TAMPEREEN TEKNILLINEN YLIOPISTO
TAMPERE UNIVERSITY OF TECHNOLOGY

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HOW INTERNET OF THINGS AFFECTS BUSINESS INTELLIGENCE?

Master of Science Thesis

Supervisors: Professor Mika Hannula
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PREFACE

This is a Master of Science thesis written for the Tampere University of Technology. I had an opportunity to write my thesis for my current employer on something that fits the needs of a client project. However I chose to keep my independent. I wanted to write an academic study about something I have a passion for. I wanted to make something for myself.

Writing this thesis has been a long project because it’s been written on my free time when I wanted to. That is why I have enjoyed (almost) every moment. Time flies when you are reading and writing about something that you are interested in, and then suddenly you are finished.

I owe a thanks to my supervisors Mika and Ilona for guiding and pushing me through my degree and through this study. In a way it is sad that writing this thesis has to end at some point. The truth however is that the study will go on. An engineer’s passion for technology will never flame out.

Olli Lindroos
Espoo

ABSTRACT

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The main purpose of this research is to find out what Internet of Things (IoT) and Business Intelligence (BI) mean and how IoT will possibly affect BI. This research has been carried out as a literature review and it is divided in three main chapters. The first section clarifies what Business Intelligence means. The second part explains the Internet of Things and the third and final part aims to find out possible synergy effects.

Business Intelligence is a process the main purpose of which is to produce the right information at the right time to the right people in order to facilitate the decision-making process. With BI an organization can reach a better business insight for their business environment. BI's challenges can be divided into social and technical challenges.

IoT is an information network that connects everything. With a common information network things can co-operate in order to reach a common goal. IoT's benefits are the real world effects, improved data analysis and a more agile communication. IoT's challenges are the rising amount of data and data complexity, information security and policy as well as the technical challenges.

This research's results shows that IoT will have a huge effect on BI. IoT will offer a large amount of new data for BI to analyze. New data offers an opportunity to get completely new results but it also offers a challenge because of the large volumes of data as well as the small number of professional capable of handling it.

TIIVISTELMÄ

TAMPEREEN TEKNILLINEN YLIOPISTO
Tietojohtamisen koulutusohjelma
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Tämän tutkimuksen päätarkoitus on hahmottaa, mitä asioiden Internet (Internet of Things, IoT) ja liiketoimintatiedon hallinta (Business Intelligence, BI) tarkoittaa ja minkälaisia vaikutuksia asioiden internetillä saattaa olla liiketoimintatiedon hallintaan. Tutkimus toteutettiin kirjallisuuskatsauksena, ja se koostuu pääasiassa kolmesta osiosta. Ensimmäinen osio selvittää mitä tarkoittaa liiketoimintatiedon hallinta, toinen osio tutkii mitä asioiden Internet on ja kolmas yhteenvetävä osio tutkii mahdollisia yhteisiä piirteitä ja vaikutteita.

Liiketoimintatiedon hallinta on prosessi, jonka päätehtävä on tuoda oikea tieto oikeaan aikaan oikealle ihmiselle avustamaan päätöksentekoprosessissa. BI:n avulla organisaatio voi saavuttaa aiempaa paremman näkyvyyden omaan liiketoimintaansa. BI:n haasteet voidaan jakaa sosiaalisiin ja teknisiin haasteisiin, esimerkiksi BI:n aineettomiin hyötyihin ja teknisesti valtaviin data- ja käyttäjämääriin.

Asioiden Internet on tietoliikenneverkko, johon kaikki maailman asiat on yhdistetty. Yhteisen tietoyhteyden avulla asiat voivat tehdä yhteistyötä yhteisen tavoitteen saavuttamiseksi. IoT:n hyötyjä ovat reaalimaailman tapahtumat, data-analytiikan uudet mahdollisuudet ja ketterämpi kommunikointi. Haasteiksi voidaan luokitella datamäärän ja datan monimuotoisuuden kasvu, tietoturvallisuus sekä käytännön ja teknologian asettamat rajoitukset.

Tutkimuksen tulokset osoittavat, että asioiden Internet tulee vaikuttamaan merkittävästi liiketoimintatiedon hallintaan. IoT tarjoaa BI:lle valtavan määrän uutta dataa analysoitavaksi. Uusi data on sekä mahdollisuus löytää paljon uusia aiemmin tiedostamattomia asioita liiketoimintaympäristöstä että haaste jo nykyisten teknisten datavolyymi- ja osaamispulahaasteiden kannalta.

ABBREVATIONS

AMI	Advanced metering infrastructure
ALM	Application life management
BI	Business Intelligence
CI	Competitive Intelligence
DDOS	Distributed Denial-of-service
ERP	Enterprise Resource Planning
IoT	Internet of Things
M2M	Machine to machine
MI	Marketing Intelligence
RFID	Radio-Frequency Identification
GDP	Gross domestic product
SoMe	Social media
VPN	Virtual Private Network

CONTENTS

1. INTRODUCTION

1.1 Background

Early Internet consisted exclusively of different kind of computers, but today you can find phones, TVs, power sockets and even fridges connecting to Internet. This has become a phenomenon, not only because of the ever-growing number of devices but also because of the variety of the devices that are connected to the Internet. Internet is not only on computers anymore, it's everywhere.

This phenomenon is called the Internet of Things (IoT) and it has a high impact on everything in our everyday life. It is an idea of technology where everything is connected to the Internet. In extreme cases it really means everything: cars, chairs, cats and even humans. When everything is connected to the Internet, things can communicate with each other and perform tasks to reach a common goal. (Coaetzee & Eksteen 2011; Vermesan et al 2011; Atzori et al 2010; McKinsey 2010; Weber 2010; Zorzi et al 2010) When things work together, some tasks can be automated and there's no need for human participation.

IoT is an interesting opportunity from the point of view of Business Intelligence (BI). BI is traditionally defined as a process that brings the right information to the right people at the right time. (Raber et al., 2013; Vitt et al., 2010; Negash, 2004; Power, 2004; Vitt & Luckevich, 2002; Gilad & Gilad, 1985; Luhn, 1958) When more and more things are connected to the Internet, there is a potential for a lot more possible data sources. When the number of data sources rises, it means that the volume of accessible data grows. Huge amount of data from different things and devices may imply new and more accurate information to report or even a change in the nature of BI.

What kind of opportunities does IoT bring to BI and will IoT somehow change the traditional definition of BI? This research tries to find out whether IoT has an effect on BI and if so, what this effect will be like.

1.2 Research problems and goals

This research studies whether the Internet of Things has an effect on Business Intelligence and what that effect might be like the goal of the study is to make a model of BI's process at a time when the Internet of Things is a daily phenomenon.

My main research question is:

- **How does the Internet of Things affect Business Intelligence?**

Other research questions:

- What does the Internet of Things mean?
- What does Business Intelligence mean?
- What opportunities does IoT offer for Business Intelligence?
- What challenges might IoT cause to BI?

Using the questions above, this research tries to find out something new related to the combination of these two concepts. By defining and gaining a good understanding of these two separate concepts it is possible to find out if IoT will affect BI and how.

1.3 Research methods

Choosing the research method is the starting point at which the researcher decides how he or she is going to carry out the research. According to Saunders et al (2009) selecting a research method includes selecting a research philosophy, a manner of approach, a research strategy, research choices, a time horizon, a technique for gathering information, the information analysis and a process for drawing conclusions. (Saunders et al. 2009) This section describes the research method selected for this research, why it was chosen and what kind of effects it has on this research. The selected research methods are summarized below in table 2.

1.3.1 Research philosophy

This section is about different research philosophies, and it explains why this research used direct realism and critical realism as research philosophies. First it describes different types of research philosophies and then it argues why direct realism and critical realism have been selected for this research. Then it recognizes the limitations this decision sets for the research results.

In order to find an answer as reliable and non-ambiguous as possible for the research questions, the research has to be based on facts. As the research subject is technology, which is hard to measure, it cannot fully rely on quantitative data and conclusions drawn from statistical facts. There is no need to estimate human aspects because this study is only about technical capabilities and how two technologies effect each other. This is why this research relies on realism. Bryman (2012) and Saunders et al (2009) describe realism as a philosophy that is close to positivism which relies on qualitative data and solid facts, and it is often used in natural sciences to remove social reality from the research. Realism accepts that everything cannot be measured and relies more on sensory evaluation. It defines the world as objects that have an independent existence and are not affected by the human mind. (Bryman 2012; Saunders et al. 2009)

Realism can be divided into two different categories that are both used in this research. Even though Bryman (2009) and Saunders et al (2009) have the same definition for both categories they call them with different names. Saunders et al (2009) divide realism into "empirical realism" and "critical realism" while Bryman (2009) names them "Direct realism" and "Critical realism". (Bryman 2012; Saunders et al 2009). This research uses Saunders' terms. According to Saunders et al (2009) critical realism recognizes the reality of natural order but questions the senses unlike direct realism. A critical realist considers reality as it is, not as he or she senses it. (Saunders et al 2009) Direct realism is used in the first part of this research's for explaining the theory of BI and IoT. It works well for finding how these terms are understood in current literature. After forming an understanding of these two different concepts, this research uses critical realism to find out how IoT affects BI.

1.3.2 Approach

This research uses a deductive approach because of the nature of the information gathering method. This section describes the research approach and the differences between two different types of research approaches. After handling different approaches it concludes why a deductive approach is the best approach for answering the research questions set for this study.

The research approach explains how the researcher forms his or her results. Both Bryman (2012) and Saunders et al (2009) identify two possible approaches: deductive and inductive. The differences between these two approaches lie in what the researcher does with the results. (Bryman 2012; Saunders et al. 2009)

A deductive approach means that the researcher has a theory that he or she wants to test. The researcher gathers results and tries to fit them into a hypothesis to find out whether the theory is true or not. (Saunders et al. 2009) According to Bryman (2012) a deductive approach fits the research approach especially when the results are quantitative. This is why it is often used in natural sciences. (Bryman 2012)

The inductive approach is the opposite of the deductive approach. According to Saunders et al (2009) the inductive approach means building a theory instead of testing it. In the inductive approach, the researcher first does the research, for example interviews, and then forms a theory based on the results he or she gets. (Saunders et al. 2009) Bryman (2012) describes the inductive approach as a more open approach so that the researcher can find more results than he or she could have found with the deductive approach in which the researcher focuses on testing only one hypothesis. (Bryman 2012)

Figure 1 shows the differences between the deductive and inductive approaches. While the deductive approach starts from a theory, the inductive approach ends up with a theory.

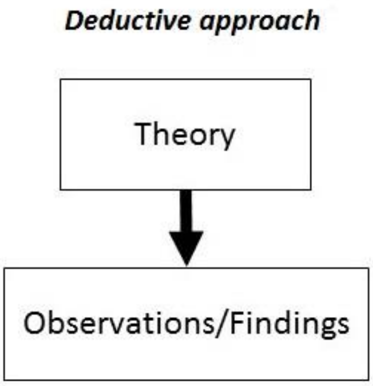

Figure 1: Deductive and inductive approaches (Model from Bryman 2012)

This research uses deductive approach because it does not have any observations or findings to start with or a theory to build. Instead this research focuses on understanding the theories behind two different concepts and finding possible relationships between them. In other words, this research does not prove any theory, it tries to find out the possible effects of IoT on BI.

1.3.3 Strategy

This research will be carried out as a concept analysis. This section describes what research strategy means and what kind of different research strategies there are. After naming and briefly describing different strategies, it explains why concept analysis research fits well as a strategy to answer the research questions and what kind of limitations it sets. As a conclusion, table 1 lists two different strategies and describes them briefly.

Table 1: Research strategies listed and described shortly (Bryman 2012)

Research strategy	Description
Quantitative research	Data-driven research. Used often in a research that produces data that can be used to analyse the researched phenomenon. For example natural sciences that test a certain theory often use a quantitative research strategy.
Qualitative research	Put emphasis on descriptions. Used often in research studies that cannot produce precise data to examine researched effect. For example usually researches studying social world uses qualitative research as a research strategy.

Bryman (2012) divides research strategies into just two different categories: quantitative and qualitative research. The difference between these two strategies is the quality of the research results. Quantitative research emphasizes analysis of data rather than words. It is often used in deductive research in natural sciences to test a certain theory. Meanwhile, qualitative research emphasizes words and an inductive approach, finding relations between results and forming a theory based on them. Bryman (2012) reminds that the division between quantitative research that relies on data analysis and a qualitative approach that emphasizes descriptions is not so straightforward but it is a good generalization. (Bryman 2012) It can sometimes be wise to consider using both strategies for a good reason. In certain conditions a qualitative approach produces data that can offer a new point of view into the research topic.

Bryman's (2012) rough division works well for this research. When trying to understand two different concepts like BI and IoT and find a relationship between them, it is not easy to use or find any quantitative data. Instead it is a lot easier to find reliable qualitative information that is easy to compare. That is why this research used qualitative research as a research strategy.

Using a qualitative research strategy makes the research ambiguous because it assumes and draws conclusions based on facts that are not as exact as measured data. It also makes it harder to repeat this research identically. Quantitative research offers a better chance to other researchers to repeat the study but it could not offer answers to this research's research questions as effectively as the qualitative approach.

1.3.4 Time horizon

This research's time horizon is a cross-sectional study. It studies how IoT will affect BI in the near future. This section explains what different time horizon selections there are and what those different horizons mean. After gaining an understanding of the various time horizons it describes why this research is carried out as a cross-sectional study.

Time horizon means a time perspective that is used in order to find the answers for the research questions. (Saunders et al 2009). Different time horizon choices support different kind of research problems. Researches that otherwise use the same research methods can have a different timeframe. Research that tries to find out how time has affected something has to have a different time horizon compared to a research that tries to find out how things are within a certain timeframe.

