Clinton signed a policy to have SA turned off in May 2000. This act not only increased the accuracy up to 10 meters but allowed GPS tracking devices to develop. Nowadays GPS is used in a wide array of fields such as in maritime, road, aviation, rail or agriculture as well as surveying purposes. There are wo ways of measurement in surveying: Real time and post processing. The accuracy in real time measurement (1-2 cm) is lower than in post processing (0.5-1 cm) and is time saving. Also real time measurement requires less knowledge and no direct visual connection (Zaidi & Suddle, 2006).
The first theodolites were used in the 18th century for triangulation by the use of goniometry and distance measurement to produce maps as a way to display the earth or parts of it but also for military purposes. The accuracy as well as the functional range increased with time (Torge, 2007).

5.1.1 Technology maturity

The number of patent filings for GNSS is decreasing (keyword GPS): 1995: 143 000, 2000: 710 000, 2005: 2.6 million, 2010: 3.04 million, 2015: 3.1 million (cumulative, via patents.google.com). GNSS patents have already reached its peak since the numbers of yearly patents are declining as it is an established technology. It started out in a niche market as its use was first restricted to military purposes and as the acquisition costs were very high. It was not until 2000 that GNSS systems became interesting for mainstream market due to increasing accuracy. Also the acquisition costs are very high. Nowadays GNSS capable systems are mainly based on standard components but GNSS based surveying equipment are rather expensive. The technology is partially cheaper (regarding mainstream purposes), simpler and definitely more comfortable in handling and more reliable than theodolites.
The key performance parameters according to the European Global Navigation Satellite System Agency are accuracy, integrity, robustness and availability (GSA, 2016). The availability for GNSS is high with 95 - 99.9 %. High reliability is achieved through redundancy and independent satellite systems. Efficiency and accuracy are high through increase in the number of satellites (Zaidi & Suddle, 2006). At least one configuration (GPS and another system) is always available. Concerning robustness at least 3 satellites have to be present, ideally four or more. As the key performance parameters are stable, their performance is comparable to established attributes and do satisfy customer needs. The uncertainty of technical performance/efficiency for GNSS is low since most of the time a combination of two to three systems is used which decreases the error rate (Hossam-E-Haider et al., 2013). However, in 2014 wrong ephemerides were uploaded and corrupted GLONASS for twelve hours (Langley, 2014).

5.1.2 Market entry level and declining costs of technology

GNSS based systems in surveying as well as theodolites are not in the low price segment nor did the prices declined over time. Nowadays theodolites are not commercially available anymore but total stations, an improved electronic version of theodolites. GNSS based systems are available from € 13 500 up to € 27 000 resulting in high switching costs (data via telephone call with sales manager of Leica). In Figure 10 the past and future core revenues of GNSS device sales are depicted. The decreasing average price for land surveying products leads to the conclusion that the volume of revenues decreased hence the average price dropping. For surveyors this characteristic turns out as sustaining. For private users GNSS based systems have a low market entry level as this service can be used for free and the prices for the devices are affordable. In this case GNSS is disruptive to private users.

5.1.3 New Value Propositions

The handling of GNSS based systems require less knowledge which simplifies the process. For the surveying sector GNSS is both sustaining and disruptive. It is sustaining because the performance parameters such as accuracy and availability are improving, while the price is staying the same. It is disruptive because the new technology comes with new value propositions as it saves time and transformations of points. GNSS based systems are disruptive for the mass market and private users because it is a new, easy, reliable and simple way to determine a place with the corresponding coordinates and record them which was not possible before or at least not without much effort. This way of connecting coordinates to places, people and time opens new possibilities for applications in everyday life and in commercial use.

5.1.4 New entrants

There has been no new entrant since in the surveying industry since the big producers of theodolites such as Leica (Wild), Topcon and Trimble, which were founded in 1921, 1978 and 1932 respectively, which later switched to offering GNSS based solutions. A lot of mainstream GNSS based system manufacturers are new entrants, an example being Garmin which was founded in 1989 and produces gadgets for outdoor and navigation. In 2005, Google launched Google Maps which offers real time navigation. Another example is Open Street Map, founded in 2004, which offers navigation amongst other services.

5.1.5 New markets

The market for global navigation satellite products and services is predicted to increase by 11 % per year to $ 244 billion in 2020 (Bowler & Wall, 2014) and the EU will invest € 7 billion on satellite navigation until 2020 (European Commission, 2014). Its potential application range is big as it can be used in a variety of areas such as in rail, surveying, agriculture, Location based services, road, maritime and aviation (GSA, 2016) and a further expansion through network effects like the Internet of Things is likely.

Today's commercial providers of GNSS based systems offer their services in various fields besides traditional car navigation: location based services (services associated with your current position), pedestrian navigation or tracking (e.g. jogging) are a few to name.

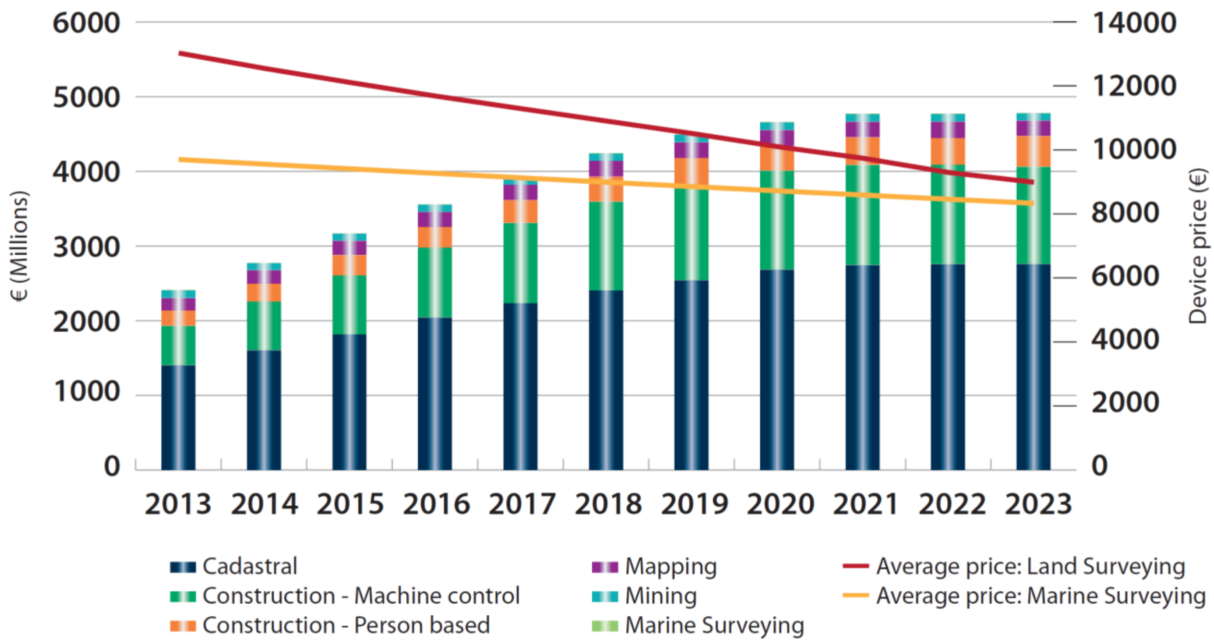


Figure 10: Core revenue of GNSS device sales and services by application
(GSA, 2016)

5.1.6 Summary

In Table 7 a summary of the checklist is displayed. For users from the surveying sector, GNSS based systems are both disruptive and sustaining. Sustaining because the performance parameters and price remain stable while the technology is easily available, more comfortable and more reliable than theodolites as well as easy to run and accessible from all over the world. It is more time saving and requires less knowledge in handling. For private users GNSS based systems are disruptive because they offer new value propositions and applications can be used for free.

