CHALMERS
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The Future of Big Data Analysis in Facility Management

- A Study of Implementation areas

Master's thesis in the Master's Program Design and Construction Project Management

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CHALMERS UNIVERSITY OF TECHNOLOGY
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Cover: The power of IoT and BDA by Malcolm Granberg & Daniel He ©
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ABSTRACT

The Facility Management (FM) sector is known to be conservative and have for a long time been struggling with digitalizing their operations. Meanwhile, other sectors have seen it necessary to digitalize and implement different technologies such as Internet of Things (IoT) and Big Data Analysis (BDA) to support streamlining, growth and innovation that are required to stay competitive. BDA is an emerging technology that enables analysis of great volumes, varieties and velocity of data that an ordinary human could not manage within a feasible timeframe. The FM sector have for some time been utilizing sensors to monitor different aspects in a facility, but the data have rarely been used for any evaluation or real time analysis. However, the sector has not adopted these new technologies at the same pace as other sectors. Therefore, the purpose of this thesis was to investigate how BDA can be implemented in FM and what challenges it is facing. This was achieved by conducting interviews with companies in Sweden that are either developing areas of implementation or are working with project related to BDA in FM and was then compared with existing literature. Despite discovering contrasting opinions, the thesis has found several implementation areas where BDA could improve the FM sector, the four major areas are: 1) Energy optimization, 2) Better indoor climate, 3) Space optimization and 4) More efficient maintenance. These areas are possible to implement if the development solves several challenges of which the five major ones have been identified as: 1) Hard to calculate returns, 2) Lack of competence, 3) Lack of standards, 4) Maintaining the digital twin, and 5) Ethical and regulatory questions.

Keywords: Internet of Things (IoT), Big Data Analysis (BDA), Facilities Management (FM), Information, Data, Artificial Intelligence (AI), Machine Learning, industry 4.0, Implementation, Energy optimization, Space management, Indoor climate, Effective maintenance

Framtiden för Big Data Analysis i Fastighetsförvaltning
En Studie om användningsområdet

Examensarbete inom mastersprogrammet Organisering och Lednings i Bygg- Fastighetsbranschen

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SAMMANFATTNING

Fastighetsförvaltningssektorn är välkänd för att vara konservativ och har länge brottats med att digitalisera sin verksamhet. Samtidigt har andra sektorer sett det som nödvändigt att digitalisera med nya tekniker som Sakernas Internet (Internet of Things, IoT) och Big Data Analysis (BDA) till stöd för effektivisering, tillväxt och innovation vilket krävs för att vara konkurrenskraftig. BDA är en framväxande teknik som möjliggör analys av stora volymer, variation och flöde (velocity) av data som en människa inte är kapabel att hantera inom en rimlig tidsram. Fastighetsförvaltningssektorn har under en tid använt sensorer för att övervaka olika parametrar i byggnader men datan har sällan använts till någon utvärdering eller realtids-analys. Emellertid har sektorn inte adapterat dessa nya tekniker i samma takt som andra sektorer. Följaktligen är syftet med detta examensarbete att undersöka hur BDA kan användas i Fastighetsförvaltningen och vilka utmaningar som behöver lösas för att lyckas med implementeringen. För att uppnå detta har intervjuer genomförts med svenska företag som utvecklar användningsområdet för BDA eller arbetar i projekt relaterade till BDA i fastighetsförvaltningen, den insamlade datan har sedan jämförts med tidigare publicerad litteratur. Trots varierande åsikter har detta examensarbete identifierat fyra huvudsakliga användningsområden som är: 1) Energioptimering, 2) Bättre inomhusklimat, 3) Ytoptimering och 4) Mer effektivt underhåll. För att kunna genomföra en implementering av dess användningsområden finns det flera utmaningar som behöver lösas, fem av dessa är: 1) Svårt att beräkna avkastning, 2) Kompetensbrist, 3) Brist på standarder, 4) Uppdatera den digitala tvillingen, 5) Etiska och Juridiska frågor.

Nyckelord: Sakernas internet (IoT), Big Data Analysis (BDA), Fastighetsförvaltning, Information, Data, Artificiell Intelligens (AI), Maskininlärning, Industri 4.0, Implementering, Energioptimering, Ytoptimering, Inomhusklimat, Effektivt underhåll

Content

Notations

AEC – Architecture, Engineering and Construction

AI – Artificial Intelligence

AR - Augmented Reality

BDA – Big Data Analysis

BIM - Building Information Modelling

FIM - Facility Information Modelling

FM – Facility Management

HVAC – Heat, Ventilation and Air Conditioning

IaaS – Infrastructure as a Service

ICT – Information and Communications Technology

IFC – Industry Foundation Class

IoT – Internet of Things

KPI – Key Performance Indicator

LOD – Level of Detail

LOI – Level of Information

PaaS – Platform as a Service

PII - Personally Identifiable Information

SaaS – Software as a Service

VR - Virtual Reality

Figure List

Preface

This thesis would not have been written without the aid from several people. We would like to thank some of them for allowing us the time and for not becoming too tired of us.