Saunders et al (2009) divides these two views into longitudinal study and cross-sectional study. Longitudinal study is a time horizon that takes a longer timeframe into consideration. For example, it is often used to study how a certain phenomenon has developed through history. (Saunders et al 2009) With a long time horizon it is possible to point out facts and trends that are not possible to find out in a shorter time horizon. This view is described in figure 2.

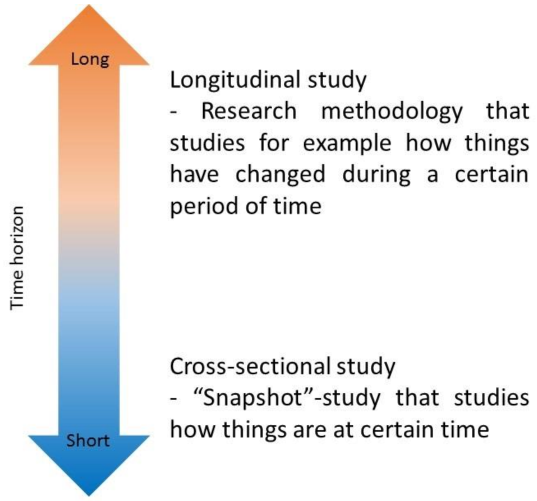

Figure 2: Research time horizons described shortly

Cross-sectional studies are considered a "snapshot" study that can study a phenomenon at a particular time. (Saunders et al 2009) A cross-sectional study may be the only possible choice when the researched phenomenon is so new that it does not have a long history. According to Bryman (2012) on qualitative research, a cross-sectional study can be used specifically to analyze a set of documents relating to a single period of time. (Bryman 2012)

Because this research studies a new phenomenon and fast developing technology, a cross-sectional study gives better answers to this research's research problems. A short time horizon offers a good change to focus on what happens now, but in order to find out how IoT affects BI, this study needs to consider a timeframe stretching from the present to the near future because IoT is such a fast developing trend right now. A longer time frame could offer some unpredictable findings but it does not fit the scope of this research. This is why this research's time horizon is from the present to the near future which means two to five years from now.

1.3.5 Gathering information

This research will be carried out as a literature review. This section explains how a literature review can be defined, how it should be done and why a literature review is used in this research. It also explains how and when the information is searched and gathered and what kind of limitations it sets for this research.

According to Bryman (2012), a literature review is a research method in which the researcher gathers up and reviews literature related to the research problem. (Bryman 2012) The researcher should not be too critical when selecting material for the first time. A wide range of material in the first round ensures that the researcher finds new ideas related to the research questions and any valuable material will not be thrown away. (Saunders et al 2009) Based on the reviewed material, the researcher tries to find an answer to the research problems stated beforehand by picking up relevant information from the research literature. (Bryman 2012)

Hirsjärvi et al (2007) defines the literature review process as a five-step process. The steps are: deciding a topic for the research, gathering different sources of information, evaluating the gathered material, finding valuable information and finally writing a review. (Hirsjärvi et al. 2007) Saunders et al. (2009) has an idea very close to that of Hirsjärvi et al (2007) about the literature review process but they represent the research process more as an iterative process. This process is based on reading the gathered material through multiple times in order to find out the most important points in the multiple literature sources. After gaining enough understanding of the research problem, the researcher is ready to answer the research questions with good insight. (Saunders et al. 2009) Figure 3 represents this circulative process.

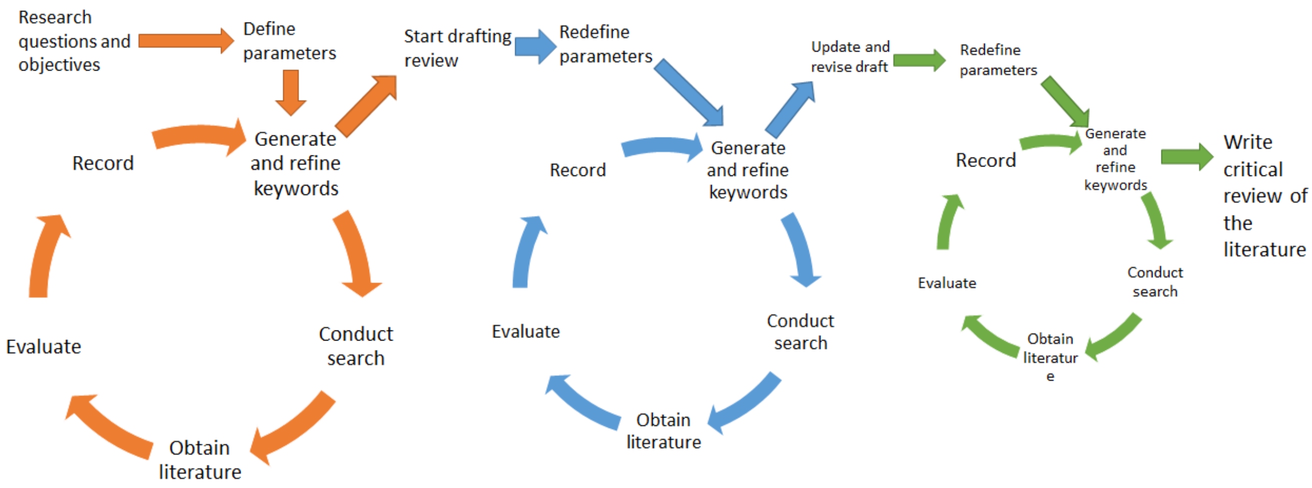

Figure 3: Iterative literature review process (Model from Saunders et al., 2009)

As figure 3 shows, when the search process is done three times, the volume of the material has to be huge at the beginning. By iterating the whole search and knowledge gathering process three times, the researcher understands the topic so well that he or she can form a theory or a model by analyzing the literature. By using this analyzing tool, the researcher can write a critical review of the subject based on the literature.

Literature review is used in this research because it offers a possibility to gain a wide point of view as to the research topic. To find a comprehensive answer to the research problems it is important to understand the concepts in comparison very well. By understanding BI's and IoT's pros and cons it is possible to find the synergy and weaknesses of these two concepts. With this information it is possible to predict what kind of effects IoT will have on BI.

*The l*iterature used in this research is mainly from the Tampere University of Technology library's internet services and Google Scholar. The literature used consists mainly of doctoral theses, articles and books. Because the studied subject is such a new trend, written columns, blogs and news that bring out new, well-argued information about BI or IoT were also accepted into this study. Twitter, LinkedIn, Reddit, Facebook and other social media as well as Google were used to find this new internet-based material from the sites of well-known news stations, technology companies or individual technology professionals. The material was considered well-argued information if it used valid references, supported information found from literary sources, presented the used research methods and offered new information that couldn't be found in books or articles released in recognized, scientifically valuable journals. Information that was not gathered from the more traditional information sources like books and articles was pointed out clearly in this research.

The key words used for searching information on Google, Google Scholar, TUT library, LinkedIn and Reddit were "Business Intelligence", "Reporting", "Internet of Things", "Teollinen internet" and "Liiketoimintatiedon hallinta". Hashtags to find the wanted information on Twitter and Facebook were "#IoT", "#InternetOfThings", "#BusinessIntelligence", "#Data", "#BigData", "#Analytics" and "#BI".

Unlike in figure 3, gathering information for this research was started in June 2014 and continued throughout the whole writing process. Gathering new information and reviewing it continued until this research was published. This decision was made because IoT is a trend that is investigated all the time and while this research was written, new information was released every day. By continuing gathering new information while writing this study it was possible to keep this study relevant up until the release.

The selected way of gathering information sets lots of different limitations for this research. Selecting literature review as a research method limits the found results to other researchers' findings. The only way in which this research can find new information is by putting together the gathered information. Since there are no experimental parts or measures, the researcher cannot find totally new information by itself. If the information that this research uses to combine new information is incorrect, the combined information can be also incorrect. This is why it is very important to use multiple information sources that support each other, and critically review the used information to reduce the risk of using faulty information. To find the best answers for this research it is important to pay attention to finding as many literature sources as possible before starting the critical reviewing process. By using a large number of different information sources, it is possible to find new and unexpected results.

1.3.6 Information analysis

This section describes what kind of a tool concept analysis is and what kind of stages it has. After gaining understanding of concept analysis this section explains why it has been chosen as the information analysis tool for this research. It also describes the kind of effects the selection has for this research.

Puusa (2008) defines concept analysis as a non-empiric research method that analyses different concepts like BI and IoT. It helps to gain a deeper understanding of the critical characteristics as well as the relationships and differences between related terms. (Puusa 2008)

According to Puusa (2008), concept analysis has eight different steps that can overlap with each other. The steps are:

1. Selecting the concept and finding its origin
2. Setting the goals for the analysis
3. Finding different perspectives of the concept
4. Finding characteristics and critical features
5. Creating an example model
6. Handling relative concepts
7. Defining preconditions and results
8. Naming empiric referents. (Puusa 2008)

Concept analysis was chosen as the information analysis method for this research because it is important to understand both concepts, IoT and BI, deeply. After gaining an understanding of these two concepts it is easy to produce a relationship analysis based on the findings answer the main research question and reach the goals.

Since the concepts and the goals of the analysis have already been set in the introduction chapter, finding the origin of the concept and performing concept analysis steps 3-8 needs to be done for both BI and IoT. This setup equalizes both concepts and runs the risk of the researcher's own opinions affecting the results. Concept analysis is also a heavy process that takes time and requires lots of different literature.

There are a few ways to reduce these risks. According to Puusa (2008), in order to ensure a successful concept analysis, it is important to use lots of different literature and to review the written concept analysis multiple times during the research writing process. By reviewing the concept analysis while working with the research, the researcher can ensure that his deepening understanding of the concept still matches with analysis results that have been written earlier. (Puusa 2008) This feature makes concept analysis a hard method because it requires a lot of work. When the researcher gains a better understanding of the subject, it may have an effect on the results of the concept analysis. Changes in particular concept analysis results may affect the conclusion. Multiple rewriting may cause humane mistakes that compromises the research's credibility.

1.3.7 Drawing conclusions

This section covers how and when this research's conclusions are drawn and presented. A conclusion is reached based on the concept research and does not present anything new as to IoT or BI but instead, tries to find out whether IoT effects BI and how.

This research presents conclusions after a concept analysis of IoT and BI. It describes the relationships that can be found between these two concepts and analyzes possible synergy benefits, common risks and how these are going to affect each other. The results are presented in a matrix that investigates how each benefit and challenge affects each other. Possible results are classified as positive, negative, and both positive and negative results.

After finding out the possible effects this research speculates on possible future visions based on the results and presents two case studies. It aims to find out how BI and IoT will develop in the future and if these two concepts will still be related to each other.

Table 2: Summary of selected research methodologies and how selections affects research

Concept	Selected methodology	Effects on research
Philosophy	Direct realism and critical realism	Relies on the facts that are discovered and limits the human aspect out of this research.
Approach	Deductive	The goal of the research is to make findings based on a theory. This research does not focus on proving any theory, it tries to find out the possible effects of IoT on BI.
Strategy	Qualitative research	Makes the research ambiguous because it assumes and makes conclusions based on facts that are not as exact as measured data.
Time horizon	Cross-sectional study	Research focuses on a short time horizon. Limits out certain significant results that could possibly be found using a longer time horizon
Way of gathering information	Literature review	The results of the research are only as good as its sources. The information pool needs to be wide in the beginning and the referenced information sources need to be reviewed critically. This research can find new information only by combining information from other sources.
Information analysis	Concept analysis	Gives a good view on IoT and BI which is a good starting point for drawing conclusions. Analysis needs to be reviewed multiple times during the writing process as the researcher gains a deeper understanding of the concept. May often cause a need to rewrite the results of the analysis which might lead to humane errors. The researcher needs to pay special attention on the research work.
Making conclusions	Comparing concepts	Compares the benefits and challenges of both IoT and BI in a matrix and tries to determine how these two different technologies will shape in the future.

2. BUSINESS INTELLIGENCE

Business intelligence (BI) is an old function in organizations and has been practiced manually, for example by salesman, for centuries. The oldest IT-system that can be classified as a BI-system was found about fifty years ago and the first well-known article about BI was written as early as 1958. (Power 2004; Luhn 1958) At first, BI was only one separate analyzing tool, but nowadays, as businesses keep growing rapidly, BI has turned into an important strategic capability improver. (Negash & Gray 2008) Why is BI such an important part of organization management and why right now? This chapter covers the concept of BI, the benefits it has, different traditional BI-process parts and possible challenges.

Views about business intelligence as a term are pretty solid even though there are still some minor differences depending on the writer's point of view. The traditional, most common idea of BI is that it is a continuing process that an organization uses to achieve a better, more agile and more complete understanding of its internal activities. By using BI, the organization's competitiveness and strategic position strengthens and all the organization's stakeholders receive significant additional value. An important notion that connects researchers is that BI is becoming a more and more significant tool in the digitalized world. (Raber et al., 2013; Vitt et al., 2010; Negash, 2004; Power, 2004; Vitt & Luckevich, 2002; Gilad & Gilad, 1985; Luhn, 1958) Raber et al. (2013) argue that BI is growing with the possibilities that come with IT-technology development. They think that improved calculation power and cheaper components open whole new opportunities for BI. (Raber et al 2013) In the other hand, Vitt et al. (2010) remind that with improved network technology, like the Internet, BI is a key tool that can answer to the challenges of the globalized business world.(Vitt et al 2010)

The main purpose of BI is to bring the right information to the right people at the right time and in the right place (Vitt et al. 2010; Gilad & Gilad 1985). The traditional view is that in order to achieve the BI's task, the process needs correct data sources, a proper BI-system, a knowledge creator and a good information sharing portal to share the knowledge created for the decision-makers needing it. This process is described in figure 4 below with some example data sources.