All the related trends involving GNSS and positioning are pointing upward. As shown in Figure 11, the shipments for GNSS devices experience annual growth while the costs remain constant. For private users GNSS based systems are disruptive because they offer new value propositions and applications can be used for free.

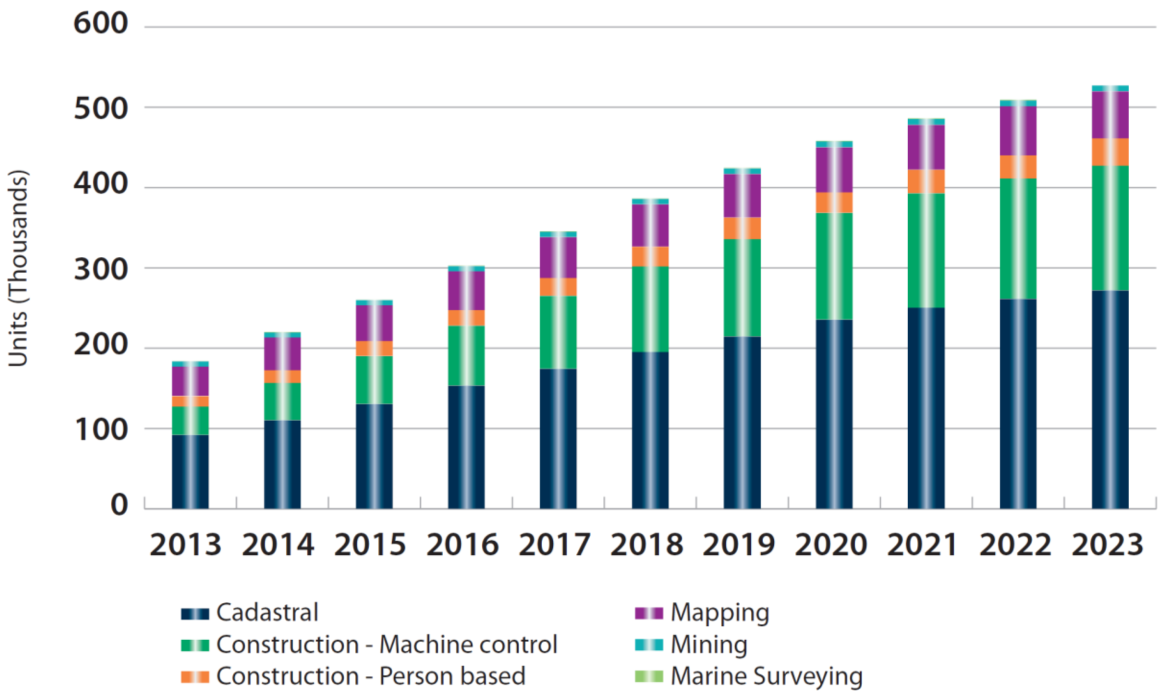


Figure 11: Shipments of GNSS devices by application
(GSA, 2016)

	Disruptive potential	Notes
Technology maturity	medium	
Market entry level and declining costs of technology	medium	Not cheap at market entry level, still expensive equipment for surveyors
New value propositions	high	Faster, less work, less knowledge
New entrant	medium	
New market	high	Big application range

Table 7: GNSS checklist

5.2 Software as a service versus Desktop software

In this chapter the disruption of Desktop software versus Software as a service (Saas) will be discussed. The term cloud computing came up in 2007 and is considered „a new computing paradigm that allows users to temporary utilize computing infrastructure over the network, supplied as a service by the cloud-provider at possibly one or more levels of abstraction" (Youseff et al., 2008, p.1) which is available on demand (Armbrust et al. 2009) and scalable on a pay-per-use basis (Leimeister et al, 2010). The Saas model developed from the application service provisioning (ASP) model which appeared in the late 1990s (Benlian & Hess, 2011).
Saas is a service where software and IT infrastructure is outsourced. The benefits of cloud computing are time savings, cost reduction through omission of staff because the work is outsourced and the need of less hardware and no updates. Disadvantages of the new business model are security issues and server blackouts. Desktop software is locally installed and can only be accessed via license on the installed computer whereas Saas can be accessed from anywhere via Internet and data is stored in the cloud (Sadiku et al., 2014). In Figure 12 the classification of cloud computing by Youseff et al. (2008) is pictured.

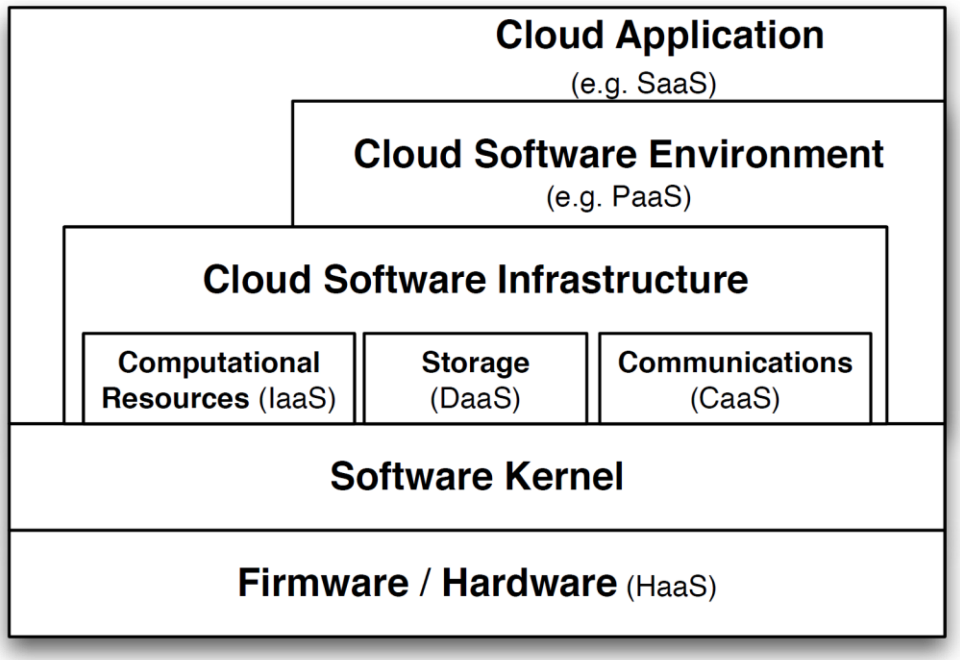


Figure 12: The layers of cloud computing
(Youseff et al., 2008)

5.2.1 Technology maturity

The technology maturity is high for Software as a service since the technological requirements are fulfilled. Uncertainty of technical performance/efficiency for Saas is at medium level because security is the main cloud computing concern besides performance and availability (Cisco, 2009). There are several outages involving Amazon, Gmail or Google Docs when servers were down for hours and the sites did not work (Leavitt, 2009; Naughton, 2009). Software as a service is based on standard components. On the provider side servers, hard- and software are needed while on the user side a laptop or PC and Internet access are sufficient.