- Mattias Roupé, our supervisor at Chalmers
- Daniel Månsson, our supervisor at Zynka BIM
- Leo and Yashar
- Our interviewees

And not least thank each other for spending half a year with the thesis.

Thank you all!

Malcolm Granberg

Daniel He

1 INTRODUCTION

"An odd pattern reoccurs with new technologies that creep into our lives: We forget we ever managed without them. Think about life before Google, or before that smartphone found a permanent place in your pocket, or you welcomed a digital assistant into your house. We adopt, adapt, then forget—and that's a good thing. If escalators, cars or even computers still seemed endlessly surprising and amazing, we'd never make it through the day."

- IBM Wired Brand Lab (2017a)

This quote from IBM gives an interesting picture of how technology changes the way we live and think. New technology will sooner or later impact all industries where people involved. The same things are occurring today in our homes and workplaces where digital tools slowly creep in and creates new opportunities such as autonomous customization of indoor climate according to your preferences or find out exactly how much time is wasted on cueing for toilets. To perfect the indoor climate, the computer that autonomously controls the building will combine and process data from your preferences with that from the room, other rooms, outside of the building, prognosis of the coming weather and several other sources to decide if any adjustments are needed to make sure the temperature and other attributes are kept where you thrive. The aggregation of data, calculations and decisions needed for this will take less time than it would take for you to decide whether you would want to make any changes yourself.

1.1 Background

Every single person in our society are in some way affected by buildings and how they are being controlled, who has not spent a day when it is too cold, or too warm, or insufficient air circulation or something else. Sensors have for some time been measuring attributes in buildings, mainly temperature, but these measurements have rarely been used for anything more than sending commands to increase the heating or cooling the room. New opportunities are emerging with the introduction of Internet of Things (IoT) which allow Big Data Analysis (BDA) to receive more information than before by working as an infrastructure gathering and transporting data. It is impossible for a human to keep up with the movements of people in a building and always optimize every room according to its needs. But with the help of BDA that can gather a larger amounts and vaster variety of data in extreme speed allows us to analyze the flow of people and adopt the HVAC-systems in real time and gain new insights. According to Manyika et al. (2011) BDA is a key basis of competition underpinning new waves of productivity growth, innovation, and consumer surplus and is essential for every market to stay competitive. There are several different applications where data gathering, or increased data gathering, combined with BDA can improve facilities, people will perform better in well suited indoor environment, lower energy costs, optimize space by measuring the use and more.

1.2 Purpose

The purpose of this thesis is to investigate how BDA can be implemented to support the control of facilities and which challenges that exist today by interviewing companies in Sweden that are working with implementing BDA into their business. The goal is to get a picture of the Swedish facility management sector views towards BDA and what the trend is leaning towards implementation areas. The study will focus on how BDA can be utilized to analyze data from sensors in facilities to improve the use or operations. The thesis will by utilizing a qualitative and abductive research strategy to gather knowledge from the field currently developing the practices.

The thesis will further collect a bricolage of suitable practices to succeed with data gathering and BDA for facilities to serve as a help for organization getting started in their work.

1.3 Research questions

The thesis will focus on and aims to answer the following two questions:

1. How can Big Data Analysis be implemented in Facility Management?

2. What challenges does the implementation of Big Data Analysis face in Facility management?

1.4 Delimitations

This thesis has studied several emerging technologies, but the study has been shallow and focused on the implementation areas rather than the technology behind. The companies interviewed are all active in Sweden and the focus have been on the Sweden Facility Management sector. By only interviewing people working with or connected to the development and implementation a risk exists of not finding critical views on the technologies, their implementation and impact.

2 METHOD

In this chapter, the methodology on which the work in this thesis are built upon are presented, explained and argued for. This is to strengthen the quality of the work as it allows the reader to understand the process and steps as well as reproduce the thesis with this guideline (Kvale & Brinkmann, 2014). Although reproduction is possible, it is unlikely that a reproduction will yield the same result since the technology studied will have advanced and changed rapidly from the point of the study.

The thesis has used a qualitative and abductive approach with a literature review, interviews with professionals in the field and studies of current technologies available. Methodology literature was studied to find the most suitable course for performing the thesis. Both authors contributed equally to this thesis and took part in a fair and equal division of the work.

2.1 Research approach and design

The thesis has been performed with a qualitative research approach which focus mainly on oral information (Patel & Davidson, 2003) since the focus of the study are sparse and not updated in written literature, or as Bryman & Bell (2011) states that qualitative research focus on words rather than numbers compared to quantitative research. This is because the empirical information predominantly has been gathered from interviews with professionals in the sector. Some critique towards qualitative research have been kept in mind, especially that the research has a risk of becoming subjective due to the researcher's personal views (Bryman & Bell, 2011) and the authors have kept in mind to avoid biases as far as possible. Below in figure 1, a general outline of a qualitative research process by Bryman & Bell (2011).