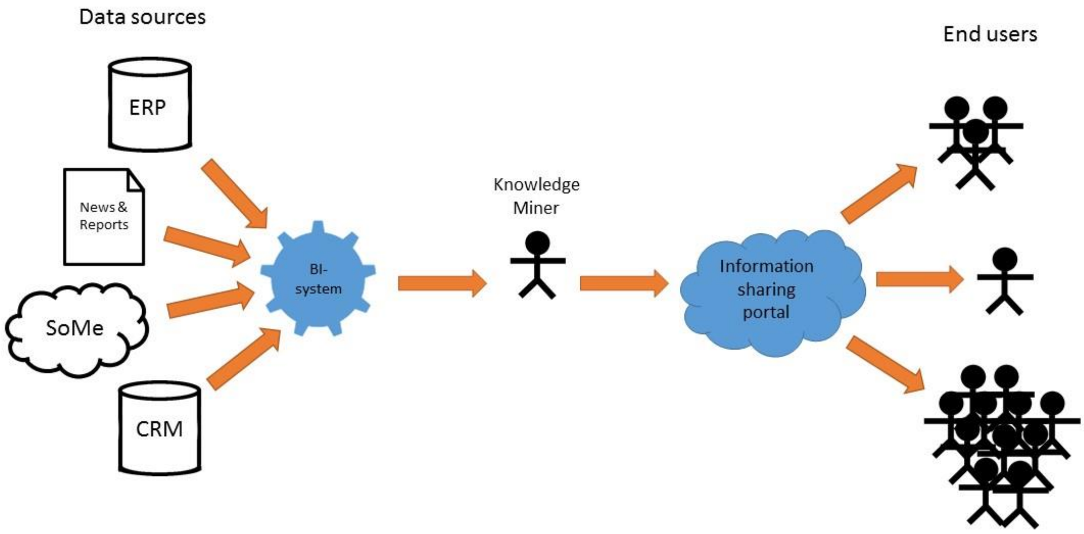

Figure 4: Traditional BI-process' information flow with example data sources

The parts of this process are handled in more detail in section 2.3 after listing the benefits of the BI process.

2.1 Related concepts

There are three similar concepts, Business Intelligence (BI), Competitive Intelligence (CI) and Marketing Intelligence (MI), that are widely used, but there is no common agreement on the definition of these concepts. Some researchers and practitioners even use these three terms as synonyms. (Wright & Calof 2006) Since there is no shared view about what BI means, it is important to understand the relationship between these three concepts to comprehend the big picture of gathering data and refining it into knowledge.

Figure 5 below describes the relationship between BI, CI and MI. BI relies heavily on internal data, while CI and MI mostly use external data. There is some overlapping in this division and some information can be used in all the functions.

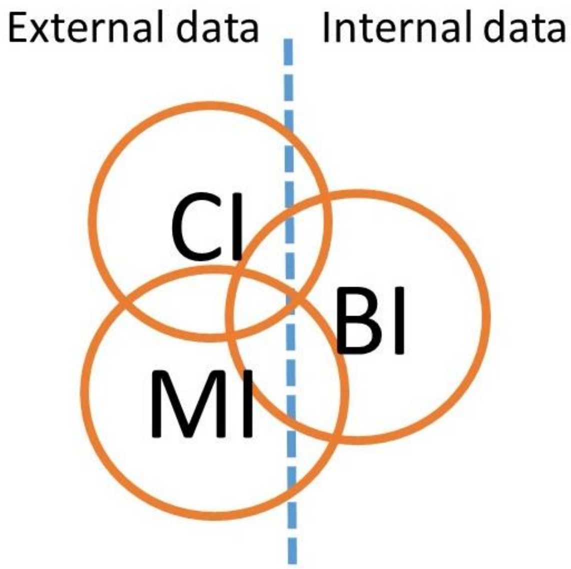

Figure 5: The relationship of the concepts BI, CI and MI used in this research

CI is often defined as an activity that gathers information about an organization's direct and indirect competitors. CI is mostly used to help the decision-making process especially in strategic planning, like significant investments. (Hughes et al 2013; Wright & Calof 2006; Chen et al 2002; Rouach & Santi 2001) An organization that uses CI can find new opportunities and avoid potential disasters by examining their business environment beforehand (Rouach & Santi 2001). CI relies mostly on external data that is gathered mostly from the Internet. The information gathered is mostly unstructured and ambiguous but a talented CI-professional can find good directional instructions on what should be done and which decisions the organization should avoid. (Chen et al 2002)

MI is an analysis process that gathers information about the organization's marketing environment and tries to find possible opportunities for attracting new clients and improving the existing client commitment. (Wright & Calof 2006) By gathering information about the surrounding marketing environment, the organization can find for example new trends in marketing, gather the opinions of the market target and recognize the potentially critical situations going on in the markets (Glance et al 2005).

The biggest difference between BI, CI and MI is the nature of the data sources and the wanted results. Since BI is most often interested in an organization's internal events it mostly uses internal data, while CI and MI use external data. Internal data offers results that are more accurate and real-time compared to the external data that CI and MI use (Negash 2004; Rao 2003). Better accuracy means better ability to use computer systems to support the BI-function. This is why BI has many computer system solutions and it is considered the most computer-based function of the three. (Hedin et al 2011)

CI and MI are concepts that are relatively close to each other. Most of the data needed for CI and MI is external and nowadays gathered from the Internet, as well as employees working closely in the market like salespeople. Gathered information is rarely exact and relies heavily on personal views and individual expertise. The difference between CI and MI is mostly in the analyzed results. Marketing intelligence examines the marketing environment and competitive intelligence focuses on the organization's direct and indirect competitors. (Hughes et al 2013; Glance 2005; Chen et al 2002; Buhner 1998) Hedin et al (2011) have noticed that the concepts CI and MI are not clear in many organizations. Many organizations that use CI and MI mix them up even within their own marketing material. (Hedin et al 2011)

Since there is not a one common way of using the concepts BI, CI and MI, it is important to fully understand what concept researchers or marketing material really mean when they use BI or the related concepts. BI focuses on an organization's internal actions, and CI and MI are interested in the organization's external environment. All the functions are used to develop the organization strategically, but they have a different point of view and different results. BI's analyses are often more accurate than CI's and MI's but only offer a limited view to the organization's environment.

2.2 Benefits

All the references of this study that cover the benefits of BI highlight that the main benefit of Business Intelligence is achieving a better business insight that supports decision-making. BI's benefits that offer better business insight can be divided into four different factors (figure 6) which are improved data quality, increased knowledge sharing, accumulated knowledge and better data utilization. It is worth noticing that all the benefit factors of BI are intangible. (e.g. Raber et al. 2013; Tyrväinen 2013; Chen et al 2012; Vitt et al 2010; Negash & Gray 2008; Ykhlef, 2006; Negash 2004; Vitt & Luckevich 2002; Gilad & Gilad 1985)

Figure 6: Business Intelligence's main benefits

An organization's data quality starts to rise by using BI. Quality improvement happens almost by itself since the organization uses the gathered data more often and the found results depend on it. (Vitt et al 2010; Vitt & Luckevich 2002; Gilad & Gilad 1985) Fragment data and low data volume lead to poor and inaccurate results. That is why good quality data is favoured in using and gathering the data.

BI encourages organizations to share information and to use the knowledge gained earlier, since sharing information raises the volume of available data and leads to even better results. (Vitt et al 2010; Vitt & Luckevich 2002; Gilad & Gilad 1985) Active information sharing forms a culture of sharing information within the organization. According to Vitt et al (2010) the culture of sharing does not only include the gathered data, but it also includes the found results (Vitt et al 2010).

Gathered information and fresh results often teach something new about the organization itself or about the business environment surrounding it (Raber et al. 2013, Vitt et al 2010). New-found information and decision-making results can be utilized in the future. This phenomenon is called “Accumulated knowledge” (Gilad & Filad 1985). An organization that has accumulated knowledge has an advantage since the lessons learned earlier can benefit it in the future.

Better data utilization is the outcome of two different factors identifying useless data and focusing more on the relevant data. By reducing useless flood of data and finding a manageable amount of useful and reliable data for the decision-making process, the organization utilizes its data more efficiently (Vitt et al 2010; Gilad & Gilad 1985). Better data utilization means lower data handling costs and a more efficient BI process.

Improved business insight gives organizations a better vision (Negash 2004; Gilad & Gilad 1985). More productive and better decisions cut expenses, decrease indetermination and increases focus on the things that need more attention. (Negash 2004; Gilad & Gilad 1985)

2.3 BI-process parts

BI-process parts are the same as described in figure 4. It consists of multiple data sources, the BI-system, the knowledge miner and the information sharing portal. These process parts are needed to produce BI-function. These process parts and the concepts related to them are described briefly below.

2.3.1 Data sources

Data can be divided based on two different properties: data source and data structure. From the point of the data gathering organization, the source can be either internal or external and the data structure can be either structured, semi-structured or unstructured. (Ykhlef, 2006; Negash 2004; Rao 2003) To utilize all the potential of the organization’s data, it needs to recognize possible data sources, handling methods and how to handle possible conflicts between different data sources. Before creating a data gathering plan, the organization needs to understand the nature of its data.

Table 3 below lists some example data sources based on the type and the source. Available data sources and placement in the table depends on the organization and data source usage but it is a good directional guide for understanding the nature of different sources of data.

Data / Data type	Internal	External
Structured	ERP, ALM	CRM
Semi-structured	Business Processes, emails, web sites, text documents	Reports, researches
Unstructured	Phone calls, photos, videos	News, Social media, Presentations

Table 3: Examples of datasources divided based on different data types and data structures (Ykhlef 2006; Negash, 2004; Rao 2003)

According to Negash (2004), structured data is well-stored data in a simple format (relational and flat files) that is easy to handle by a computer. Good examples of systems that gather structured data to relational databases are ERP, ALM and CRM. This data is easy to gather and handle by automated reporting systems. (Negash 2004) Structured data sources are the data sources most often used knowledge mining processes in various organizations. Structured data sources are the most popular data sources since many organizations have one, and automating structured data handling is easy. (Rao 2003) The benefits of automating data handling are resource efficiency and good predictability.

There are slightly different views between different researches about what can be categorized as semi-structured data (Ykhlef 2006; Negash 2004; Rao 2003; Abiteboul 1997). Different views are mostly about drawing the boundaries. For example, Ykhlef (2006) and Negash (2004) represent two distant views: Ykhlef (2006) interprets semi-structured data as very close to structured relational data while Negash (2004) has a lot wider interpretation of semi-structured data. Ykhlef (2006) sees semi-structured data as data the structure of which is not constrained by a schema. He describes semi-structured data as nested and non-nested information relations that are usually stored in xml-files and represented in a graph-like manner. According to Negash (2004), semi-structured data has a lot wider definition. Negash (2004) lists almost all data that is not relational to semi-structured data. As an example Negash (2004) lists text documents, emails and phone calls as good examples of semi-structured data. (Ykhlef 2006; Negash 2004). Both of these views have the same definition for semi-structured data. Computers can handle it automatically, but it is not easy. For example search engines can be used to search a documents' contents but the process is not as reliable as handling relational data. (Ykhlef 2006; Negash 2004) More complex data handling rules mean more expensive manual work. To cover the raised costs, the analyzing process needs to find new significant results to make it useful.

Unstructured data is data that is hard or even impossible to handle by a computer without pre-processing. A good example of unstructured data is photos, videos and phone calls. Usually organizations use this kind of data only once and then discard it because of the lack of data storing processes. (Rao 2003) Hard automating makes utilizing unstructured data expensive, because it requires a lot of work and resources to store it efficiently and in such a way that users can find the needed information later. According to Rao (2003) and Abiteboul (1997), the key to utilizing unstructured data in daily business efficiently is to automatize the process that turns unstructured data into semi-structured data which is possible to query. (Rao 2003; Abiteboul 1997)

All data can be divided into internal and external data. Internal data is data about the organization itself. Internal data usually has better accessibility, the data is more specific, structured and more reliable and usually gathered from the organization's internal systems. Examples of data sources for internal data are ERP and ALM. (Negash 2004; Rao 2003) Good accessibility and reliability combined makes internal data sources easy and cheap to utilize. Measuring and reporting the organization's own action also turns rewarding quickly because it is usually easy to optimize the organization's business based on the measured results. This makes internal data sources a good starting point for companies who want to start reporting.

External data is data that describes an organization's surrounding business environment. External data has usually more variety than internal data, and it is not as reliable or specific. This makes external data harder and more expensive to utilize and usually requires a lot more manual human work and computational power to use it. (Negash 2004; Rao 2003) Despite several challenges, using external data can be very rewarding because of the amount and variety of available data. Nowadays no one can find and use all the external open data sources. Undiscovered data sources mean that there are always possibilities that competitors have not yet found that can be turned into competitive advantage.

To accomplish BI's basic task of creating the right information for the right person needing it, the knowledge creator needs to find the right data sources. To select the right data source for the wanted result, the knowledge creator has to consider what kind of data types he or she needs based on the situation. To answer this question, the knowledge miner has to understand the problem and the factors affecting it.

Based on the image of the problem and the resources available, the knowledge creator chooses between internal or external data sources or combines data from both types of data sources. The selection between the used data sources and data structure is usually a trade-off between report quality and resources. Going through unstructured data is an operation much slower and much more expensive than handling structured data in databases. In situations where the decision makers need information as fast as possible, there is usually no time for processing all kinds of phone calls, photos and videos without significant computational capacity and an effective BI-process.

2.3.2 BI-system

A business Intelligence system is a tool that can be used to analyze information from various databases. A BI-system is usually built up of selected sources of data, ETL, external reporting database, BI-engine, reporting tool and OLAP-tool. ETL is a system that extracts data from various data sources, transforms it into the wanted form and loads it into a reporting database.