5.2.2 Market entry level and declining costs of technology

There are two user price models concerning Saas, one is usage price and one is fixed monthly (Laatikainen & Ojala, 2014). Microsoft Office for example can be bought as a licensed Desktop software for businesses starting from € 8.8 to € 34.4 per user per month. For € 6.7 per user per month the online Office version can be obtained. For big companies the latter could be a more cost-efficient option. Dubey & Wagle (2007) compared Saas to Desktop software for a medium sized enterprise (200 seat license). In this comparison the costs of the Desktop software are € 2.3 million compared to € 1.6 million for Saas due to reduced deployment and the omission of infrastructure and application testing. Some WebGIS providers have free software that is designed for non-commercial use, others charge a monthly fee (see Table 8). This leads to the conclusion that Software as a service is disruptive for private users and companies. For service providers of Saas no new technology is required, only investments in servers and maintenance staff.

Company	Price
ArcGISonline	0/ > € 1300/ year
Giscloud	0 – $ 95 /user/month
Mangomap	$ 49 -$ 399/month
Mapbox	Starter $ 0 Premium $ 499/month
Map2net	> € 2000 / year (~€ 170 ($ 200) / month)
Thundermap	Not available

Table 8: Price for Web GIS

5.2.3 New Value Propositions

For private users Software as a service comes with several advantages: the software program can be accessed online from everywhere, there is no license bound working place and no updates are needed resulting in cost reduction in hardware and IT staff. As users do not need to purchase an expensive software license anymore, Saas can be used on a monthly basis. Licensed software often requires a subscription of at least one year. A new business model was created. In addition, the technology of Saas is cheaper and more comfortable to use than Desktop software.

5.2.4 New entrants

There are new entrants in the Saas sector as well as existing companies that have switched or are about to switch to this sector. ArcGIS, which include several geospatial information software was launched in 1999 by ESRI. In 2010, ArcGISonline was available as a Saas. Most new entrant companies were found around the year 2010 (see Table 9). Reasons are based on the declining costs of technology and the easy technological feasibility to implement the service.

Company	Founded in
ArcGISonline	2010
Giscloud	2008
Mangomap	2010
Mapbox	2010
Map2net	2013
Thundermap	2012

Table 9: Foundation year of Web GIS providers

5.2.5 New markets

In 2012 the forecast for 2015 was that about 24% of all business software acquisitions would be cloud based (Mahowald et al., 2011). Another forecast states that the number of companies using cloud technology will double until 2015 (Berman et al., 2012). The extent potential application range is big. The investment in technology development is at its maximum, the worldwide public IT cloud services revenue in 2018 is predicted to reach as high as $ 127 billion. In 2013, spending in public IT cloud services already reached $ 47.4 billion, growing five times faster than the whole IT sector Microsoft's cloud computing platform Azure had an annual growth of over 54% in 2015 (Rhipe, 2015). Gartner's forecast for Saas for 2016 was 20.3 % from $ 31.4 to $ 37.7 billion. The extent of potential application range is big because any application that was desktop-based before can be used as a Saas application.

5.2.6 **Summary**

The technical requirements for Software as a service are given but the technology readiness level is medium due to security issues. The difference between a Desktop version and a webversion of a software is that it does not need to be installed on the computer instead it is retrieved from the cloud. This leads to savings in maintenance and time as all updates happen in the cloud. With a rate of 20 % in 2016, the Saas industry is growing fast, so a market for Saas products is definitely present and can be extended to various software. The only barrier that has to be overcome is the security issue which can be improved in order to protect data. Software as a service shows a high disruption potential for private users and companies whereas for Saas providers this technology is both sustaining and disruptive.

According to Sultan and *van de Bunt-Kokhuis* cloud computing can be considered as both sustaining and disruptive: *„As a business model, cloud computing is a huge improvement on timesharing, a case of sustaining innovation. Unlike timesharing, cloud computing allows organisations to remotely buy a variety of computing services at a click of a button, and to scale their needs of those services up or down as and when required in real time. It has created opportunities to economically deliver a range of 'good- enough' computing services (a case of low-end disruptive innovation) that historically required consuming companies to devote large expenditures in terms of hardware, software and labour, and, in the process, benefited many companies with humble resources. It has also created a new market where organisations can make 'pain-free' use (at affordable prices) of a range of historically expensive and hugely complex technologies (a case of new-market disruptive innovation)" (Sultan & van de Bunt-Kokhuis 2012, p.172).*

	Disruptive potential	Notes
Technology maturity	medium	Security issues
Market entry level and declining costs of technology	high	Affordable prices, cheaper than Desktop software
New value propositions	high	less costs for IT and staff, local independence, no updates required
New entrants	high	Many new entrants
New market	high	High growth rate

Table 10: Software as a service checklist

5.3 Open Street Map versus analog maps

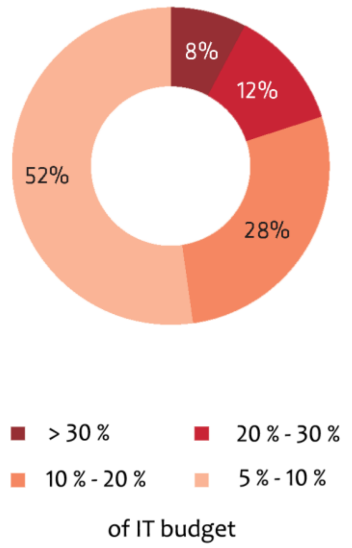
The first analog maps were created over 8000 years ago. After thousands of years of development for various purposes accuracy increased in reproducing our surroundings. With the invention of printing maps could spread much faster. Starting in the mid-20th century the computer played a major role: analog maps became digital and the Internet contributed to the development of geographical information systems (Friendly & Denis, 2001).
This case study discusses the comparison between Open Street Map and analog maps in regards to disruption. Open Street Map is a geospatial application which stores and processes uploaded geodata and provides a free editable map of the world.

5.3.1 Technology maturity

Open Street Map is based on existing technologies such as computer, the Internet and GPS devices. OSM is accessible from every compute worldwide via the Internet. No unplanned outage has happened so far. The disadvantages are the quality control since the maps can be edited and altered by every user as well as the low density of data in rural areas (Haklay, 2010; Goodchild & Li, 2012). Problems arise when not all contributions are constructive, some are even damaging like false classification of objects. As for paper maps the uncertainty of technical performance/efficiency is very low, but the data in the map is verified. Each form of paper maps is predetermined and available in shops or can be bought online. OSM started out in a niche market as the percentage of people using analog maps was high while the group of contributors to OSM was small in the beginning (see Figure 16).

5.3.2 Market entry level and declining costs of technology

Open Street Map or Open Source software in general, are free for use software and therefore in the low price segment. Figure 13a and Figure 13b show cost savings of Swiss companies using Open Source software. This study can also be used for Austrian companies as both countries are of similar geographical and economical settings. In the study 200 companies had been asked if they had savings in the past 3 years through using Open Source Software and how high these savings were: 20 % of the companies had cost savings of 20 % or more, 28 % save 10 - 20 % and 52 % save up to 10 % of their IT budget (Figure 13a). Overall, companies saved up to 45 % of their IT budget in the past three years and were expecting to save more during the following years (see Figure 13b; Dapp, 2015).