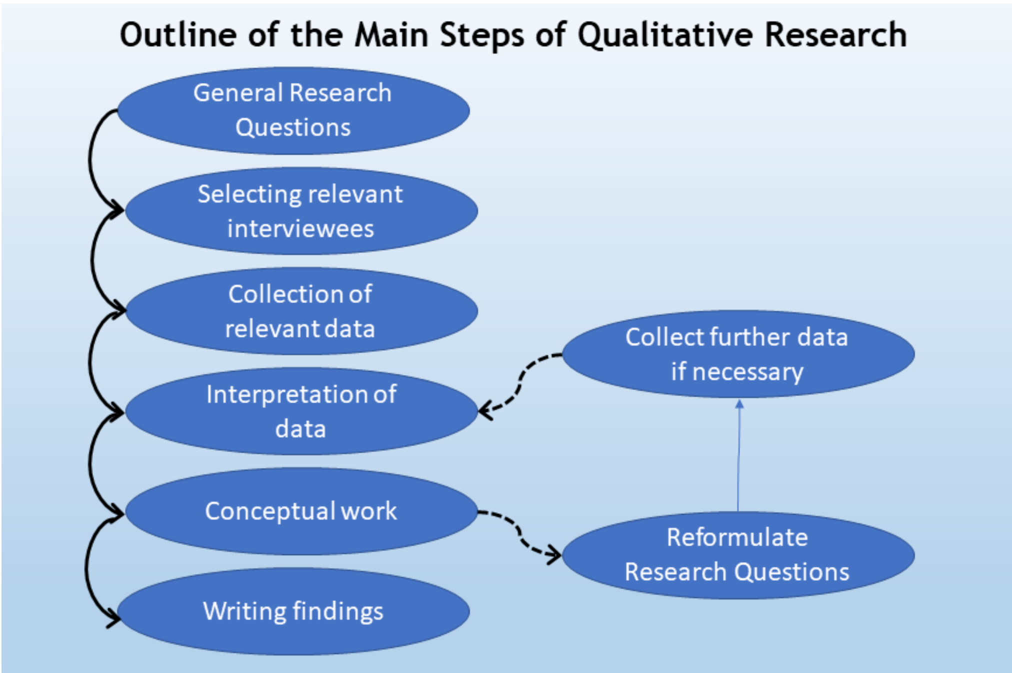

Figure 1 - Outline for Qualitative Research inspired by Bryman & Bell (2011, p.390)

Since the thesis have looked at relatively new technology that is under development, an abductive research strategy was chosen since it allows new theory to be introduced during the process to complement collected empirical data (Dubois & Gadde, 2014); Patel & Davidsson, 2003). Meanwhile Kvale and Brinkmann (2014) see the abductive approach as an iterative process where the theoretical and empirical information can be collected in several steps which suited the authors well since new information were expected to appear throughout the process. According to Dubois and Gadde (2014) quoting their own previous paper

> *"*an abductive approach is fruitful if the researcher's objective is to discover new things […] rather than confirmation of existing theories*"*.
> -Dubois and Gadde (2002, p.559 in Dubois & Gadde, 2014, p.1281)

The thesis will explore new information and combine it with current knowledge in the field to show what exist and present new insights (Patel & Davidsson, 2003).

2.2 Literature study

The aim of the literature study was to identify and map out what is known in the academic world regarding the topic of the thesis, which method the thesis should use and if any previous studies have material that could be used. The focus in the search were on what is already known in the field (Bryman & Bell, 2011). The literature study was performed by using the search engines Chalmers library Summon, Google Scholar and in some instances Google to find material. The material included scientific articles, books, reports as well as webpages and magazine articles covering topics related to the thesis. The literature found were used to refine the thesis aim and research questions as well as support the decision of which actors that was chosen for interview requests (Bryman & Bell, 2011).

During the literature review it has been found that little have yet been published about the implementation of IoT, BDA and AI in the FM sector. The work that are missing in literature is currently taking place and has therefore not been publicized when this thesis was written. This have impacted this thesis since the authors had to interpreted data from sectors such as the IT-sector where much of the technology behind the implementation are based.

Search terms include the following terms in English and the same terms in Swedish were also used: Facility Management, BIM, Internet of Things, IoT, Big data in FM, Big data Analysis, Industry 4.0, etc.

2.3 Interviews

Interviews were chosen as the tool to collect the empirical data for the thesis from professionals working with Big Data Analysis or Internet of Things in the FM field. The choice was made since the thesis was looking for expert's knowledge with experience in the field. The interviews were performed with both Property Owners and Consultancy firms of which one also works as a FM provider.

The interviews were planned and executed as semi-structured, to be able to have an open and flexible conversation with a framework of questions as base (Bryman & Bell, 2011). Kvale and Brinkmann (2014) pushed that the authors should know beforehand what they want to get out from each interview performed, but also to learn from each interview and iteratively change the process forward. Therefore, after each interview the authors reflected on what the gain had been and if some questions should be removed or changed to the next interview.