A reporting database is a database that holds pre-processed data only for the reporting function. A BI-engine is a system that works as a logical layer and provides BI-services and tools for different user interfaces. A reporting tool is a tool that can be used to create report forms. Report forms are usually used via OLAP-tool. (Wu et al 2007; Lee & Park 2005) Wu et al (2007) remind that there are several kinds of architectures that differ especially from the point of view of the integration level of the reporting database. On a conceptual level, this can be kept as a basic architecture. (Wu et al 2007)

It is hard to predict what kind of reports are needed in the future, and this basic structure is usually not agile enough if reports are needed as soon as possible. This is why a BI-system has to support gathering information from the reporting database manually and creating new reports of it even on the move. There are situations in which quick information reporting can create competitive advantage. For example, if a client asks something about a bought service, and customer support does not know the answer to the question. In this situation, customer support may need to create an ad-hoc report to find an answer quickly in order to keep the customer pleased. This can be possible even on the move by creating reports on mobile devices with OLAP-tool. Sometimes it can be useful to connect directly to the data sources to examine the data situation in the present moment. A direct connection to the data source can be used when the knowledge miner needs data that has not yet ran through ETL

The BI-system's most basic architecture is presented in figure 7 below. The main information flow is represented with filled arrows, and white arrows with borderlines show possible information flows that can improve the BI-system's agility.

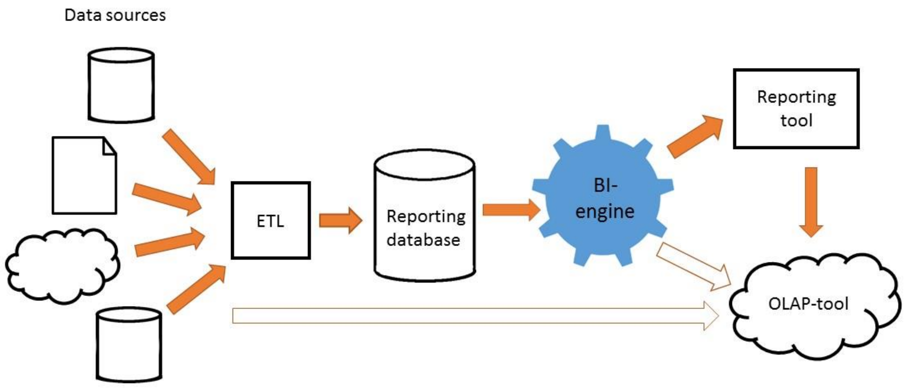

Figure 7: Basic structure of a BI-system. Information's main flow filled on orange.

There is no one best solution for the BI-system's architecture. Wu et al (2007) suggest hub-and-spoke architecture and data-mart bus architecture as alternative possibilities for a basic, independent reporting database-architecture. In hub-and-spoke architecture, the reporting database is in a centralized data warehouse and in data-mart bus architecture, the reporting databases are on linked, conformed, dimensional data marts. (Wu et al 2007) The choice of system architecture depends on the requirements set for the system and the organization's existing environment.

2.3.3 Knowledge miner

The knowledge miner is a person who uses the BI-system to create the needed information for the decision-makers. A good analysis helps the decision-maker to make better decisions for the business. (Fayyad et al 2002; Gilad & Gilad 1985) But if the knowledge miner doesn't have the skills required to do his job, wrong analysis or inefficient presenting can disturb the decision-making process and shake the reliability of the company's BI-process. To prevent this and to produce the best BI-service for the client, the knowledge miner has to have the skills required for his or her job.

To work efficiently, the knowledge miner has to understand the BI-process thoroughly. After understanding the available data and its sources, the knowledge mining tools, the clients' business environment and the information presenting tools, the knowledge miner has a good starting point for producing efficient information presentation. (Fayyad et al 2002; Gilad & Gilad 1985) The BI-process is as good as its weakest link is. For example, if the found information is useless or in the worst case even misleading, it can lead to incorrect decisions and cause some damage for the client's business. On the other hand, even the best analysis is useless if it is presented poorly and the client does not understand the message the analysis tries to tell.

To understand the data and its sources, the knowledge miner has to know what kind of data sources he or she has available, where that data is gathered, how it is handled and where it is stored. (Ykhlef 2006; Negash, 2004; Rao 2003) To retrieve and to handle the data in the necessary way, the knowledge miner has to know how to use data tools like databases, data querying languages and statistics methodologies (Wu et al 2007; Wold & Geladi 1981).

Choosing the right form for presenting the data is one of the key parts in the BI-system. According to Fayaad et al (2002) and McDonald (1991), the choice between different presentation tools depends on the used data and the needs of the decision-makers. There are several techniques to make data easier to understand, but visualization is the most common tool for it. For example different kinds of graphs and maps are common visualization tools. (Fayyad et al 2002; McDonald 1991) With a good presentation it is possible to pass on the message of the analysis to the decision-maker. An analysis that is easy to understand makes the data more usable and the decision-making faster. Furthermore, the possibility for misunderstanding the message decreases which means better decisions and possible competitive advantage.

Sharing analysis results with people who need them is also an important part of the BI-process because if no one ever sees the analysis, it is useless. According to Talja (2002) sharing information is an important but a challenging task. It is not always possible to know beforehand who might need the information you want to share. (Talja, 2002) The knowledge miner has to have the skills for sharing his analysis with all the people who need it to get the full potential value out of his work. Without planning the information sharing carefully, there is a chance of overlapping with the work of other knowledge miners, or situations where someone makes a bad decision because he or she did not have the analysis results.

The knowledge miners' necessary skills and the tasks of the role can be divided into three categories that can be linked together. Table 4 presents those tasks and skills. On the left side is the task that the knowledge miner needs to perform in his or her job, and on the right side is the skill family that he or she needs to master to successfully do his or her job.

Table 4: Skills and corresponding tasks that a knowledge miner needs in his or her role.

Skill	Task
Business understanding	Finding and understanding the needed data.
Technology	Gathering the data and finding a way to present it.
Social	Finding and sharing the analysis with the people who need it.

A knowledge miner is a person who keeps the business intelligence process running. He or she refines the raw data into an understandable form in a report and makes the decision-making processes easier and faster.

2.3.4 Information sharing portal

The information sharing portal is a tool in the digital environment that is used to gather information and to share it to all the people who have access rights and the need for it (Pilerot & Limberg 2010; Dyer & Nobeoka 1998). A well implemented information sharing portal offers significant competitive advantage especially in the long term (Dyer & Nobeoka 1998). An organization that has a good information sharing culture and tools for it has a good starting point to share the results of the BI process. On the other hand, a BI-process without a proper sharing capability is useless, because it does not matter how good the reports the knowledge miner produces are if no one ever finds the needed information.

According to the studies of Van Baalen et al (2005) and Dyer & Nobeoka (1998), information sharing portals are good for sharing explicit information and for reaching people that the information sharer has not met before. (Van Baalen et al 2005; Dyer & Nobeoka 1998) These benefits fit well the BI-process' needs of sharing the new reports to all the people needing them. Predicting who needs and who will need the information that the knowledge miner has produced is impossible, so a good information sharing portal offers a solution for this problem. The analyzed information is stored in the information sharing portal in a place where everyone can find it after a short search.

Neches et al (1991) suggest that the information sharing portal should be as integrated as possible. Using several portals and interfaces leads to technological problems and missing information. When information is centralized to one system, it is used more often and it is easier to share to wider audience. (Neches et al 1991) Van Baalen et al (2005) also support the idea of an organization-wide user base to find new opportunities and weaknesses in the organization knowledge. With one shared system people can find new information from a contact that they have not met before which creates a permanent information sharing link between them. (Van Baalen et al 2005) Strengthening an organization's employee networking often leads to a more agile organization and supports faster decision-making as people know who has the information they need. This is the point where a successful knowledge miner has a perfect chance to offer his or her services.

The information sharing portal is an essential tool for the business intelligence process; it is the best place to make BI's results visible and to reach as many potential clients as possible. By doing this it is possible to get the full potential out of BI work for the whole organization.

2.4 Challenges

The challenges of Business Intelligence's are more ambiguity than its benefits. There is no clear categorization for BI's challenges among different researchers but two main challenge groups can be identified: social challenges and technical challenges. (Chen et al 2012; Airinei 2010; Vitt et al 2010; Negash & Gray 2008; Ykhlef, 2006; Negash 2004; Gilad & Gilad 1985) Social challenges are the challenges that rise from human culture and organization culture aspects. Technical challenges are the possible limitations or requirements that BI-systems, information security or any other technical system sets.

Section 2.4.1 goes through the kind of social challenges that BI comes across. It divides BI's social challenges into cultural challenges and personal challenges and finds out the major challenges as well as other challenges. Section 2.4.2 finds BI's four main technical challenges and describes those briefly.

2.4.1 Social challenges

There are several different social challenges in BI that the organization needs to face before acquiring the full potential of BI. Social challenges can be categorized as cultural and personal challenges. (Chen et al 2012; Golfarelli et al 2004; Negash 2004; Gilad & Gilad 1985) Cultural challenges concern high level challenges that the organization faces when using BI. Personal challenges are challenges that the organization's individuals face while being in the role of knowledge miner or the end user of the reports.

The main cultural social challenges are often the result of BI's intangible benefits. Usually companies that are founded to yield profits for the owners want that investments pay back as fast as possible. The challenge with measuring BI's benefits and payback-time is that it does not produce any money by itself; the gained business value depends on how the produced information is used (Negash 2004). This is why BI can be classified as a business supporting function. To achieve a stable status in an organization, BI has to prove its usefulness in a company by other means than simple profit level. Proving the usefulness to people who decide how the organization's funds and other resources are divided is important. If the resource planners cannot see the benefits of BI and under-resource it, they can decay BI-function's chances to succeed. This is why BI's success is heavily depended on the organization's management. The decision-maker's attitude to BI defines BI's possibilities. Even the best analysis is useless if the decision-maker does not have trust in it.

Personal challenges are the challenges that individual people, like knowledge miners and report's end users, face while taking part in the BI-process. The main challenge that individuals face is the risen complication level of the analytics. According to Chen et al (2012), the increasing amount of data sources and data volume requires a lot more complex analysis and more advanced tools to handle it. New tools and analyses that are even more complex require new skills. (Chen et al 2012) Golfarelli et al (2004) remind that the organization's knowledge miner is not the only one who needs new skills. Too complex business rules discourage the BI-system's users because they do not understand how the results are formed. On the other hand, reporting that is too simple does not use all the potential of the BI-system. (Golfarelli et al 2004)

Some other challenges that Watson (2007) and Gilad and Gilad (1985) highlight are growing user base, prioritizing and resistance to change. If BI-function is successful and it has the organization management's support, the user base is growing. (Watson 2007; Gilad & Gilad 1985) More end users means different kind of needs, requirements and levels of analytics skills. To gain the full benefit, the BI reports need to be so easy to understand that even more people have skills to use them. Larger report user bases mean that BI-function has an even bigger effect on the organization's actions. If reports are misunderstood, it may have unpredictable results since the decision-makers are basing their actions on misinterpreted results. To prevent this, dashboards made for end users have to be as user friendly as possible. (Watson 2007)

After even more users have adapted BI reports to their use, some of them may face prioritizing problems. Sometimes the decision-maker may feel that their personal feeling differs from the reported results or that different reports' results are conflicting with each other. This feeling usually comes from a lack of understanding of the BI-process. When the decision-maker does not understand how the reports are formed and how the results should affect the decision-making process, they might have problems on with prioritizing the found results. (Gilad & Gilad 1985)

At some point of BI's distribution, the organization often faces resistance to change and ethical questions. The organization has to decide what should be reported and when they should honor an individual person's privacy. Failure on leading the measuring culture leads to a situation where some individuals feel that they are constantly measured because the organization's management is not trusting them. (Gilad & Gilad 1985) The negative effect on the organization culture is hard to measure and it may have some unexpected results.

BI's main challenges and other social challenges found above are listed in table 5. Most of the found challenges are somehow linked to people's know-how and the intangible benefits. The reason for that is BI's business supporting nature. If an organization does not want to or cannot use support functions in its daily business, it does not produce any value by itself.

Table 5: BI's main and other social challenges

	Main challenges	Other challenges
Cultural challenges	Intangible benefits are hard to measure.	Resistance to change, ethical questions
Personal challenges	The risen complication level of the analysis requires a new set of skills from knowledge miners and end users.	Prioritizing the found results, risen requirements for reports' user friendliness

2.4.2 Technical challenges

Technical challenges are non-social challenges and limitations that an organization may face while implementing the BI-process. There is no such consensus between researchers about the major technical challenges as there is for social challenges. The most usual categorization contains four different categories: data, risen requirements, widening user base and information security. (Chen et al 2012; Airinei 2010; Watson 2007; Wiant 2005; Golfarelli 2004) These four different categories are summarized and described briefly in table 6 below.

Table 6: BI's technical challenges listed and described briefly

Challenge	Challenge briefly
The amount and amount and quality of data	Amount of analysed data is growing exponentially and the quality of historical data can be problematic
Risen requirements	Risen requirements for real-time data and willingness to make ad-hoc reports on mobile devices causes challenges for the BI-system architecture.
Widening user base	BI-system, bugs and possible misunderstandings have a significant role in the organization’s actions since the reports are used especially in decision-making.
Information security	Reported sensitive information can be misused or breached by crackers.

According to Chen et al (2012), one major challenge for BI is the exponential growth of the amount of data to analyze. New, larger data sets require more calculation power, better optimized software and data mining algorithms. (Chen et al 2012) The growing amount of data can cause problems, especially when the analyzed reports go through large amounts of data within a long time horizon, like annual financial reports. Running these annual reports may require huge calculation power to be completed on time. The requirement for huge calculation power leads to the need for even more powerful analytics servers that are possibly used on full power only a few times in a year. Low server usage-level may feel like an additional cost for many organizations, as the bought system can handle more than it is used for. Golfarelli (2004) adds that the amount of data is not the only problem for calculation processing but also the data quality may cause some trouble (Golfarelli 2004). Historical data may not be as accurate as the data the new sensor systems can gather, data may have been corrupted during storing and some content may even have been lost. Bad data quality can distort the results of the analysis and lead to incorrect results.