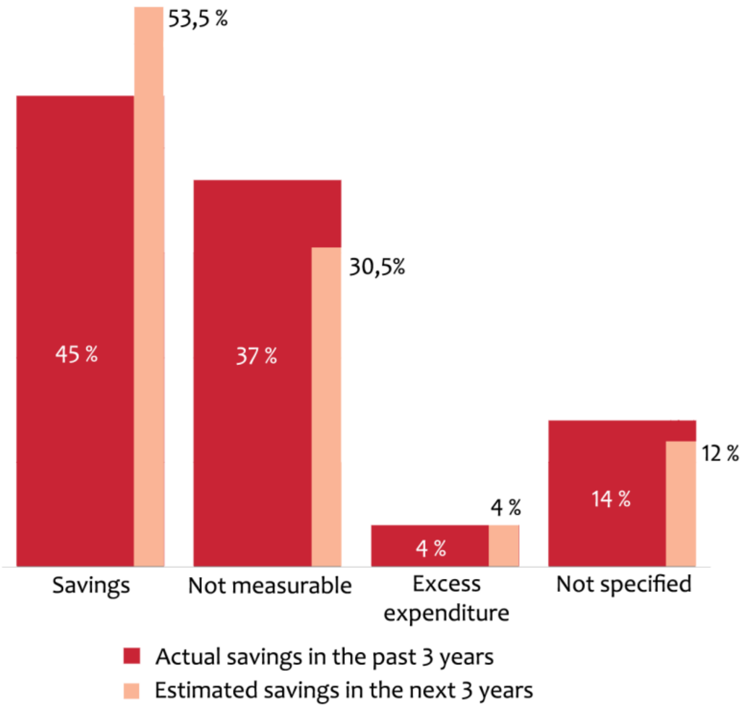


Figure 13a: Amount of savings of IT budget (Dapp, 2015)

Figure 13b: Cost savings through Open Source software in Switzerland (Dapp, 2015)

5.3.3 New Value Propositions

There are new value propositions coming along with the use of digital maps and Open Street Map. First of all, the process of mapmaking and the data therefor are new. In Austria, the BEV (Bundesamt für Eich- und Vermessungswesen; founded in 1923) is the NMA responsible for gathering the data. Data from NMA are verified. OSM can include inaccurate data as they are gathered via volunteered geographic information (VGI) which involves people collecting, providing and uploading data on a voluntary basis. The recorded data is free and available for everyone. Furthermore, the accuracy of OSM data can differ up to 6 m which is in the accuracy range. Rural and poorer areas coverage is less dense and OSM does not aim to achieve complete coverage (Haklay, 2010; Goodchild & Li, 2012). The way of creating a map between NMAs and OSM varies: for analog maps it is a top down and a one way process involving the NMA distributing the map to the user while for OSM (founded 2004), uses a bottom up process that works both ways (see Figure 14; Dapp, 2015).
Another new value proposition comes with routing: analog maps require the user to know how to read a map and navigate from point A to point B whereas with OSM your position can be tracked down and your itinerary will be calculated if needed. The lack of elevation data and therefore incompleteness are to be kept in consideration. However, there are frequent

updates and more input can be acquired over time. In recent years, the number of natural disasters has risen. OSM could provide help by having users generate maps for the affected regions.

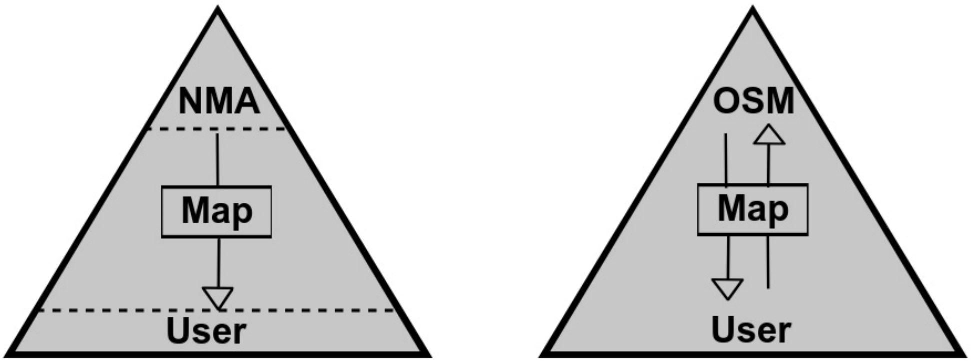


Figure 14: Top-down model of NMAs compared to bottom-up model of Open Street Map

5.3.4 New entrants

Open Street Map was founded in 2004, providing free geospatial data. There are companies using OSM data for commercial purposes, just to name a few: Geofabrik (founded in 2007) provides routing, geocoding and OSM consulting, GraphHopper (founded in 2015) offers routing and MapBox (2010) provides navigation and data visualization.

5.3.5 New markets

The extent of potential application range is versatile as every map can be customized and developed according to one's needs. So far the purpose of analog maps have been for recreational and public functions. With OSM and digital maps, new markets are opening up both for private users and service providers, e.g. tracking and tracing in sports and fitness, public transport, services and anything that can be geographically linked to.
In Figure 15 a study about the distribution of Open Source Software in Swiss companies is shown. 89% respectively 94 % of the companies use Open Source software, two thirds using it frequently or more often. Based on this study from Switzerland the percentage of Open Source Software users can also be applied on Austria (Dapp, 2015). In Figure 16 the increasing number of OSM users and data are shown (OSM, 2017).

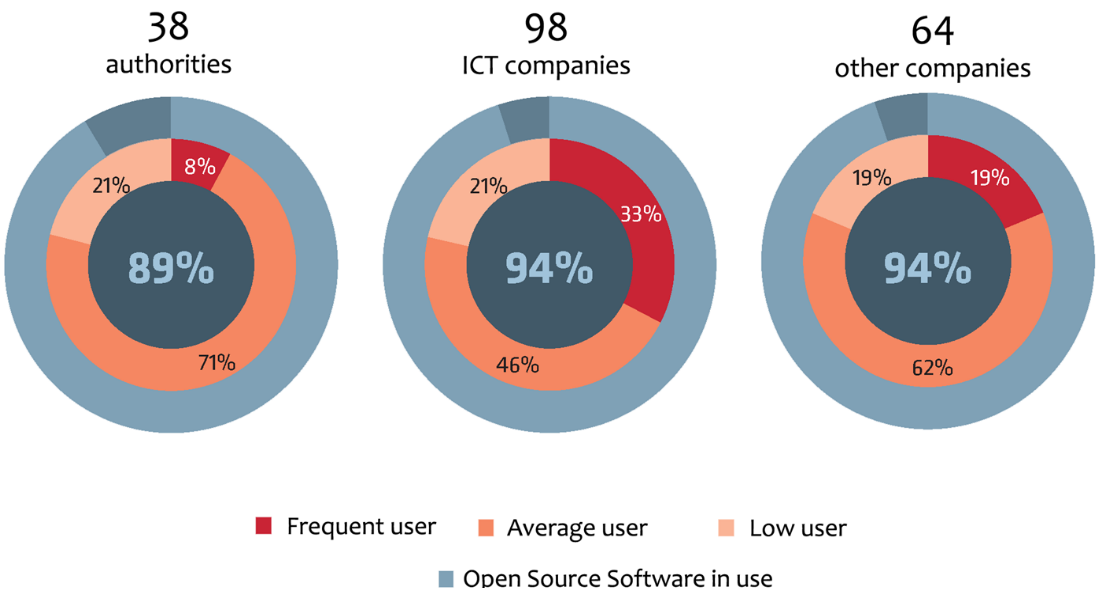


Figure 15: Distribution of Open Source software in Switzerland
(Dapp, 2015)