The interview framework was prepared by performing the literature study to have a basic knowledge of the topic and to formulate questions that would help answer the thesis research questions (Bryman & Bell, 2011). Questions that were negative, assuming, long or double phrased were changed or removed to get a better conversation (Patel & Davidson, 2003) before they were cut down into an appropriate amount to keep the interviews around 60 min long. The length 60 min is according to Gillham & Jamison Gromark (2008) the maximum length wanted since both the interviewer and the interviewee will become tired and lose focus after that time which the authors tried to follow throughout, although not always able to. The questions were before each interview looked over and adapted to each interviewee by substituting different word to the expected knowledge and role. This to get the most out of the interview and try to avoid having to explain words or concept that the interviewee could be unfamiliar with (Patel & Davidson, 2003). The framework used in the interviews can be found in the Appendix.

The thesis sought having a more personal interview and to better be able to read the interviewee by performing them in person rather over skype or phone (Patel & Davidson, 2003). Three of the interviews were performed in person and due to scheduling two were performed by telephone.

At the start of every interview the authors shortly presented the background to their thesis and what the interview were to be about without having the authors go too deep into details or to purposefully steer the interviewee into some specific track other than the thesis (Patel & Davidson, 2003). All interviews were digitally recorded with the consent and knowledge of the interviewee except for one where the interview included a tour in the facility which made it technically difficult to record with good quality. Instead extensive notes were taken by both authors during and after the one interview which was not recorded. The recording allowed the authors to focus on the conversation and implications instead of remembering every detail. During the interviews, the two authors divided the roles into one lead interviewer and one who took extensive notes and asked follow-up questions. Further the authors gave the interviewees large freedom to explain and discuss the issues they saw in the larger questions while staying with the framework and asking follow-up questions to ensure all wanted details were covered (Bryman & Bell, 2011). The interviewee´s were also able to express themselves fully since the authors utilized silence and fully allowed the interviewees to finish their train of thought before interrupting or changing direction of questions (Bryman & Bell, 2011; Kvale & Brinkmann, 2014). During the interviews, the authors made sure to ask for clarification and to ask follow-up questions when needed to be certain they understood the interviewee or when a deeper answer were wanted (Kvale & Brinkmann, 2014).

Shortly after each interview, the authors sat down and wrote down their thoughts of the interview as well as a summary of the most important points from the interview (Bryman & Bell, 2011). It was done to get as much information as possible written down, so it was not solely up to the authors memory. The interviews were performed in Swedish since the authors and interviewees were native Swedish speakers and the authors expected to experience a more relaxed and more productive conversation in Swedish. It was also preferred to use Swedish since there are many technical terms that does not have an exact translation which helped both parties to get a better understanding of the topic.

2.4 Analysis

Each interview was after it was performed summarized by both authors separately with help of memory, notes and in all but one interview the digital recording. The recordings were listened through once while making notes and once when pausing and making detailed notes. The recordings allow the authors to write down the precise and complete answer from the interviewee. The recordings were not completely transcribed but only bite wise pieces needed for the analysis or quotes. Two reasons exist for not completely transcribing the interviews, it is to the reduce the time spent transcribing and to avoid creating a large volume of information which could be overwhelming and could make it harder to perform an extensive and detailed analysis (Bryman & Bell, 2011; Kvale & Brinkmann, 2014). Thereafter the authors together combined their notes and summaries from the interview into one summary per interview which was sent to the interviewee to confirm that they were understood and quoted correctly (Bryman & Bell, 2011). The comments from the interviewees that had any, were small and, in most cases, minor thing without impact on the thesis. Therefore, the interview summaries were translated into English by the authors, although both the Swedish and English summaries were used in the analysis to avoid missing some detail lost in translation. This was done by the authors together while being meticulous to not influence the translation with the authors own opinions or to change the meaning of words chosen by the interviewee´s.

In qualitative research, few widely accepted methods exist to analyze qualitative data, therefore the method used by the authors will be explained (Bryman & Bell, 2011; Patel & Davidson, 2003). According to Kvale & Brinkmann (2014) the method used to analyze the material is called Bricolage, which means that no complete system was used. Instead the method or tool found appropriate were utilized which is popular in qualitative research. The data acquired were categorized in larger topics and not coded further to not simplify the data or risk to fragmentize the data and lose focus of the context and narrative of the interview (Kvale & Brinkmann, 2014; Bryman & Bell, 2011). Thereafter the different interviews were compared to spot similarities and differences before lining up the empirical material next to the theoretical material in the same topic for comparison and discussion amongst the authors.

2.5 Report Writing

The findings from the interviews and literature studies in the thesis were compressed in the thesis report which explains the context and information to the reader (Kvale & Brinkmann, 2014). Bryman and Bell (2011) urge the authors to start writing early in the project and not wait until everything else is done since that allows the writing to be an iterative process. The authors began writing at the same time as the literature study and kept the work up with pauses for interviews, analysis and discussion, although much of the writing could not be finished until after the interviews and analysis due to emerging needs in the theory chapter to match information not expected in the interviews.

During the writing process, the message aimed at the readers have been lifted by the authors to get a report easier to read and understand (Kvale & Brinkmann, 2014). To consider the message helped the authors to maintain a red thread in the story and arguments for the reader to follow through (Kvale & Brinkmann, 2014; Bryman & Bell, 2011). Quotes that have been used have helped paint a picture of the issue or argument and presented with context to give the reader the understanding of where it came from (Kvale & Brinkmann, 2014).