The end users’ rising requirement levels can also lead to new challenges. Some end users want to examine real-time data and even create their own reports, wherever they are, on their mobile devices. The BI-system providers need to create their own mobile software and modify their existing architecture solutions to suit the limitations of the mobile environment. An example of the limitations compared to computer systems are simple operating systems, smaller screens and lower calculation power and memory. (Airinei 2010; Watson 2007) The wide variety of different technical platforms have driven some BI-system developers to web-based solutions. Web-based solutions provide access to data from anywhere with access to the Internet. (Watson 2007)

BI-system developers have answered these new requirements by developing their solutions and releasing new versions frequently. Developing new software versions means that the older BI-systems drop out of support which leads to a situation where an organization's existing BI-system needs constant upgrading. (Chen et al 2012) Upgrading BI-software license versions, reporting servers and existing reporting solutions to fit new systems costs money. Increasing BI-costs can lead to re-estimating BI-section's necessity in some organizations.

A widening end user base may also lead to some technical challenges. According to Watson (2007), having more end users means higher influence level in the organization. Higher influence means that possible defects in BI-system solutions also have a stronger influence in the organization. (Watson 2007) To eliminate defects in the reporting systems, the organization has to invest even more on testing the system and improving its usability. Golfarelli (2004) suggests that BI-systems should be integrated more seamlessly to other systems in order to reduce misunderstandings and to find possible defects in the system as early as possible (Golfarelli 2004).

Information security can also be a challenge in the BI-process especially if the reported data is not public. Wiant (2005) presents a case where healthcare providers and insurance companies have had problems when their employees have watched peoples' medical records without permission. (Wiant 2005) This case is an example of a situation where someone has to have access to certain data but he or she has to have a proper reason to use it. To prevent possible misuses, the BI-process' report users has to be registered and watched over. Another challenge is malignant crackers who may want to breach to system to gather information. Implemented web-solutions can open new possibilities to crackers to hack the system security for example by phishing user credentials. Preparing for information security breaches like this can raise the BI-system's implementing costs even more.

3. INTERNET OF THINGS

Internet of Things is one of the hottest rising trends in IT business. Trends usually come and go, but some of them leave a permanent mark. What kind of chances does IoT have to offer for organizations, and should organizations be prepared for it? This chapter's purpose is to gain an understanding of the concept of IoT, what it means, what business benefits it has to offer and what challenges are related to the IoT.

Google trends is a service that figures the number of Google searches at different times. Below, figure 8 shows how the number of Google searches for "IoT" (red curve) and "Internet of Things" (blue curve) has developed from 2005 to 2015. As the figure shows, the number of Google searches has doubled for "IoT" and tripled for "Internet of Things" in one year (Google 2015).

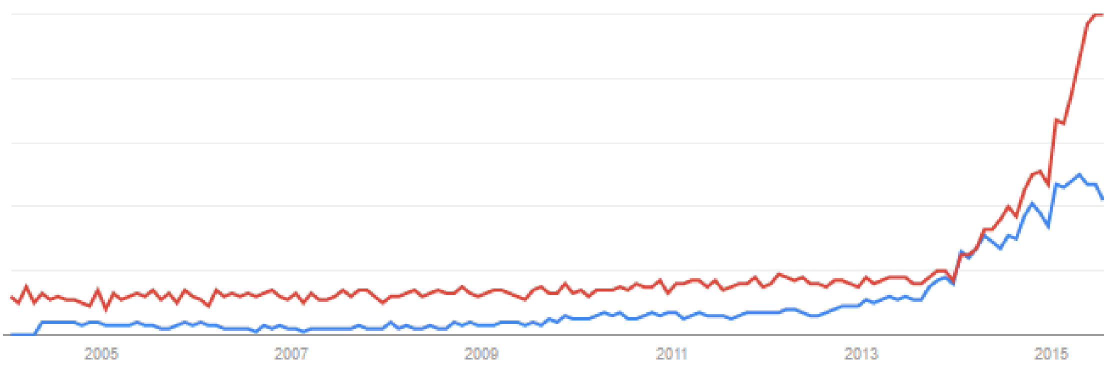

Figure 8: Google searches, red curve is for "IoT" and blue for "Internet of Things" (Google 2015)

There are many terms that share the idea of IoT. These are usually older terms that different companies still use or that are more narrowed down for certain business industry. For example, there is the Internet of Services, 3D Internet, Internet of Content, Next-Generation Networks, Industrial Internet, Internet of Everything, Web of things, Industrial Internet of Things and Smarter Planet (Sterling 2014; Haller et al 2008). Worth of noticing is that all these different Internets are not different parallel ones, but instead, they are the same huge future Internet. (Haller et al 2008) This thesis uses the term Internet of Things (IoT).

Internet of Things is an idea of a world where all physical objects are connected to the Internet and can communicate with each other in order to gain information about the surrounding physical world and other machines in it. With this shared information, different objects can co-operate to reach a common goal. (Atzori et al 2010) Zorzi et al (2010) describe IoT as an "unexplored Wild West" where all current technologies could play a role, but no one knows the real borders of IoT. Governance is very limited at the moment and any individual actors can change the IoT field dramatically. (Zorzi et al 2010)

Gartner estimates that by the year 2020 there will be 26 billion devices connected to the IoT and it provides 300 billion dollars foundation per year. (Biscotti et al 2014) VTT Technical Research Centre of Finland has predicted that with IoT, it is possible to make an additional 15 trillion dollars to the global GDP by the year 2030. (Jurvansuu et al 2013).

From a company's point of view Haller et al. (2008) emphasize that IoT is a solution for the gap between the physical world and virtual systems. With IoT it is possible to integrate physical objects seamlessly into information systems and make them an active part of business processes. (Haller et al. 2008)

When IoT is taken to the extreme, all objects could be part of IoT and that way, made intelligent. Homes, food, pets and even humans could be attached to IoT with different kinds of sensors that gather information from the physical world. (Cooper & James 2009) For example, a company called SST has made a product called "ShotSpotter" that detects gun firing with microphones installed to city environment and calculates where the shots were fired. SST estimates that the results can be reported to the police on a map in only 30 to 45 seconds. (Shankland 2014).

3.1 Related concepts

Internet of Things is such a wide concept that it unites lots of different, smaller concepts and technologies into one hypernym. That is why this section covers only the most important related concepts briefly. The most important concepts related to IoT are Machine to Machine (M2M) network, embedded Internet and Sensor web (Wu et al 2013; Zhang et al 2011; Gupta et al 2005; Gibbons et al 2003; Burton 1998). The relationship between these four different concepts are analyzed and summarized in figure 9 below.

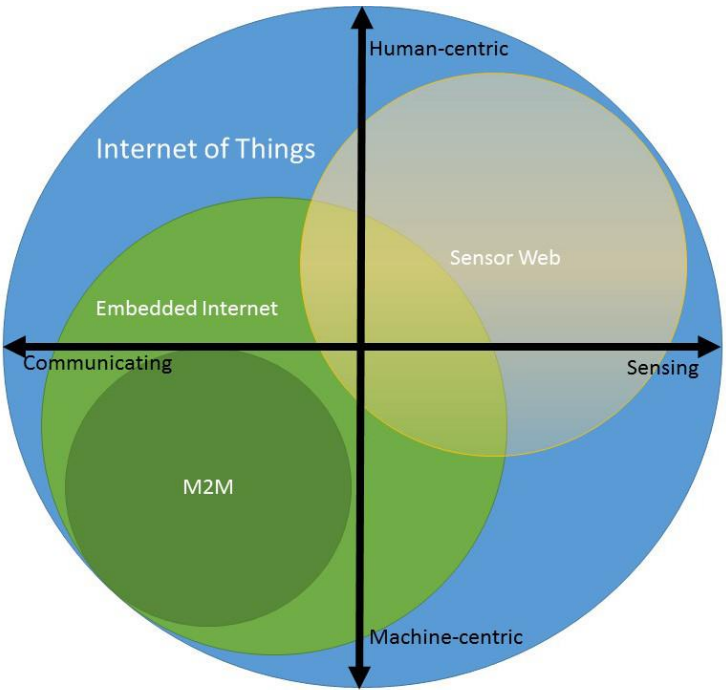

Figure 9: Relation of IoT, M2M, Embedded Internet and Sensor Web

M2M network is a network that is typically formed of different devices connected to each other and a gateway. The gateway's job is to handle the connection between the connected devices and the network's connection to other networks like the Internet. (Zhang et al 2011) Mobility and lowered device costs has widened M2M networks' physical distribution and, according to Wu et al (2011), made embedded Internet possible (Wu et al 2011). One of the key factors of M2M networks is reducing the need for human intervention in order to perform necessary tasks. (Wu et al 2011; Zhang et al 2011) With M2M networks, it is possible to make devices connect and communicate with each other to complete tasks assigned to them. It has a slight difference to IoT, since in IoT everything is connected and working together, not just devices. M2M networks depends on smart devices but does not rely as heavily on sensing the surrounding world and co-operating with things (humans as well) as IoT does.

Embedded Internet is a subset of the Internet of Things. Embedded Internet is a network of resource-limited, embedded devices that are connected to the Internet. Embedded Internet relies heavily on the latest technology development. New low-powered devices, more powerful battery-technology and new internet protocols make embedded internet possible and the ever lowering costs make it more distributed (Shelby & Bormann 2011) Embedded Internet basically means integrating smart devices seamlessly to everyday things combined with M2M (Wu et al 2011; Shelby & Bormann 2011). Like M2M, it does not focus on sensing the surrounding world and co-operating with all the things around it. However, embedded Internet is a concept of even smaller smart devices focusing on even smaller tasks. It brings M2M closer to humans but does not reach the same level as IoT does.

Sensor web is a network of thousand or even millions of sensors and devices using sensor data connected to the Internet. Sensor web gathers, stores, models, retrieves, shares, analyses and visualizes information gathered by sensors. It is used mostly for gathering data about the surrounding world, and that data is used in different analyses like forecasting weather and natural disasters. (Calbimonte et al 2012; Sheth 2008; Gibbons et al 2004) The difference between Sensor web and IoT is in the level of communicating. Sensor web gathers data that is analyzed mainly by analysis for humans but it does not emphasize automatic device communication based on the gathered data.

3.2 Benefits

IoT has many estimated benefits but there is one common benefit that many IoT researchers agree on: huge rise in productivity (e.g. Jurvansuu et al 2013; Coetzee & Eksteen 2011; Atzori et al 2010; Chen et al 2010; Kortuem et al 2010; Tan & Wang 2010; Haller et al 2008) There are a few different views on why IoT will be such a significant productivity booster. Most of the views can be divided into three categories: real-world effects, more agile communication and data analytics. Below, in table 7, these three different point of views are described with some examples.

Table 7: IoT's the most important features in three categories listed with few example supporters

IoT's most important features as productivity booster	Example supporters
Real world effects	Coetzee & Eksteen (2011), Kortuem et al (2010), Haller et al (2008)
More agile communication	Jurvansuu et al (2013), Atzori et al (2010), Tan & Wang (2010)
Data-analytics	Chen et al (2010) Haller et al (2008)

Kortuem et al (2010) and Haller et al (2008) see that the main reason for IoT's productivity is that IoT's results are visible real-world effects. (Haller et al 2008) They think that with RFID-chips, it is possible to create a cheap enough network to track the operational level and optimize it with real-time analytics. (Haller et al 2008) Objects carrying RFID tags can be tracked down and they can store information about the product and its state (Kortuem et al 2010). Combining this RFID information to companies' manufacturing execution systems and enterprise resource systems enables a bunch of new possibilities. For companies, more data and analytics means new products and especially service possibilities for the customers. (Haller et al 2008)

On the other hand, Atzori et al (2010) and Tan and Wang (2010) see that the most essential feature of IoT's productivity boost is to reduce human-centralized interacting and to increase automatic communication between machines. (Atzori et al 2010; Tan & Wang 2010) When things are communicating directly with each other without humans intercepting between them, information does not need to be converted into an understandable form for humans or wait for the humans' information handling. (Tan & Wang 2010). Taking the human influence away from repetitive processes can speed up the process dramatically and reduce any humane errors.

To emphasize the importance of data analytics in IoT, Chen et al (2010) claim that the huge amount of data generated by IoT has enormous possibilities in data analytics. (Chen et al 2010) The growing amount of data also makes measuring different business processes easier and more transparent. (Haller et al 2008)

3.3 Object types at Internet of Things

Internet of Things can be categorized into four different types of objects. Those objects are: identification tags, identifiers, sensors and actors (Jurvansuu et al 2013; Atzori et al

2010; Kortuem et al 2010; Haller et al 2008). Their description and some example technologies are listed in table 8 below and described more closely below each object type in its own section.

Table 8: Object types in the IoT. (Combined from Jurvansuu et al 2013; Atzori et al 2010; Kortuem et al 2010; Haller et al 2008).

Object type	Purpose	Related technologies
Identification unit	To store and identify information about objects	RFID, IPv4, IPv6, uID
Smart items	Self-conscious smart individual objects	Small computer, Mobile device, Television, Car
Sensors	Sensors producing information about their environment.	RFID reader, Router, Thermometer, Camera, Microphone
Actors	Gives wanted real-world results based on a received command.	Electric locks, a motor's throttle, Radiator

3.3.1 Identification unit

Identifying is related to a process where a sensor identifies an object so that it can individualize it out of other similar-looking objects. After the identification, the controller can download information saved to the object and link it to the information stored in the system. (Jurvansuu et al 2013). Based on the situation, the controller can decide what to do with the item and even modify the item's information, if needed. With the identification technology, it is possible to get important location and status information about an object. (Atzori et al 2010).

Tan and Wang (2010) state that identification is becoming more and more important when IoT grows. When the amount of connected devices in a network grows to dozens of billions, finding the wanted data and object becomes exponentially harder. (Tan & Wang 2010) Actually, to get any benefit out of IoT, the traceability and the correct identification of an object are a must. Without the ability to identify individual objects and the connected devices, it is impossible to find the wanted data or decide what to do with an object. If all objects in the world will be connected, we will need lots of individual identifiers.