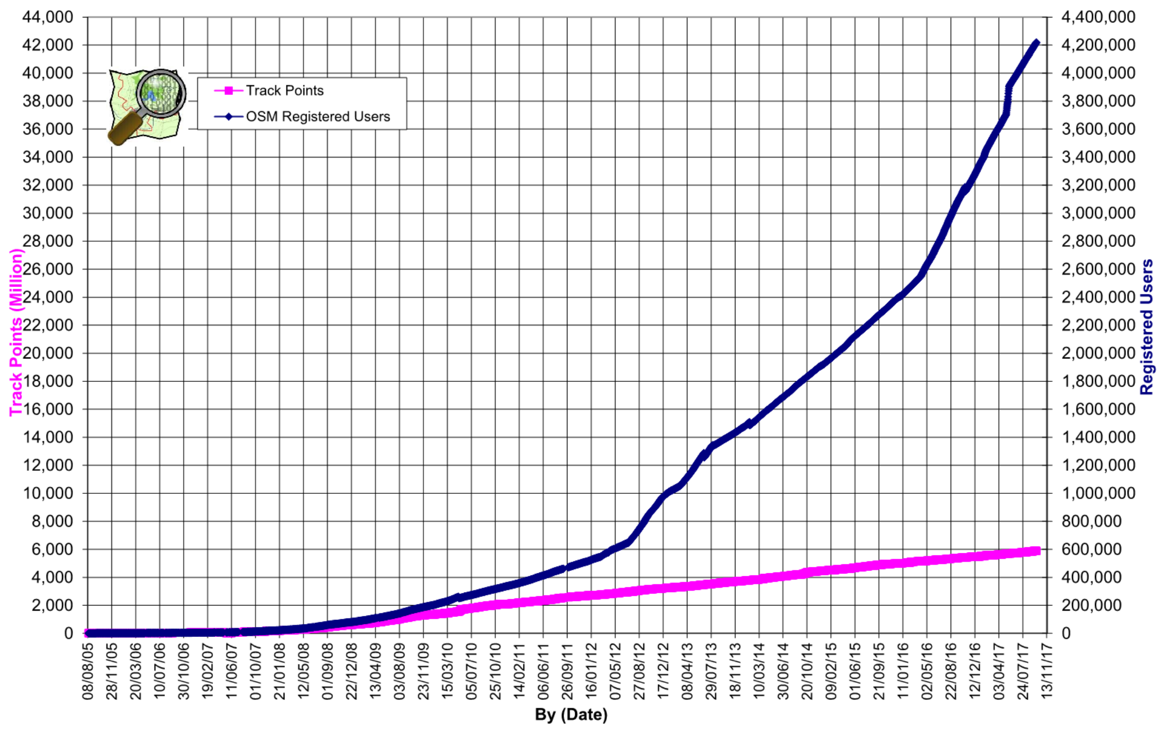


Figure 16: Number of Open Street Map users and uploads
(OSM, 2017)

5.3.6 **Summary**

Open Street Map is a useful tool in creating and using license-free maps. OSM comes with a lot of advantages both for companies and private users such as no cost for data, current data and many extension possibilities starting from routing to tracking and tracing to 3 D modeling whole cities. The number of OSM users as well as that of businesses using Open Source software are increasing as the rising data input on OSM suggests. Downsides of Open Street Map are the lack of support for companies and little to no elevation data. For both private users and companies, Open Street Map shows a high level of disruption because its application possibility is versatile and everyone is to a certain extent involved (see Table 11).

	Disruptive potential	Notes
Technology readiness level	high	Technology available
Market entry level and declining costs of technology	high	Free to use data
New value propositions	high	Everybody can participate, free, new bottom up business model
New entrant	high	Many new entrants
New market	high	Various application fields

Table 11: OSM checklist

6 Interviews

This chapter is about interviews with experts from the geospatial industry, their experience with disruptive technologies, their know-how and their evaluation regarding upcoming disruptions. These interviews were held in addition to gathering information from academic literature completing the empirical part of the master thesis. The statements of the interviewees are expected to match up with the results from the case studies in the previous chapter as the interviewees are involved in current developments and have insights into them. The interviews had a duration of 30 minutes each and were either conducted personally (interview B) or through voice over IP (e.g. Skype; interview A, C, D). The evaluation was done anonymously and the interviewees were four experts in their respective fields:

(a) A German Geospatial Systems Architect
(b) An Austrian company for geographic information systems
(c) A British Professor, an expert in Citizen Science
(d) A British Geospatial Technologist in the Virtual Globe sector

The questions specifically were as follows:

- Which are the main technologies you work with?
- Looking back at the development of the technology in your workfield, how would you describe it?
- Have you ever witnessed disruptions in your area? If yes, which ones?
- How was it possible to detect disruption and who detected them?
- Which technologies will play a major role in the future and why?
- Looking at your field of expertise, are there any future technology you would describe as disruptive? Why?
- Which possibilities do companies have to identify disruptions?
- Do you use these methods?

The interview was divided into three parts: Part one started with general questions regarding their present situation such as their tasks and their main use of technologies. In part two a look into the past was taken by discussing previous disruptions the interviewees have experienced in their sector and how those were distinguished. Looking from the past to the future, in part three the experts were asked to share their views on possible future technologies. The question if they could be disruptive and methods for detecting them are approached thereafter. In the subsequent chapters results and conclusions drawn from the interviews will be presented. The interviews serve to show the current trend in which technologies might be developing and possible disruptive technologies.

6.1 **Results**

The answers from the experts are analyzed and compared with each other for similarities. An overview of the results is shown in Table 12. The interviews contain five major questions directly approaching disruption while the remaining questions are secondary questions. The main technologies all four interviewees worked with was the computer and the Internet, also software used on computer, mobile phones or tablets. Expert A, who works as a Geospatial Systems Architect, uses geo based tools such as geodatabases, geodata server or Desktop GIS. Expert B mainly uses both the Desktop version and the online version of the software SmallWorldGIS. Experts C and D mainly use Google Earth besides GIS software.

The Internet in general and things connected to the Internet such as Virtual Globes or Open Source software were unanimously considered as disruptions. Expert B and C both agreed on the Internet as a disruption, B also assigned new business models as an additional source of disruption. In expert A's opinion, previous disruptions are Open Source and Open Standard but it took them 10 and 20 years respectively to overcome the so called innovation gap to become disruptive. The innovation gap is the time in between innovation and broad utilization of the product. Expert D brought the example of the analog map which had been replaced by the digital map used in navigation systems in the car and nowadays on mobile phones. The statement about new business models being disruptive matches with the Open Street Map check where it is a new value proposition. And expert D's example with the digital map replacing the analog one is also outlined in chapter 38of this thesis.