The report has several times been sent to the supervisors for feedback, the feedback has been taken into consideration and mostly implemented after discussion amongst the authors. In addition to the supervisors, peers to the authors have provided feedback on the text, thesis and planning of text and thesis.

2.6 Research Ethics

During the thesis the authors have constantly been clear with everyone met that they are students performing research for their thesis at Chalmers University of Technology in cooperation with Zynka BIM. This was done to allow the respondents to either open up knowing they are contributing to an academic study, while it also could make them hesitant to answer to not make themselves or their organization look bad (Dyer & Wilkins, 1991).

Before the interviews, the authors considered which and how much information that the respondents were to receive from them, the goal is to give them enough to understand what the interview is about and what focus the research has but not to influence them away from their understanding of the topic (Kvale & Brinkmann, 2014). The interviewee was never obliged in any way to answer a question, the interviewee could always choose not to during the interviews (Bryman & Bell, 2011). The respondents were given to opportunity to read and confirm the authors summaries of the interviews to know they were understood correctly and to correct eventual errors (Kvale & Brinkmann, 2014). The identity of the interviewees and companies involved in the thesis were anonymized by replacing them with pseudonyms to make the report and thesis focus on the information rather than specific companies of people, as well as to protect the interviewees from eventual future problems they might not have considered (Bryman & Bell, 2011).

3 THEORY

In this chapter, a theoretical framework related to the area of study will be presented. The goal is to provide the reader with an overview and background of the areas that this thesis will bring up. First there will be an introduction to Facility Management (FM), what it is and the challenges it is facing. It is followed by new technologies that will have an impact on FM such as BIM, Big Data Analysis (BDA) and the whole Industry 4.0.

3.1 Facility Management

The last and longest phase of a buildings lifetime is the Facility Management (FM) phase, which start when the construction is completed. The FM phase is to maintain and develop the function of the building, during which, the building is in a constant process of change both physically and how it is being used (Nordstrand, 2000; Shalabi & Turkan, 2017). FM emerge from the actual practice and were formed as a concept with the combination of Facility Management, Facility Operations, Facility Maintenance and Office Administration (Kincaid, 1994). Further Nordstrand (2000) have distinguished FM into two tracks, the technical and the administrative. The technical track handles the maintenance and practical operations while the administration handles rental management, accounting and procurement of services and products.

The technical track of FM, which is Operations and Maintenance of facilities. Operations are described by Nordstrand (2000) to make sure that the building functions and solves the daily needed from the tenant, such as daily activities like cleaning, waste management and fixing of small issues. Maintenance is on the other hand the efforts to retain the value and function of the building by caring for it. Maintenance can further be broken down into urgent and planned actions, where the urgent are to immediately fix things that are reported broken by unforeseen events which affect the daily operations in the building. The planned maintenance is then measures that are planned in advance, either by a periodic plan or from a condition from something in the building, for example the run time on some equipment.

Facility management requires knowledge about the facility that is to be managed, which means to have information as Atkins & Brooks (2015) state, data holds value. To keep track of the information needed to manage a facility, different FM systems are used, these can control a buildings HVAC-system (Heat, Ventilation and Air Conditioning), handle maintenance information etc. Traditional systems are very good at keeping track of data with high quality and complexity but lacks when they are to communicate with other systems and visualize the data and information (Shalabi & Turkan, 2017).

3.1.1 Facility Management as a service

According to Högberg & Högberg (2000), a service provider can achieve success by creating the most value possible for the customer, a Facility Manager can succeed in this by utilizing the existing utilities properly and by focusing on the customers value creating processes. By understanding the needs for these processes, the facility can be adapted and developed to suit the customer better. Further Atkins & Brooks (2015) state that

> *"Today, facility management is a service sector in its own right and has helped to establish a new professional discipline with its own principles, standards, codes and technical vocabulary"*
> -(Atkins & Brooks, 2015, P.5).

3.1.2 Roles in FM

In the FM sphere there are several different roles that take work within the company, some of them are: The Facility Manager are responsible for the relationship with the customer and the economical result; The Technical (Property) Manager have the short and long term responsibility for the development of the property; The Property Developer are responsible for leading project for new properties and to adapt existing facilities to current or new customers; The Facility Technician are responsible for the building's operation, to make sure it constantly functions and are experts in optimizing and operating their property (Vasakronan.se, 2018).

3.1.3 Productivity in Facilities

It is stated by many authors that the cost to employ people is much higher than it is to rent or own and operate a building (Clements-Croome & Baizhan, 2000; Haynes, 2008), therefore the payback to improve the work environments is higher than the payback to save cost of energy or other facility costs. This is the case since the effect of increasing the productivity of people result in a larger effect on the company's profitability (Clements-Croome and Baizhan, 2000). Every investment in improved indoor environment can almost always be cost effective since the benefits from it will exceed the investment within a few years (Roelofsen, 2002).