At the moment, the most important identification tag technology is RFID because of its small size, usability and very cheap prize. (Tan & Wang 2010; Cooper & James 2009) RFID is not the only way to identify things. There are also already the widely used techniques called Universal Identifier (uID) and Internet Protocols 4 and 6 (IPv4 and IPv6) (Atzori et al 2010). The cheapest RFID chip type, the passive RFID-chip, only costs a few American dollar cents and is so small that it can be installed even to the smallest packages handled by humans. (Tan & Wang 2010; Cooper & James 2009) For example, in 2010 Hitachi developed a tag that was 0.4mm x 0.4mm x 0,15mm (Atzori et al 2010). The RFID-chip reader has a range from a few meters up to even hundreds of meters and it does not require direct visual contact to the chip. (Tan & Wang 2010; Cooper & James 2009)

3.3.2 Smart items

Smart items are individual, self-conscious items that are capable of logic reasoning and connected to a network. Smart items also have to be proactive and context-aware. (Atzori et al 2010) They carry information about themselves and the devices they are connected to (Jurvansuu et al 2013). According to Tan and Wan (2010) and Atzori et al (2010), smart items are the most relevant part of IoT. IoT is as smart as the items connected to it. When provided the information that the smart items need, they can act individually and together to reach a common goal. (Tan & Wan 2010; Atzori et al 2010)

For business purposes, self-conscious, smart individual items allow a lot of new business models. For example, with a smart item it is possible to make a pay-per-use funding system where the client pays based on the item's usage. It is also possible to use the object's intelligence to track down misuse, for example with a falling sensor it is possible to gather information about an object if it has been dropped at a certain time and how many meters the object fell before hitting the ground. (Kortuem et al 2010) This kind of information could offer, for example, new guarantee possibilities for mobile device manufacturers. They could for instance promise a full refund if the mobile device breaks up after falling under one meter. Possible guarantee misuses could be revealed by using the data from the the data from the falling sensor.

3.3.3 Sensors

Sensors bridge the gap between the information world and the physical world by measuring its surroundings. With sensors, smart items can sense the surrounding world and respond when needed. (Haller et al 2008) A common adaptation is, for example, a RFID-tag reader or a thermometer (Jurvansuu et al 2013; Haller et al 2008). With these sensors, a smart package receiver can inform the post package receiver that the package has been sent and a radiator can decide if it needs to warm up.

A sensor network is a network that has many different sensors connected to it. A sensor network can be used to create an advanced metering infrastructure (AMI). AMI is a system that can measure, collect and analyze information for smart items. With AMI, it is possible to gain real time information about the physical world, make decisions and act based on it. (Haller et al 2008) A good example of using AMIs at e-health systems is to measure people's health better and notice possible health conditions even before patients notice them by themselves. When the patient gets help on time, the doctor has all the needed information from the patient's current and historical health data. (Jurvansuu et al 2013; Atzori et al 2010)

A sensor network consists of hundreds or even thousands of sensors per machine (Jurvansuu et al 2013). If one factory uses tens of thousands of machines, it means that they gather data from hundreds of millions or billions of sensors at the same time. Depending on the measuring frequency and the format of the measured data, the volume of produced data can be huge even in an hour.

3.3.4 Actors

Actors are an object type in IoT that carries out real-world tasks based on the smart item's orders. Based on the collected sensor data, smart items know how to modify real-world processes by controlling the actors. (Chui et al 2010) Actors can be for example motor remote controls, valves, electric locks, radiators, ingredient mixtures, hydraulic pumps or pressures (Jurvansuu et al 2013; Chui et al 2010). With actors, IoT can interact with the physical world and make IoT's real-world effects happen.

For example, when a smart item like a door with a RFID-reader notices a key with a RFID-tag attached to it approaching it, and checks if that key has a permission to open the door. If it does, an electronic lock unlocks itself and a door pump opens the door.

Without actors, the smart items cannot carry out any real-world actions. On the other hand, actors needs something to control them. The smart items know what needs to be done, but the actors make things happen.

3.4 Data types in the Internet of Things

There are several different types of data in the Internet of Things. Data in IoT can be divided into seven different types that are: addresses/unique Identifiers, descriptive data about objects, processes and systems, positional data and pervasive environmental data, sensor data, historical data, physics models, state of actuators and command data for control. (Cooper & James, 2009) These data types are listed and explained briefly in table 9.

Table 9: IoT data types (Cooper & James 2009)

Data type	Explanation
Addresses/Unique Identifiers	Identifying data about individual things in IoT.
Descriptive Data about Objects, Processes, and Systems	Metadata – information about data
Positional Data and Pervasive Environmental Data	Physical location data
Sensor Data	Data gathered by sensors
Historical Data	Data that is not new anymore and stored for later use
Physics Models	Information about the real world and the laws of physics
State of Actuators and Command Data for Control	Data about actuators acts and commands

Addresses and unique identifiers are meant to identify things in IoT, for example RFIDs. All objects need a unique identifier (Cooper & James 2009). Examples of unique identifier technologies are UUID, IPv4 and IPv6. With these technologies, it is possible to identify individual objects in a network to make a point-to-point connection for data transfers. (Fall & Stevens 2011; Leach et al 2005)

Descriptive data about objects, processes and systems is called metadata (information about data), and it is important in IoT. With metadata, objects can store information for example about their current state and target destination. (Cooper & James 2009) With metadata, objects can affect processes and the way they are handled (Harris et al 2009). For example, in an automated factory a resource object can contain information about the factory processes it has to go through, when and in which order.

Positional data and pervasive environmental data is data about an object's positioning in the global positioning system (GPS) or in a local position system, for example a factory. (Cooper & James 2009) Location data is used, for example, to track down different objects, and find out where they have been and when (Atzori 2010). As an example of tracking the location of objects is a European company that gained a patent for adding RFID-chips to containers in 2002. When an RFID-chip is added to a container, the company can search for a certain container and see where it has checked in or out from their database last. (Pat. US6483434 B1)

Sensor data is data collected from different kinds of sensors. Sensors in a network can produce multidimensional data about an object. (Cooper & James 2009) Sensor data plays a very important role in business intelligence when reporting about objects' state in IoT. (Chen et al 2012)

Historical data is data stored to different databases. Data becomes historical data as time passes and new data is gained. In IoT especially, data volumes can be a problem, since there are many data collectors. (Cooper & James 2009) A huge amount of data offers lots of new possibilities and challenges (Howe et al 2008). For example, a larger and more complex dataset requires more calculation power, and it can have a huge number of different internal relations.

Physics models is information about the real world. With physics models, it is possible to tell machines about the laws and limits of the physical world, for example about gravity and speed of light. (Cooper & James 2009) Physical models are essential to that can do almost anything in the physical world. When a machine has information about the laws of the surrounding world, it is possible to create complex autonomous systems, for example automated cars have to know their physical limits when handling the car's braking. (Chui et al 2010; Cooper & James 2009)

State of actuators and command data for control is data related to one of the object types, actuators (Cooper & Jaimes 2009). To control the actuators safely, the actuator controllers need real-time data about the actuators' state (Jurvansuu et al 2013; Chui et al 2010). Other part of this data is the commanding data from controllers

3.5 Challenges

The Internet of Things has some significant challenges to overcome. There are many listings about IoT's challenges and estimations about what kind of challenges it will face before turning into an everyday thing. Some of the challenges are harder to beat than others and some are mentioned more often than others. Referenced articles had three major in common challenges and they were: growing amount of data and new information dimension, information security and policy and technology limitations.

3.5.1 Data amount growing & new information dimension

Connecting in the world before IoT had three dimensions, that were time, place and a human. With the help of IoT and connecting devices, connection dimensions has changed into time, place and a thing. (Coetzee & Eksteen 2011; Tan & Wang 2010) These new dimensions of IoT and some examples are shown in figure 10.

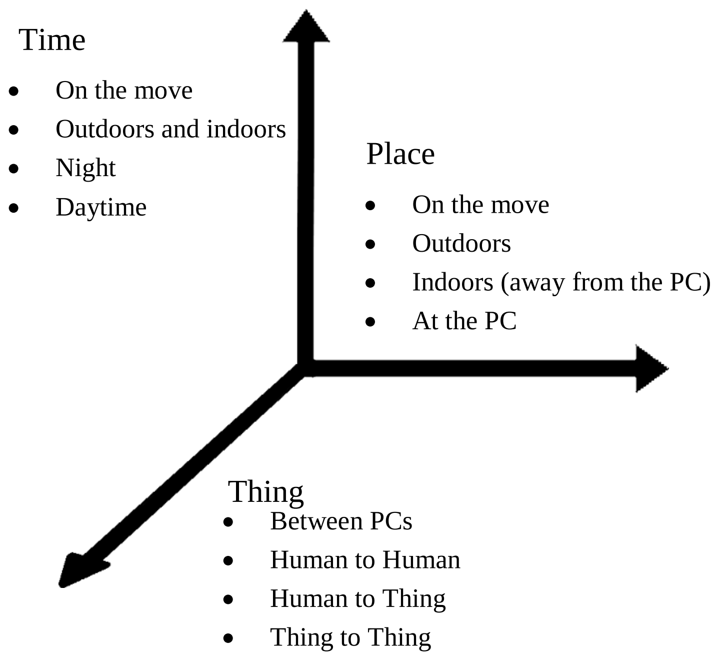

Figure 10: Connection dimensions in IoT (Adapted from Tan & Wang 2010)

When a new technology or paradigm is invented, there are always some new challenges. In the Internet of Things there are lots of them because it affects everything. Even though IoT is not a single new technology, it is all about combining several new technologies and connecting existing things to get new benefits.

When developing IoT, the number of nodes is growing a lot. The more there are sensors, the more it affects internet traffic. If all physical objects are connected to the IoT there will be a huge amount of internet traffic.

IoT also sets lots of new requirements for network protocol technologies that technologies used nowadays cannot reach. According to Shelby (2011), the most important new challenges for internet protocols are the requirements for lowered power consumption, the need for multicasting, the needed mesh topologies, the limited bandwidths and the risen frame size and requirements for better reliability. (Shelby 2011) For example, in many scenarios, most of the sensor nodes spend most of the time out of the network's reach in sleep mode to prevent unnecessary power consumption. Also the number of devices connected to the internet will rise exponentially which sets huge requirements for the number of individual addresses. (Azori et al 2010).

IoT and the rapidly growing number of sensors may cause a lot of different kinds of problems, but there are two main categories: problems related to data amount exploding and information security questions. When it is possible to measure and virtualize everything in the physical world, there are many hard questions to answer. For example; who is authorized to access all that data gathered and who has the ability to process it into something productive?

3.5.2 Information security

Usually the most thought-provoking subject in information security as to the Internet of Things is privacy. Privacy is an important part of it but it does not cover all of the problems of the Internet of Things. In fact, information security faces a lot of new challenges in the world where all objects are connected to the internet. When security breaches move from overloaded websites to everyday objects like cars, we have a totally new scenario to handle. What information security issues does IoT contain and how is security handled nowadays?

Information security challenges can be divided into four different categories that are resilience to attacks, data authentication, access control, and client privacy as listed and described briefly in table 10 below. These topics are not new in information security, but the scope of IoT's volume brings challenges that have not been faced before. (Weber 2010; Fabian & Günther 2007)

Table 10: Information security challenges categorized (Weber 2010; Fabian & Günther 2007)

Information security challenges	Brief description
Resilience to attacks	Capability to maintain service level under security attack
Data authentication	Verifying data validity
Access control	Only people who are allowed to use data have access to it
Client privacy	Who has access to the data that the client has gathered?

Resilience to attacks means the ability to continue action under malicious attack. This subject is known nowadays especially in website service providing companies who want to achieve full operability under DDOS attacks. (Goh et al. 2002). In IoT, resilience to attacks basically means the ability to continue working on a wanted task even if some of the working systems are unavailable for some reason. (Fabian & Günther 2007) For example, a logistics company has to be prepared for a situation where an important part of the food-chain supply, for example a truck, is not working for some reason. The truck could be replaced with another one and food stored properly until the error has been fixed.

Data authentication is a function that recognizes the data's validity. Data is valid in context of data transfers when it is not corrupted during transfer and it is received from the sender it says it is. (Laur & Nyberg 2006) In IoT, data authentication is for example securing that sensor data is correct and really received from the wanted sensor. (Fabian & Günther 2007) This way it is possible to recognize a damaged sensor or information connection and protect oneself from malicious crackers. The problem is that more secure systems are needed, and additional verification data needs to be added to the actual wanted data (Laur & Nyberg 2006). Additional data means more problems with data volume.

Access control rises to a new level of importance when following up companies' physical objects and sending that data over the Internet. When gathering sensitive business information there is a high risk that someone is intercepting and reveals vital business information to the company's competitors. (Weber 2010) Access control is all about controlling data sharing between users and ensuring that only those who have permission to access data can access it. For example, it is possible to protect data transferring by using a technique called "VPN" (Virtual Private Network). VPN can be used to make a point to point connection on several devices and encrypt the information moving between them. By using VPN it is possible to make intercepting connections useless because all moving data is strongly encrypted. (Tipton & Krause 2012)

Client privacy can be divided into two different versions based on the security level. In the more secure version only the information provider has access to the gathered data. The second, and a lot weaker, version is one in which it is very hard for a casual attacker to gain access to the gathered information. (Fabian & Günther 2007) This division is a good reminder that if the gathered data is shared there is always a possibility to breach the security if someone has enough resources and is willing to do that. According to Weber (2010), privacy questions also concern questions about data ownership. He reminds that contracts will have a high importance in the future when agreeing on who can use the data and how. And if a service provider changes, can the old service provider prevent the client's access to the data gathered earlier? (Weber 2010)

As mentioned before, IoT is a new trend and when first mass-produced implementations are done, device producers are in hurry. Many companies are competing against each other on who will be the first well-known producer in a certain technology area. Products made in a hurry usually have some problems especially when the company doesn't have earlier experience in the product family. Is information security handled well or is it forgotten? What really is IoT's situation nowadays?