To the question on how past disruptions had been identified the experts' answers were within the field of added values such as price decrease, affordability and availabilty. Expert A noticed that duration and size of orders as well as the price declined. Expert B says that disruptions in his field of expertise have been a continuous process so far and in expert C's opinion no methods to detect disruption exist. In expert D's map development example disruption could be detected through several indications: the technology was cheaper, required no skills and saved time. These characteristics are classified as added values which are typical characteristics for disruptive technology.

Expert C and D see the Internet of Things and machine learning as well as artificial intelligence and automated systems as future disruptive technologies. Other answers included augmented reality, cloud computing and Open Source. The answers from all four experts match with current developments of smart devices which can lead to the Internet of Things, supported by Open Source and cloud computing.

No expert could give a precise approach on how to identify disruptive technologies ex ante. Expert A and D agree that observing the market and experimenting with different technologies to find out what works best leads to a more efficient working process. Based on their know-how the experts were asked if there are possibilities to detect disruptions beforehand. Expert B and C said that they do not know of a method. Expert A and D both agree on experimenting new options and doing research.

	Expert A	Expert B	Expert C	Expert D
Main technologies	Geodatabase, Geodataserver,Front-end, LightClient, Desktop GIS	SmallWorldGIS	Internet, GPS	Internet, Apps, GPS
Previous disruptions	Open Source, Open Standard	Internet, new business models	Internet	analog maps to digital maps to satellite navigation systems in the car to mobile phones taking over
How to detect disruption	Duration and size of orders, price decrease	Continuous process	-	Availability, affordability, advantages compared to previous technology
Future technologies	Lightway Scripting, Open Source	Cloud computing, augmented reality	Internet of Things, machine learning, artificial intelligence	Internet of Things, machine learning, automated systems
Possibilities to identify disruption	Experimenting	No	No	Involvement in research, thinking ahead, experimenting

Table 12: Interview results

6.2 Conclusion

Although the experts come from different fields of geospatial industry, their work rely on the computer and the Internet as well as GIS software. They all witnessed disruptive technologies taking over their area of operations, starting with the Internet, then new business models and the transition from analog to digital maps. In retrospective they were able to list characteristics of past disruptions such as declining costs, availability or added values. As future disruptions the experts named technologies like Open Source or cloud computing that have already begun to establish themselves in the industry. Further mentions were the Internet of Things, augmented reality, artificial intelligence and automated systems. Looking back at the Gartner Hype Cycle in Figure 7, smart robots, connected home and machine learning are on the rising, reaching their peak in probably 2 to 10 years whereas augmented reality according to the classification of Gartner is in the trough of disillusionment taking 5 to 10 years to reach the plateau of productivity and get into mainstream market. On the question if there are possibilities to detect disruption in advance, two interviewees said that they do not know of a method and the other two said that the best way to adapt to the market is through observation and experimenting with different options. This statement leads to the conclusion that although there are methods based on retrospective analysis which can be used for future predictions, the interviewed experts do not rely on them nor have used them.

7 Discussion and conclusion

The goal of this research was to look for characteristics that come with disruption and to find a method to predict it. In order to do that, secondary research questions were deployed. Disruptive technologies normally underperform in the beginning and are found in niche markets where they are appreciated for their added values. Added values are an advantage of the disruptive technology compared to the mainstream technology such as convenience or price. Characteristics are shown in technology maturity and market entry level, new value propositions, new entrants and new markets as well as in simplification and declining costs. Based on Christensen's framework and characteristics expanded by several author and case studies a questionnaire was established and applied on two general past cases of disruption and three from the field of geospatial technologies. Experts had been consulted to contribute to the research. During the research many methods on technology forecasting came up but none fitted for the purpose of the master thesis so a checklist was compiled. By creating a checklist characteristics of disruptive technologies can be analyzed but this method relies on characteristics based on past disruptions. For example, many disruptive technologies show disruptive characteristics but not all technologies showing these characteristics are disruptive (Hardman, 2013). Furthermore, characteristics are just an indication for disruption or rather its disruptiveness potential (Sainio et al., 2007; Govindaraj & Kopalle, 2006). Questions for the checklist were retrieved from other case studies and categorized into characteristics. As this method is based on five categories and overall 13 questions which allows to be answered with either yes or no, the procedure and obstacles of collecting data for answers will be illustrated. Some questions from other case studies such as „Does the technology satisfy customer needs? “or „Are customers willing to pay for an increase in mainstream performance attributes? “are difficult to answer ad hoc because first you have to find out what the needs of customers are and then how high/low you have to go to pass their satisfaction level. Determining the answers to these questions require immense effort as seen in several case studies that had been discussed in this thesis and can be an incentive for further research. In order to quicken up the process, more accessible questions were set up. Another problem was the lack of data particularly regarding the number of users and sales volume over time. These numbers could have contributed to a more efficient evaluation of the case studies but companies providing commercial software or high end products do not release any information. To compass this obstacle numbers from other operating fields such as number of patents or growth forecasts were deployed. Three geospatial technologies cases in particular were evaluated: GNSS based systems compared to theodolites, Software as a service to Desktop software and Open Street Map to analog maps. These three technologies show a high disruption level for private users. For commercial providers the technologies are more disruptive than sustaining. Sustaining because they are partly a further development of the existing technology and disruptive as new value propositions predominate. The checklist method is no definite determination of the disruption level of a technology and a technology rated as „disruptive“ might not turn out as one. This method rates the technologies based on their characteristics and can be used as a

quick method and an indicator for disruption.
All innovations have advantages and disadvantages over their counterpart but they have one thing in common: The way they are used changes the process of the whole industry. Using GNSS based systems compared to theodolites speeds up the process of surveying in many ways such as in time saving, automation of point acquisitions, simultaneous calculations, transformations for surveyors. Surveying, previously a time consuming and laborious task, can often times be handled by a single person. GNSS based systems influence the private life of private users as routing, tracking or tracing functions.
Software as a service compared to Desktop software changes the way software can be used and the way data can be stored. Software is not bound to a yearly license anymore nor to a specific computer but is retrieved from the cloud. So is the data, which leads to the acceleration of data processing. Open Street Map changes the way maps are produced and their availability. Conventional analog maps are produced by National Mapping Agencies and are usually updated yearly. The process of data gathering is done in one way meaning the NMA provide the data and present the map as a final product to the user. The process of creating maps in Open Street Map is a more dynamic and two sided as data gathering is not restricted to an institution but to the crowd. Data is gathered through volunteered geographic information and supplied to Open Street Map. As it is not a final map, data can be continuously edited to be up to date. It is a free map created with free software and available to anyone.
In addition to the case studies, interviews with four experts from geospatial technology were held. They confirmed the trend of Open Street Map, Cloud computing and GNSS based systems and gave insights into their methods to deal with disruption. Opinions on this subject were that it is difficult to impossible to detect disruption but with involvement of research and experimenting, they can be detected. This statement differs from the implemented method as it is less academic but more practically oriented, so there is plenty space left for further research on this matter, both in qualitative and quantitative ways.
All the afore mentioned innovations are based on technology and its progress, especially relying on both hardware and software. Declining costs in technology plays a major role in its development, affordability and distribution. The geospatial information sector emerged with the development of technology in hard- and software as in declining costs, the emergence of the Internet and its broad band access. All these factors led to the possibilities of cloud computing, Software as a service and in the near future it could lead to machine learning or the Internet of Things when your whole life can be managed over a smartphone.
The rating of the disruption level of a technology could be achieved through a new created checklist and the proposed hypothesis can be confirmed.
This master thesis only illuminates a fractional amount of work that can be done in this area. However, an insight into the topic of disruptive technologies in geospatial technologies could be gained. More research has to be done to examine this phenomenon.