According to Haynes (2008) it is hard to measure the improvement in productivity since it does not exist a universal method of measuring productivity, but self-assessed is often used since it offers something instead of nothing. Studies have found that people participating in self-assessment of productivity report an increased productivity of up to 10 % when the indoor climate were improved (Atkins & Brooks, 2015; Roelofsen, 2002). Further they state that it is important to consider that the correlation between productivity and the physical setting is not small just because it is hard to measure it. Since it is easier to measure the work quantity compared to work quality does not mean that a certain action helps the overall productivity for employees since both quality and quantity are needed and expected by companies today. It has also been found that the ability to individually control the indoor climate increases the productivity, mainly the two attributes temperature and air quality. Atkins & Brooks (2015) found in their research six aspects of work environment which are seen to influence the productivity: Indoor air quality; noise control; thermal comfort; privacy; lightning comfort; and spatial comfort.

Indoor environment connects to how humans perceive the surrounding environment, the indoor environment is good when the people residing in it perceive it as neutral (Boverket, 1998). The perceived comfort depends on the human body's difference from the surrounding climate and always strives to be in equilibrium (Munker, 1982). Different aspects that affect how the indoor climate is perceived include:

- Humidity (Penthon, 2016)
- Air velocity (Munker, 1982)
- Noise (Munker, 1982)
- Light (Ljuskultur, 2016)
- Temperature (Munker, 1982)
- Air Pollution (Boverket, 1998)
- CO_2 (Boverket, 1998)

3.2 Building Information Modelling

BIM have been around for a long time in the construction sector but there is still no general agreement of what BIM is. This chapter hopes to provide the reader with a guideline of what this thesis defines BIM and want and the potentials it can provide. The following quote provides a good introduction to this chapter.

“The construction industry is in the midst of a technology renaissance. BIM served as the initial catalyst for this period of innovation, but has now grown beyond “just BIM” to include innovations in many other areas such as mobility, laser scanning, and Big Data analytics among others. Supporting processes are changing as well. The construction industry is realizing that these new technologies don’t fit into previous processes.”

- Hardin & McCool (2015, p.1)

3.2.1 What is BIM

Building information modeling or BIM is a term that is buzzing around in architecture, engineering and construction (AEC) industry for several decades now but still does not have a widely accepted definition. Some of the early definitions

“was structured model that representing building elements”

- Ameziane F. (2000, p.1)

and later new definitions have come up such as

“BIM is a set of digital tools that helps AEC industry to manage projects effectively by improving the planning process, design and others activities in construction”

- Aryani, A. L., et al (2014, p. 628)

There is also more specific definitions such as

“A tool to manage building information over the whole life cycle, it is adequate to support data of maintenance and the construction process”.

- Volk et al., (2014, p.110)

This shows the variance of definitions of BIM, some just referring to BIM as a 3D-model and other who include data that will be used for the entire lifecycle of the building. This have led to a new concept known as Level of Detail or LOD that divides BIM in to different levels. LOD 100 that consists of the conceptual representation of a building while LOD 500 includes accurate information of the building (See figure 2). Another concept that is related to LOD is level of Information (LOI). While LOD mainly focuses on geometrical or geographical data level LOI digs deeper into textual data that LOD cannot visualize such as installation information, maintenance instruction, warranty, etc. These is no standard of how much information should be included, the LOI will differ from project to project and should be adjusted to the client’s demand and needs (Weygant, 2011).