There have been a few big studies concerning IoT's information security in 2014. For example, HP released a study during the summer of 2014 and Eurecom, a French research centre, released an analysis about embedded firmware security in August 2014 (HP 2014, Costin et al 2014). Both studies announced that IoT's information security level is poor.

HP's study (2014) found out that 80 percent of devices raised privacy concerns. For example, 80 percent of devices had insufficient password policies, 70 percent of devices used unencrypted communications to the Internet and 60 percent of devices did not use encryption on software update downloading (HP 2014). Eurecom (2014) found several open software backdoors and poor SSL key-management. These errors allow attackers to retrieve personal data from infected devices or even hijack them. (Eurecom 2014)

3.5.3 Policies & Technology limitations

One of the key issues in creating one big global IoT are policy and technology limitations. Weber (2010) states that IoT raises many of political and ethical questions. For example, who has a permission to collect data and how can it be used? Where goes the line between providing new services and an individuals' personal privacy? Who is the right authority to state this and lead the IoT development? (Weber 2010) If policy questions are too easy, technology sets its own limits, too. At the moment there are so many different kinds of devices, technologies and services that there is no way to connect all these together without global co-operation. (Zorzi et al 2010) Different technologies have different supporters and developers, and it's obvious that everyone wants to use their own.

Zorzi et al (2010) claim that today it is impossible to create a real IoT because of the lack of standards. We have several different connecting technologies and different kind of devices. This causes an unorganized environment and integration problems so big that it is impossible to develop a truly global device network. Zorzi et al (2010) think that when networks are not truly global, the word "Internet of Things" is not really describing the real situation. They prefer the term "Intranet of things". Figure 11 demonstrates the Intranet of Things, the real situation of IoT nowadays. (Zorzi et al 2010)

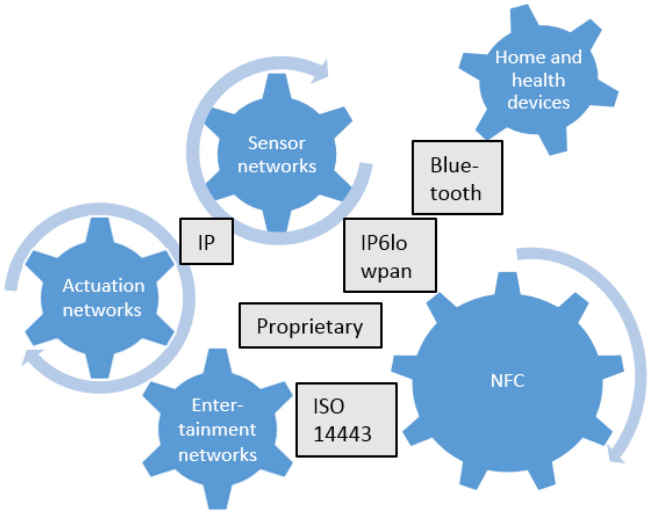

Figure 11: INTRAnet of things (Adapted from Zorzi et al 2010)

Without any connection between different intranets we are talking about a different concept than the Internet of Thing. IoT means, in the extreme case, that everything can communicate with everything in real time. This requirement is hard to fulfil when there are so many different technologies in the world as there are, until some kind of standards have been agreed upon.

4. BUSINESS INTELLIGENCE WITH THE INTERNET OF THINGS

This chapter describes how the Internet of Things will affect Business Intelligence. It clarifies what kind of synergy benefits and challenges combining these two different concepts may offer. Results are presented in a matrix form and explained in the text.

As summarized in figure 6 earlier, BI's main benefit is giving a better business insight to the organization using it. Insight gets better with improved data quality, accumulated knowledge, increased knowledge sharing and better data utilization. IoT's main benefits are in the real world effects, more agile communication and on data-analytics. Table 11 categorizes what kind of effects IoT's benefits have on BI's benefits.

Table 11: IoT's benefits positive/negative effects on BI's benefits

IoT benefits / BI benefits	Real world effects	More agile communication	Data-analytics
Improved data quality	+		+
Accumulated knowledge		+	+
Better data utilization	+	+	+
Increased knowledge sharing		+	

Data-analytics is the most important benefit of IoT from the point of view of BI. The most important benefit of IoT is its ability to offer a huge amount of real-time data with accurate quality for BI's use. More real-time data available means the possibility of finding results that could not have been found earlier. IoT's M2M connections reduce human participation in the BI-process. Things are better at handling huge masses of information than humans are, thanks to their immense calculation power. When things take the role of the knowledge miner, the knowledge's end user organization's ability to utilize information rises since its employees can concentrate on operations that are more reasonable to automate and things can work on larger information sets from past to present.

IoT's real-world effects make the data concrete since more and more things in the physical world will operate based on that data. IoT's actors make data easier to understand by humans and generate interest in data quality. When IoT and BI are combined, poor data quality can lead to physical security risks that need to be handled. IoT's real-world effects also help in data utilization. When data becomes a concrete thing, it offers a new perspective to it. With new perspective, an organization's employees can find new possibilities to use the gathered data in other situations.

IoT's benefit of more agile communication supports BI's benefits of better data utilization, accumulated knowledge and increased knowledge sharing. When everything is connected to the Internet the ability to retrieve historical and present data and share information rises dramatically. With IoT, things can query data from other things in order to gather information needed for decision-making and after that, proactively notify other things about the findings.

Benefits are not the only thing that BI and IoT have in common. IoT's challenges are the rapidly growing amount of data, new "Thing"-information location dimension, information security and policy and technology limitations. BI's challenges are cultural challenges, personal challenges, the growing amount of data and data quality issues, risen requirements, widening user base and information security questions. BI's and IoT's challenge-relations are summarized below in table 12.

Table 12: IoT's challenges positive/negative effects on BI's challenges

IoT challenges / BI challenges	Data amount growing	New information dimension	Information security	Policies & Technology limitations
Cultural challenges				+/-
Personal challenges	-	-	-	
Data amount & quality	-	-		
Risen requirements			-	
Widening user base				
Information security	-	-	-	+/-

IoT's challenge of rapidly growing amount of data causes even more work for BI's personal challenges, data amount challenges and information security challenges. In the era of IoT, individuals have to handle larger and larger datasets to find the wanted information. Handling larger datasets efficiently requires new tools and skills from knowledge miners and information end users. The data amount growing also challenges information security: when even more things are gathering information it is hard to predict what knowledge attackers can extract out of the gathered data when a security breach occurs. For example, it is hard to secure individual freedom rights when everything gathers data about everything.

New Information dimension “Thing” makes datasets more complex than ever before. The need for the amount of gathered metadata rises when time and place is not enough anymore since one object can gather information from hundreds or even thousands of different sensors. This grows the amount and the complexity of gathered data. Larger volume and complexity leads to new personal challenges and can risk information security.

IoT’s information security threats raise the requirements and personal challenges. Since BI already has problems with the rising requirements, it does not help at all that IoT brings so much analyzable data with real-world effects. When BI’s end users figure out what IoT offers for reporting, there will be a huge amount of new requirements about the data’s freshness and the sources. When answering to these new requirements it is not easy to maintain the wanted information security level. New possibilities often lead to new requirements and information security threats.

Policy and technology limitations’ effects on BI’s cultural challenges and information security depend a lot on how things turn out. Especially BI’s other social challenges, like resistance to change and ethical questions, are a big question. If a company has a good attitude and is successful in implementing IoT’s possibilities, IoT can help BI and organizations’ knowledge mining practices. But if an organization’s employees get scared for their individual freedom rights and feel that IoT is going to replace them, things will not go as smoothly. It depends on whether the chosen IoT policies will support or aggravate BI’s information security problems. The data that IoT gathers can be used to keep track of information security in order to improve it but it can also be misused.

IoT’s benefits also have a relation with BI’s challenges, and table 13 below lists those. Some of the correlations are positive, some negative, but even more of the relations depend on how things turn out when IoT becomes a more daily thing.

Table 13: IoT's benefits positive/negative effects on BI's challenges

IoT benefits / BI challenges	Real world effects	More agile communication	Data-analytics
Cultural challenges	+		
Personal challenges		+/-	-
Data amount & quality	+/-	-	
Risen requirements	-		-
Widening user base	-		
Information security	+/-	+/-	+/-

The real-world effects have a positive effect on cultural challenges, negative effect on BI's risen requirements and widening user base and either positive or negative effect on the amount and quality of data and on information security. When IoT's real-world effects perform real action and things starts to function based on data and analysis, humans starts to understand the results of data quality. When data quality has an effect on everyone's daily work, it encourages people to help themselves by helping things and improving data quality. The real-world effects may also help people to understand information security's purpose in both good and bad. The real-world effects helps people to understand how important information security is, but it also helps people to find new security defects. For example, when automated cars handle logistics automatically, it does matter whether your mail reaches you or goes to the neighbors.

More agile communication helps information transferring, which can be a confidentiality problem but will also improve availability. BI's challenge of data amount and poor data quality is at a risk to get worse because more agile communication decentralizes data to several different communication channels which may lead to severe data fragmentation. From the point of view of an individual professional, more agile communication is an ambivalent feature. More agile communication can mean better availability of information, but when combined to an excessive amount of data, it might lead to an overflowing amount of information for an individual person. Huge data masses require a new level of professionalism to analyze and find meaningful information efficiently.

IoT offers lots of new opportunities for data analytics. When everything is connected to the Internet, there are lots of new reporting possibilities. New possibilities often lead to requirements as different stakeholders want to get out all the potential of new opportunities. Using new features requires learning which raises personal challenges.

Table 14 lists the kind of effect IoT's challenges have on BI's benefits. Just like in table 13, that listed IoT's benefits' effects on BI's challenges, IoT's challenges have both positive and negative effects on BI's traditional benefits. New information dimension is the highest risk for BI. Growing amount of data, information security and policy and technology limitations depend on how things turns out.

Table 14: IoT's challenges effect on BI's benefits

IoT challenges / BI benefits	Data amount growing	New information dimension	Information security	Policies & Technology limitations
Improved data quality		-		
Accumulated knowledge				
Better data utilization	+/-	-		
Increased knowledge sharing			+/-	+/-

The growing amount of data can be an improvement towards better data utilization. IoT connects to the Internet things the state of which has been a mystery earlier. New data can be combined with old data to find new utilizing possibilities. If knowledge miners cannot find a way to use the collected data, the data amount growing leads to worse data utilization level.

New information dimension and growing amount of information connections lead to data decentralizing and possible fragmentation. When data is not centralized, it may lose its context and the important connection to other related data. This lowers data quality and compromises the good data utilization level. Fragmented or incorrect data should not be used in data analysis.

Information security and policy and technology limitations challenges may enforce knowledge sharing or hinder it. Possible restrictions made on policies and the information security sector may regulate what information can be shared and what information is too delicate to share. If data availability is highlighted even more than before, knowledge sharing will play an even more significant role than before.

5. FUTURE VISIONS OF BI & IOT

To make IoT efficient at reaching its goals, it needs intelligence. Intelligence is the result of the best possible decisions based on analysis. Analysis is based on the gathered information and knowledge gathered earlier. With BI, individual IoT devices can gather the found knowledge into reports about their surroundings and share it in a common network with other devices. By using analyzed knowledge, devices can act wiser even when they do not have access to the original data source or have enough calculation power to produce the same information.

Data is fuel for BI, and IoT gathers lots of data and engines capable of processing it. By combining real-time data gathering and things capable of crunching it to meaningful information with smart devices, productivity will rise dramatically. IoT offers vital data for BI, and BI makes IoT intelligent. With BI, IoT can achieve a state where things can work independently without human interception. BI and IoT will develop together in symbiosis.

5.1 BI-process renewed

In the future, when IoT becomes a daily thing, the BI's main task and the whole process will change. Humans are not the only decision-makers and authorities anymore. Smart device networks have taken on the simpler tasks to handle automatically. IoT changes the physical world as much as IT has changed information management. Productivity will rise dramatically when things can work together based on gathered and combined information without pending decisions from humans.

To reach a common goal, things needs information to act upon. With M2M and smart analysis services, things can work as knowledge miners by themselves and pass analysis results on to other things needing that information. This development means a radical change to the original BI-flow presented in figure 4. When things produce and use information, they have actually became knowledge miners and end users. BI and reporting is not only for humans anymore. Figure 12 shows how the traditional BI-process has renewed, when IoT is an active part of the daily world. Things will be a part of every role in BI-processes: data sources, knowledge miners and end users.

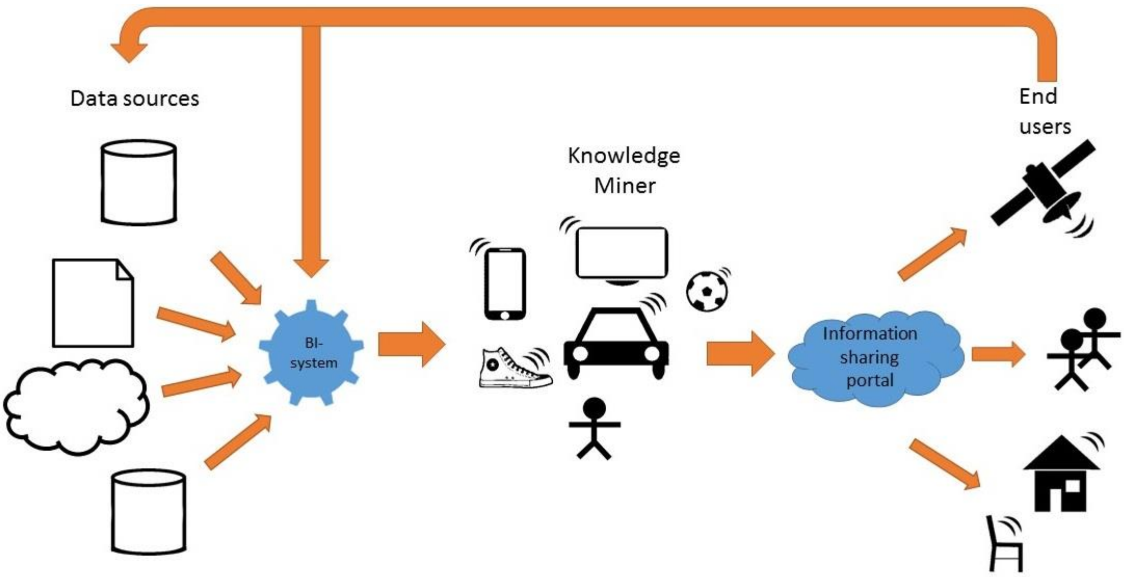

Figure 12: Renewed BI-process

The renewed BI-process also affects BI's main task that was stated earlier: "The main purpose of BI is to bring the right information to the right people at the right time and in the right place". The new main task of BI is to bring the right information to the right ***thing*** at the right time and in the right place.