8 Bibliography

Amshoff B., Dülme C., Echterfeld J., Gausemeier J. (2015). Business Model Patterns for Disruptive Technologies. International Journal of Innovation Management, 19(03), 1540002.

Armbrust M., A. Fox, R. Griffith, A. D. Joseph, R. Katz, A. Konwinski, G. Lee, D. Patterson, A. Rabkin, I. Stoica and M. Zaharia (2009). Above the Clouds: A Berkeley View of Cloud Computing. EECS Department, University of California, Berkeley.

Benlian A., Hess T. (2011). Opportunities and risks of Software as a service: Findings from a survey of IT executives. Decision Support Systems, 52(1), p. 232-246.

Berman S., Kesterson-Townes L., Marshall A., Srivathsa R. (2012). The power of cloud: Driving business model innovation. Retrieved from http://www-935.ibm.com/services/us/gbs/thoughtleadership/ibv-power-of-cloud.html, 25.10.2017

Bower J. L., Christensen C. (1995). Disruptive technologies: Catching the wave. Harvard Business Review, 73(1), p. 43-53.

Bowler T., Wall M. (2014). Galileo: What does a more accurrate sat-nav system mean? Retrieved from http://www.bbc.com/news/business-28779524, 13.03.2017

Choi, C., & Park, Y. (2009). Monitoring the organic structure of technology based on the patent development paths. In Technological Forecasting and Social Change, 76(6), p. 754-768.

Christensen C.: The Innovator's Dilemma. HarperBusiness, New York 2011.

Christensen C.: The Innovator’s Dilemma: When New Technologies Cause Great Firms to Fail. Harvard Business Review Press, Boston 1997

Christensen C. (2002). How Growth Makes “Good” Management Easy. BSSE Course Note. Harvard Business School, Cambridge, MA.

Christensen C., Raynor M. (2003). The Innovator’s Solution. Boston: Harvard School Press, Boston.

Christensen, C. M., Anthony, S. D., & Roth, E. A. (2004). Seeing what's next: Using the theories of innovation to predict industry change. In Harvard Business Press.

Christensen C., Matzler K., von den Eichen S.: The Innovator's Dilemma. Vahlen, München 2015.

Cisco (2009). The Cisco powered network cloud: An exciting managed services opportunity. Retrieved from http://www.hit.bme.hu/~jakab/edu/litr/Cloud/Cisco_Cloud_white_paper_c11-532553.pdf, 15.03.2017

Danneels E. (2004). Disruptive Technology Reconsidered: A Critique and Research Agenda. In

Journal of Product Innovation Management, 21(4), p.246–258.

Danneels E. (2010). Disruptive Technology. In Narayanan, V. K., & O'Connor, G. C., *Encyclopedia of technology and innovation management* (p. 47 f). Chichester: John Wiley & Sons.

Dapp M. (2015). Open Source Studie Schweiz 2015, retrieved from http://www.swissict.ch/fileadmin/customer/Publikationen/OSS-Studie2015.pdf, 25.10.2017

DaSilva C. M., Trkman P., Desouza K., Lindič J. (2013). Disruptive technologies: a business model perspective on cloud computing. In Technology Analysis & Strategic Management, 25(10), p. 1161-1173.

Downes L., Nunes P. (2013). Big bang disruption. Harvard Business Review, 91(3), p. 44–56.

Downes L., Nunes P.: Big Bang Disruption. Penguin, New York 2014

Dubey A., Wagle D. (2007). Delivering software as a service. The McKinsey Quarterly, 6, p. 1-12.

European Commission (2014). Galileo – the EU's satellite navigation programme. Retrieved from http://europa.eu/rapid/press-release_MEMO-14-509_en.htm, 13.03.2017

European Global Navigation Satellite Systems Agency (2016). GNSS Market Report Issue 4. Retrieved from https://www.gsa.europa.eu/system/files/reports/GNSS-Market-Report-2015-issue4_0.pdf, 13.03.2017

Eversheim W.: Innovationsmanagement für technische Produkte. Springer, Berlin 2003

Friendly M., Denis D. J. (2001). Milestones in the history of thematic cartography, statistical graphics, and data visualization, retrieved from https://www.dl.icdst.org/pdfs/files/196e83b63284cb72a93b1ca82ec767f5.pdf, 25.10.2017

Focus online (2005). Ipod Historie – Alle Modelle, alle Preise. Retrieved from http://www.focus.de/digital/multimedia/ipod/ipod-historie_aid_15139.html, 3.5.2017

Gartner (2017). Top Trends in the Gartner Hype Cycle for Emerging Technologies 2017, retrieved from https://www.gartner.com/smarterwithgartner/top-trends-in-the-gartner-hype-cycle-for-emerging-technologies-2017/, 25.10.2017

Gartner (2016). Gartner Says Worldwide Public Cloud Services Market Is Forecast to Reach $204 Billion in 2016, retrieved from http://www.gartner.com/newsroom/id/3188817, 15.03.2017

Gilbert J. (2012). Confronting disruptive innovation. In IT insight, p.39-41.

Goodchild M. F., Li L. (2012). Assuring the quality of volunteered geographic information. In Spatial statistics, 1, p. 110-120.

Govindarajan V., Kopalle P. (2006). The Usefulness of Measuring Disruptiveness. In Journal of Product Innovation Management, p. 12–18.

Haklay M. (2010). How Good is volunteered geographical information? a comparative study of OpenStreetMap and ordnance survey datasets. In Environment and Planning B: Planning and Design, 37(4), p. 682–703.

Hardman S., Steinberger-Wilckens R., Van Der Horst D. (2013). Disruptive innovations: The case for hydrogen fuel cells and battery electric vehicles. In International Journal of Hydrogen Energy, 38(35), p. 15438–15451.

Hofmann-Wellenhof, B., Lichtenegger, H., Wasle, E.: GNSS–global navigation satellite systems: GPS, GLONASS, Galileo, and more. Springer Science & Business Media, Wien 2007

Hossam-E-Haider M., Tabassum A., Shihab R. H., Hasan C. M. (2014). Comparative analysis of GNSS reliability: GPS, GALILEO and combined GPS-GALILEO. In Electrical Information and Communication Technology, p. 1-6.

Hüsig S., Hipp C., Dowling M. (2005). Analysing disruptive potential: the case of wireless local area network and mobile communications network companies. In R&D Management, 35(1), p. 17-35.

Keller A., Hüsig S. (2009). Ex ante identification of disruptive innovations in the software industry applied to web applications: The case of Microsoft's vs. Google's office applications. In Technological Forecasting and Social Change, 76(8), p. 1044–1054.

Kostoff, R. N., Boylan, R., & Simons, G. R. (2004). Disruptive technology roadmaps. In Technological Forecasting and Social Change, 71(1), p. 141-159.