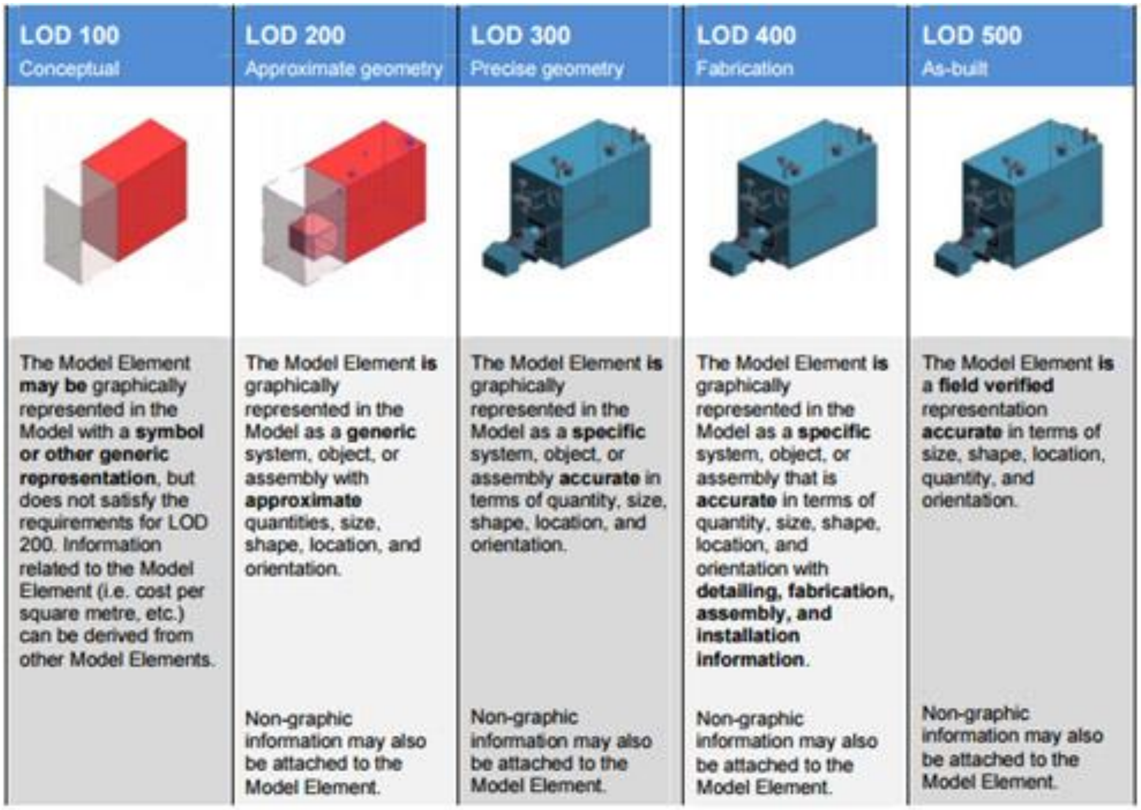

Figure 2 - Level Of Detail from bimandco.com (2018)

The definition this thesis will be using for BIM is the one provided by Volk et al. (2014)

> *"A tool to manage building information over the whole life cycle, it is adequate to support data of maintenance and the construction process"*
> - Volk et al. (2014)

This specific definition was chosen since this thesis will be studying the integration of BIM into FM. So, BIM is more than a 3D-model of a building. According to Eastman et al. (2011) BIM consists of three different components, a model creation tool, definitions of objects and support for team collaboration. The first criterion is a model creation tool, which could range anything from a CAD model to some more advanced CAD systems where the data is more important than the model itself, similar to the LOD model mentioned earlier. The second criterion is that the objects in a BIM model needs to be able to contain information such as hierarchy between different object and connected to another object in the BIM model. For example, if the door size is changed the hole in the wall adapts accordingly. There should also be warnings if an inappropriate change is made for example clashes between of pipes, electrical wires and ventilation ducts. Finally, BIM models needs be able to be interoperable with other data formats (to support integration with other application and workflows) ether by integrating everything into one software or be compatible with other industry standards for example Industry Foundation Classes (IFC).

3.2.2 Potentials and Challenges of BIM

BIM is one of the most promising developments in Architecture, Engineering and Construction (AEC) industry and when implemented correctly can integrate the design, construction and operation phase and increase the quality of the building as well as reducing both cost and time (Eastman, et al., 2011). The list of potential improvements that BIM can bring in comparison to traditional 2D paper drawing is long but some of the major benefits is:

- BIM allows integration between different actors between different phase such as design and FM, providing a deeper understanding (Liu & Issa, 2014; Eastman et al.,2012).
- BIM provides more accurate and updated reports and drawing on demand for example cost estimations in the designs phase, updated drawing during construction and precise location for building components during maintenance (Eastman et al., 2012).
- Improve energy efficiency by linking the model to energy analysis tools allows evaluation and simulation (Habibi, 2016; Eastman et al., 2012).
- More detailed handover of component information and located in a structured way for the receiver to use (Eastman et al., 2012).
- BIM can serve as a framework for real-time data and function as a digital twin of the building to aid pathfinding and optimizing movement paths (Delbrugger, 2017).
- Integrating BIM with operation & managements systems to provide updated information and an ideal platform when implementing real-time control systems (Eastman et al., 2012).

However, there are currently still many challenges with BIM, Eastman et al. (2012) state that there are great gains if implemented correctly, but in cases where it is poorly implemented it will just take extra time and resources as well as cause frustration and confusion for the people involved. Eastman et al. continues to state that BIM is a complex process and that the people involved in the BIM process needs general knowledge about what BIM is. There are still discussions whether BIM is profitable or not since it is mainly only applied in the design phase when the real value lies in the use throughout the lifecycle (Eastman et al. 2012). Many companies see the value of implementing BIM through the whole lifecycle but there are many challenges hindering the progression, such as lack of knowledge and competences between different actors, no clear standards (although, the exist some e.g. CoClasses and BSAB), legal issues regarding documentation and accountability just to name some (Eastman et al., 2012).

3.3 Big Data Analysis

Big Data analysis (BDA) is one of the technologies that is included in the Industry 4.0 which will be covered in the next chapter. BDA on its own does not contribute much without the for example the infrastructure that Internet of Things brings or support to reach its full potential utilize machine learning and Artificial Intelligence (AI). Despite this, with BDA being the main focus of this thesis is it positioned in its own chapter.