5.2 Case example – Smart home

IoT and BI have many possible applications in every home. This case example shows how IoT and BI could help a person who often sleeps in and has trouble waking up early in the mornings. This system only needs a weight sensor attached to a bed, a remote-controlled wall plug that controls the coffee machine, a Bluetooth speaker, a water flow sensor and a smart phone. All the items are in figure 13 below. From the IoT point of view, in this case the bed and the sink acts as sensors, the speaker works as an actor, the smart phone acts as a smart item and the coffee machine works as an actor. From BI's point of view the bed and sink work as data sources, the mobile phone works as a knowledge miner and knowledge end user and the coffee machine and the speaker work as an end users.

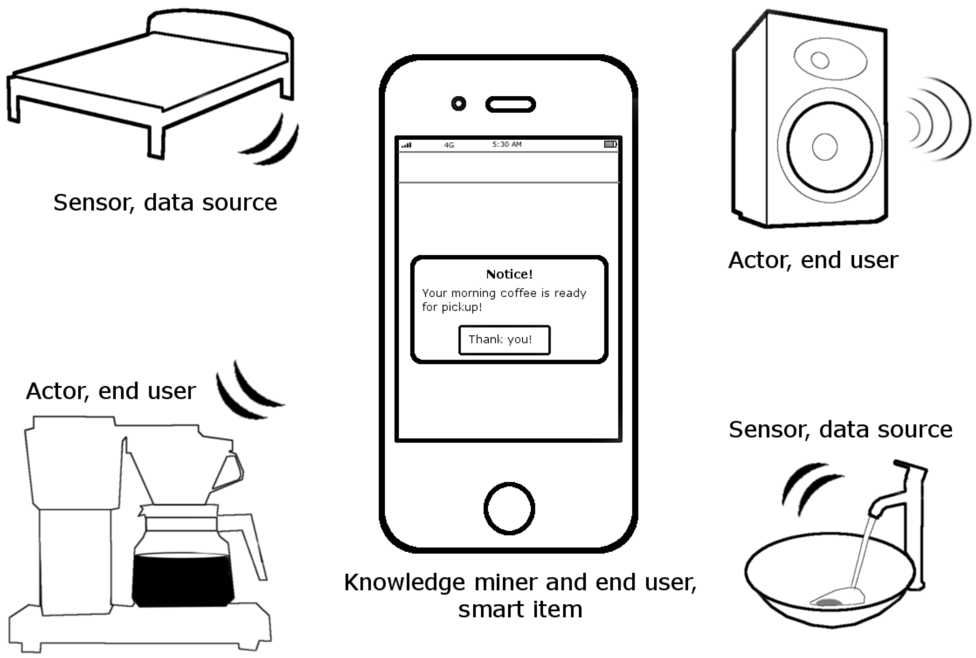

Figure 13: Needed devices for the smart home case

Alarm clock rings at 5 AM, and its sleepy owner hits the snooze button. The mobile phone starts to count down from five minutes before ringing again and starts to play music that its user has predefined. After five more minutes, when the alarm rings again, the user hits the dismiss button but does not wake up. Five minutes later, the mobile phone notices that the user has not got up because the bed's weight sensor informs it that the user is still lying in bed. The mobile phone starts to ring, raises the Bluetooth speaker's volume to the max and does not stop before the user really gets up from bed.

The water flow sensor in the sink tells that the user has gone to the bathroom to brush his or her teeth and to dress up for the day. The mobile phone has analyzed that the user leaves bathroom usually in five minutes after using the sink for the last time. After five minutes have passed, the mobile phone starts the coffee machine, and after it is ready, it notifies its late user that coffee is ready for pickup before he or she runs off to work late.

5.3 Case example – Midsized electronics shop

In the second case we will examine a mid-sized electronic shop using an advanced BI and IoT system. The parts of the system environment are in figure 14. In this case example, a customer has entered the electronic shop with a smart phone that has the shop's app installed. The customer wants to upgrade the TV of his existing home cinema. From the point of view of IoT in this case example, the customer's existing speakers, mini-fridge, HDMI-cable and TV work as an identification unit, the RFID-reader works as a sensor, his smart phone and BI-system act as a smart item, the salesman works as an actor and the forklifts work as independent systems that have smart items, actors and sensors within them. In the BI-process, all the items except the salesman and the BI-system are data sources. The BI-system and the smart phone work as individual knowledge miners. Since the salesman and the forklifts use gathered knowledge, they are the system's end users.

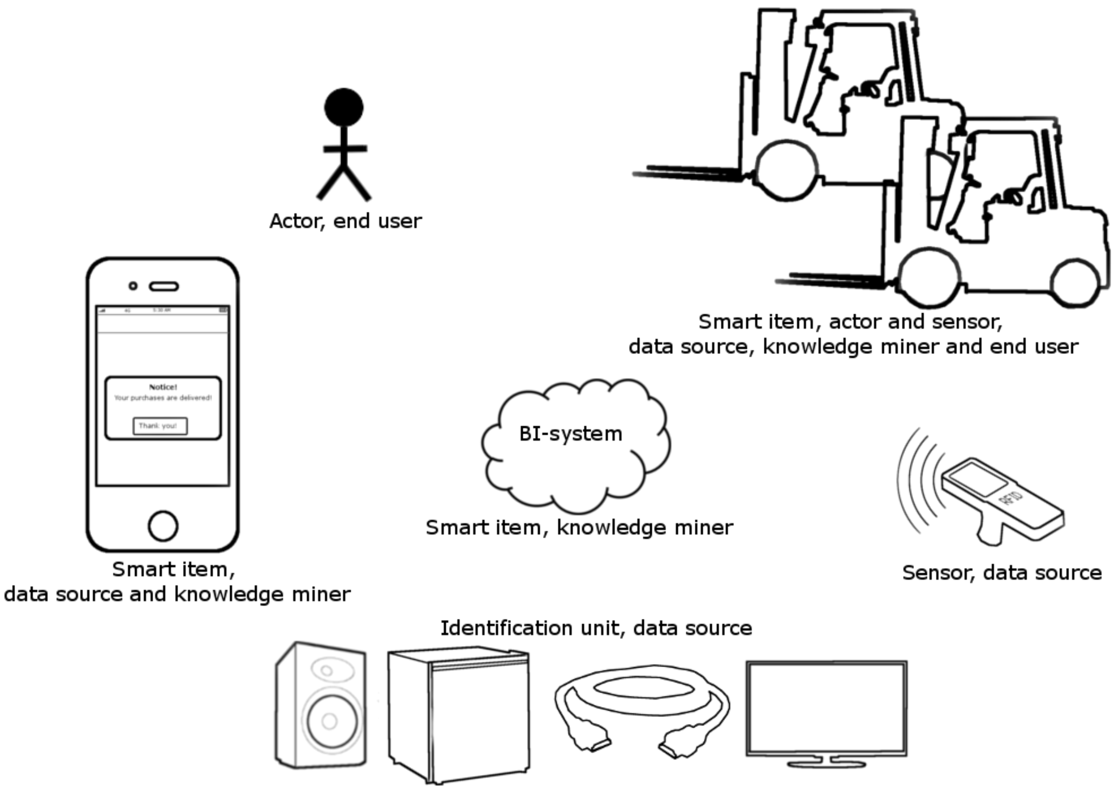

Figure 14: Electronic shop's IoT environment for BI-system

For example, when the customer enters the shop, his mobile phone's app informs the shop's BI-system that he wants to upgrade the TV in his existing home theatre. The customer's app tells the BI-system that he already has nice speakers in his home so the customer should upgrade only his TV and the wirings related to it.

The software finds a TV and a HDMI-cable that can be integrated into the customer's existing home theatre and reminds that usually, if people have bought home theatres they have also bought a mini-fridge to keep their movie-lemonades close and cold, and they happen to have all the recommended items in the shop. After the client has accepted the recommendations, the magic happens.

By using RFID-tags and RFID-readers, the BI-software can recognize how many items the shop has and where they are located. In this case, the BI-system notices that the shop's last HDMI-cable is not where it should be at the cable shelf, it is actually next to the mobile phone shelves.

The software on the customer's mobile device makes an assumption based on the customer's purchase history that the customer likes to have personal service and does not want to carry heavy objects. The BI-system can alert the shop assistant to serve the customer and offer that the heavy TV, mini-fridge and home theatre system can be brought automatically wherever the client wants them.

After accepting the automated heavy item transfer to the shop's parking lot, two automated forklifts start to gather the ordered electronics in co-operation to get the products ready for the delivery. After the cash register notices that the customer has paid his new purchases and the mobile app notices that the client has left the shop the BI-system gives an order to the forklift to deliver the products for the client.

6. SUMMARY

This research is a literature review that studies how the Internet of Things will affect Business Intelligence. It first examines the two concepts, IoT and BI, individually and after that, tries to find common challenges and benefits between them. Based on the findings it forms future visions for BI and IoT with two different case examples.

Business Intelligence is a process that gathers data and refines it to information for the right people at the right time and in the right place. BI gives a better insight to the organization which can be used in decision-making processes. BI does not produce any value in itself; its value is based on the decisions made with the information gathered. BI’s intangible nature and ever-rising requirements are the most remarkable challenges now.

Internet of Things is a concept where everything is connected to the Internet. IoT makes things less dependent on humans and can make things work together to reach a common goal. IoT’s benefits are the real-world effects, more agile communication and the new huge possibilities it offers for data analytics. IoT’s challenges are mostly related to the growing amount of data, information security and policy and technology limitations.

IoT offers many new opportunities for BI’s data analytics but it also makes it much more complicated. Table 15 below summarizes the results of this research. It lists BI’s benefits and challenges and how many of IoT’s features either support it or aggravate it. The values presented are calculated from the matrixes in chapter 4, so that each benefit and challenge is worth 1 point. The “±”-sign represents a situation where the results depend on how things will turn out when IoT becomes a daily thing. If a benefit or a challenge has gained over 2 points, it is considered as a meaningful effect. If a BI feature gets a ± 2 or more it can be a risk or a possibility. The positive meaningful features are highlighted with green color, the risks with red color ,and unclear features are marked with yellow color.

Table 15: Summary of how IoT affects BI

	IoT supports	IoT aggravates
BI's benefits		
Improved data quality	+2	-1
Accumulated knowledge	+2	0
Better data utilization	+3 ± 1	-1 ± 1
Increased knowledge sharing	+1 ± 2	± 2
BI's challenges		
Cultural challenges	+1 ± 1	±1
Personal challenges	± 1	-4 ± 1
Data amount & quality	± 1	-3 ± 1
Risen requirements	0	-3
Widening user base	0	-1
Information security	± 4	-3 ± 4

As table 15 presents, IoT supports three of BI's benefits, aggravates three challenges and is a risk or possibility for one of BI's benefits and one of BI's challenges. Based on these research results, IoT will improve data quality, help organizations to accumulate knowledge and improve data utilization. On the other hand, IoT will aggravate BI's personal challenges, raise the amount of data and risk its quality and raise the requirements that are set for BI. It is not clear how IoT's features support or aggravate BI's benefit of increased knowledge sharing or BI's challenge of information security concerns.

Based on these results, IoT will probably reform the whole BI-process. In the future, more often things will be knowledge miners and end users of the analyzed information. BI will not be just for humans anymore, because in order to act IoT's things need the knowledge that BI produces.

6.1 Limitations

Every research has its limitations and this research does not make an exception to that rule. The largest limitation of this research is the research method, a literature review. Missing empiricism and concept research at the simplified theory level based on other researches is a major perspective narrower. Fast developing technologies also offer a big challenge for the research.

Since this research is a literature review, it can be only as good as its references . Without any empiricism, this research does not have any touch with the real world or the possible results that empiric research could have offered. A literature review cannot offer anything that has not been seen before, it just combines existing knowledge into something new.

It is difficult to try to understand fast developing concepts like both IoT and BI by doing a literature review. Since the technologies develop so fast, used references might get outdated even during the research process. Fast development also causes that this research will also be outdated as early as just a few years after releasing it.

6.2 Suggestions for further research

To keep this research's findings up to date, new researches are needed. By researching IoT and BI from different perspectives and with different research methods, the gathered information base widens and the knowledge about both concepts deepens. With the new information it is easier to understand how these concepts will affect each other in the future on a more specific level.

This research should be continued by making an empiric research about IoT and BI. By constructing a real BI solution based on IoT technologies it could be possible to widen the research perspective and find new possibilities and challenges that are faced in the real world. It could also provide a new point of view by turning the research question around: "How will BI affect IoT?" or "How BI and IoT will affect each other?". Since the concepts are so closely related to each other at the moment, changing the research question could offer totally new findings that this research could not find.

It is also vital to keep concept understanding up to date since IoT and BI are fast developing trends at the moment. If a researcher does not keep his or her information actively up to date there is a high risk that the gathered knowledge expires and is not valid anymore. New innovations in the markets can be huge game changers when the technology is young.

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