Laatikainen G., Ojala A. (2014). SaaS architecture and pricing models. In Services Computing, p. 597-604.

Langley R. (2014). GLONASS fumbles forward. In GPSWorld, 05/2014.

Leavitt N. (2009). Is cloud computing really ready for prime time? In Computer, 42(1), p. 15-20.

Leimeister S., Böhm M., Riedl C., Krcmar H. (2010). The Business Perspective of Cloud Computing: Actors, Roles and Value Networks. In ECIS, p. 56.

Linstone H. (2011). Three eras of technology foresight. In Technovation, 31(2-3), p. 69–76.

Little A. D. (1981). The strategic management of technology. Cambridge, Mass, USA.

Lucas H. C., Goh J. M. (2009). Disruptive technology: How Kodak missed the digital photography revolution. In The Journal of Strategic Information Systems, 18(1), p. 46-55.

Mahowald R.P., Konary A., Sullivan C.G. (2011). Market Analysis Perspective: Worldwide Saas

& Cloud Services.

Markides C. (2006). Disruptive innovation: In need of a better theory, In Journal of product innovation management, 23(1), p. 19-25.

Microsoft (2017), retrieved from https://news.microsoft.com/bythenumbers/planet-office, 23.08.2017

Miller Jim (2001). Comparison of portable MP3 Players. Retrieved from http://www.personal.kent.edu/~jimiller/techpaper.html, 3.5.2017

Momeni A., Rost K. (2016). Identification and monitoring of possible disruptive technologies by patent-development paths and topic modeling. In Technological Forecasting and Social Change, 104, p. 16–29.

National Research Council: Persistent Forecasting of Disruptive Technologies Report 2. National Academies Press, Washington D.C. 2010

Naughton J. (2009). There's silver lining to Google's cloud computing glitch. In The observer., retrieved from https://www.theguardian.com/technology/2009/mar/01/gmail-outage-cloud-computing, 15.03.2017

Nunes P., Downes L. (2014). The Five Most Disruptive Innovations at CES 2014. In Forbes, Retrieved from http://www.forbes.com/sites/bigbangdisruption/2014/01/10/the-five-most-disruptive-innovations-at-ces-2014/, 25.10.2017

Open Street Map (2017). Stats, retrieved from http://wiki.openstreetmap.org/wiki/Stats#Accumulated_users_and_GPX_uploads, 17.10.2017

Rafii F., Kampas P. (2002). How to identify your enemies before they destroy you, In Harvard Business Review, 80 (11), p. 115–123.

Rhipe (2015). Cloud licensing landscape, retrieved from http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1082&context=ecis2010, 15.03.2017

Ritala P., Golnam A., Wegmann A. (2014). Coopetition-based business models: The case of Amazon. com. In Industrial Marketing Management, 43(2), p. 236-249.

Rosenbloom R. S., Christensen C. M. (1994). Technological discontinuties, organizational capabilities, and strategic commitments. Industrial and corporate change, 3(3), p. 655-685.

Rowe G., Wright G. (1999). The Delphi technique as a forecasting tool: issues and analysis. In International journal of forecasting, 15(4), p. 353-375.

Sainio L. M., Puumalainen,K. (2007). Evaluating technology disruptiveness in a strategic corporate context: A case study. In Technological Forecasting and Social Change, 74(8), p. 1315–1333.

Sultan N., van de Bunt-Kokhuis S. (2012). Organisational culture and cloud computing: coping with a disruptive innovation. In Technology Analysis & Strategic Management, 24(2), p. 167–179.

Statistisches Bundesamt Deutschland: Wirtschaftsrechnungen: Laufende Wirtschaftsrechnungen Ausstattung privater Haushalte mit ausgewählten Gebrauchsgütern, retrieved from https://www.destatis.de/DE/Publikationen/Thematisch/EinkommenKonsumLebensbedingungen/AusstattungGebrauchsgueter/AusstattungprivaterHaushalte2150200167004.pdf?__blob=publicationFile, 10.08.2017

Steffof, Rebecca: The Camera. Marshall Cavendish, New York 2007

Stewart T. R. (1987). The Delphi technique and judgmental forecasting. In Climatic Change, 11(1-2), p. 97-113.

Tellis G. J. (2006). Disruptive technology or visionary leadership? In Journal of Product Innovation Management, 23(1), p. 34-38.

Torge W.: Geschichte der Geodäsie in Deutschland. Walter de Gruyter Verlag, Berlin 2007

Treacy, M., Wiersema F.: The discipline of market leaders. Addison-Wesley, Reading 1995

Wang, C., Liu, X., & Xu, D. (1999). Chaos theory in technology forecasting. In Management of Engineering and Technology, p. 357-360.

Webmasterpro (2010), Webanalyse: OpenOffice auf über 21% der Computer (Update), retrieved from http://www.webmasterpro.de/portal/news/2010/01/25/verbreitung-von-office-programmen-openoffice-ueber-21.html, 23.08.2017

Yu D., Hang C. (2011). Creating technology candidates for disruptive innovation: Generally applicable R & D strategies. In Technovation, 31(8), p. 401–410.

Youseff L., Butrico M., Da Silva D. (2008). Toward a Unified Ontology of Cloud Computing. In Grid Computing Environments Workshop 2008, p. 1-10.

Zhang M. (2015). Back in 1995, a 1 MP Pro Digital Camera cost $ 20 000. retrieved from https://petapixel.com/2015/07/17/back-in-1995-a-1mp-pro-digital-camera-cost-20000/, 23.08.2017

Zaidi A. S., Suddle M. R. (2006). Global navigation satellite systems: a survey. In: International Conference on Advances in Space Technologies, p. 84-87.

Illustration directory

Figure 1: Research design 3
Figure 2: Long waves or K wave cycles 4
Figure 3: The conventional technology S-curve 9
Figure 4: Disruptive technology S-curve 9
Figure 5: Declining costs in technology 11
Figure 6: Disruptive innovations create a new performance and price trajectory. Sustaining innovations, in contrast, move a new product or service along its existing trajectory 14
Figure 7: Gartner Hype Cycle 19
Figure 8: Number of operations in text editing software 24
Figure 9: Comparison of sales numbers of analog and digital cameras 1994-2005 26
Figure 10: Core revenue of GNSS device sales and services by application 32
Figure 11: Shipments of GNSS devices by application 33
Figure 12: The layers of cloud computing 34
Figure 13a: Amount of savings of IT budget……………. 39
Figure 13b: Cost savings through Open Source software in Switzerland.................................39
Figure 14: Top-down model of NMAs compared to bottom-up model of Open Street Map .. 40
Figure 15: Distribution of Open Source software in Switzerland 41
Figure 16: Number of Open Street Map users and uploads 41

List of tables

Table 1: Definitions of disruptive technologies 6
Table 2: Indicators of maturity stages of disruptive technologies according to Little 8
Table 3: Characteristics of disruptive technologies 14
Table 4: Checklist method to identify disruptive technologies 22
Table 5: Checklist for Google Docs 25
Table 6: Checklist for digital camera 28
Table 7: GNSS checklist 33
Table 8: Price for Web GIS 35
Table 9: Foundation year of Web GIS providers 36
Table 10: Software-as-a-service checklist 37
Table 11: OSM checklist 42
Table 12: Interview results 45