3.3.1 What is Big Data

Big Data is a term that have gained a lot of media attention the past decade, but the definition is still argued among different sectors that is working within the area. But the definition that will be used in the thesis is the one provided by Apache Hadoop (Chen et al., 2014) which is the largest open-source computing platform for Big Data,

"Big Data is a dataset which could not be captured, managed, and processed by general computers within an acceptable scope."
- (Chen et al., 2014, p.2)

A common description of Big data is the 3Vs, Volume, Velocity and Variety. The volume referring to the tremendous amount of data generated every day. According to IBM, 2.5 quintillion (10^18) bytes of data are generated per day worldwide which is over 1.7 million Terabytes (TB, 10^12) every minute. This amount is increasing exponentially as more people and devices gets connected to the internet. All this data holds valuable information that companies can use to learn more about their customers behaviors and increase their revenues or as The Economist and Gartner Company put it

"Data are becoming the new raw material of business: Economic input is almost equivalent to capital and labor"
- The Economist (2010)

"Information will be the 21th Century's oil"
- Gartner Company (2011)

Some examples are E-Bay and Amazon who analyze how long their customers takes to make a purchase, how many different products they browse before making the purchase, etc. or Facebook and YouTube that measure how much time you spend on their websites after introducing new features and design. The next criterion, velocity is referring to the speed data is generated or collected. It is not uncommon for data to be generated in nanoseconds, whether it is the geographical location of your mobile device or operation from a production plant in real-time. This is at a speed that humans cannot monitor or evaluate the data in any conventional means. The last criterion is variety which refers to the different types of data that is generated today. Historically there were only a few different types of data such as documents, finances, stock records and personal data. But today there are a vast number of different data types such as photos, audio & video, 3D models, simulation, location data, etc. which makes it a lot more challenging to work with the data (Sendler, 2018).

These 3Vs are all challenges that that needs to be solved because data does not hold any value on its own, it needs to be structured and analyzed to provide any value. Therefore, many speaks of including a fourth V for Value. The gathering of data is easy, websites generates tons of data, applications on your smartphone is another source or just by installing sensors. Many companies often have too much data that they do not know how to use. So, for Big Data to be useful the companies need to specify what Key Performance Indicator (KPI) they want to extract and put in those specifications into the analytics software. The analytics software then extracts the data, transforms the information into desired visualization such as list, graph, pie chart, etc. and then loads it (e.g. of analytics software is Hadoop, spark, YARN or combination of many software's). Thus, the analytics program can filter out unnecessary data and present it in forms of descriptive analytics in forms of dashboards (shows what is happening), predictive analytics that predicts future outcomes based on historical events or prescriptive analytics that helps optimizing the decision (M. Chen et. al., 2014)

3.3.2 Applications of Big Data Analysis

Big Data Analysis have been used in a wide variety of fields where it has been used to find useful patterns that could provide new business insights, predictive analytics based on gathered data to support decision making just to mention some (Bilal, et al., 2016). This is also strengthened by

Manyika et. al. (2011) BDA who states that Big Data Analysis is a key basis of competition underpinning new waves of productivity growth, innovation, and consumer surplus and is essential for every market to stay competitive. They researched 5 major markets which includes healthcare in the United States, the public sector in Europe, retail in the United States, and manufacturing and personal-location data globally and concluded that BDA could improve all these markets drastically. An example if the retail industry would implement BDA to its full potential they could increase its operating margins with up to 60% or if the US healthcare were to use BDA creatively and effectively to drive efficiency and quality, the sector could create more than $300 billion in value every year. Manyika et. al. (2011) continues to map out five ways BDA could bring value. The first being, making information transparent and usable at a higher frequency. Second, organizations can collect more accurate data in any part of their operation from inventories to employee's sick days. This can be used to make better management decisions leading to increased performance. Third, BDA allows organization to get to know customers and provide tailored products and services. Fourth, BDA can improve decision making. Finally, BDA can be used to improve the development of the next generation of products. But it will be a challenge reaching the point of full adoption of BDA. Two of the greatest challenges Manyika et. al. (2011) have identified is a shortage of qualified labor to take advantage of BDA and there are concerns regarding policies related to privacy, security, intellectual property, and even liability. On top of this the organization also needs to create a structured workflow and incentives to optimize the use of BDA. It should also be noted that there is a difference when it comes to gains between different industries.

3.4 Industry 4.0

There are several different emerging technologies that have been entering the market which together often are referred to Industry 4.0, or the fourth industrial revolution (Sendler, 2018). The first revolution being the invention of the steam engine that gave rise to the iron and textile industry in late 19th century. The second revolution occurs just before the world war II which was mass production that shifted the way people live and formed the consumer society we live in today. The increase in productivity and reduction in cost now enabled people to not only buy essential goods but also a multitude of consumer goods. The third revolution is the digital revolution which includes the Personal Computer (PC), the Internet and Information and Communication Technologies (ICT). These innovations enabled us to create things digitally trough 3D-modeling where you can visualize and simulate prototypes without building them physically. The internet connected the world and enables information and communication sharing which led to a boom in knowledge. And today people are talking about the fourth industrial revolution which is referred to as "Cyber-physical systems" or the integration of technology with the human society (Davis, 2016). The first step in the integration is already going on through the smartphone, which a clear majority of the people owning a smartphone today could not imagine living without it. The reason being that smartphones gives us all the information on the internet which allows us to keep in touch with our contacts and to stay connected with the entire world (mainly people). But in the future, it will have the information about the entire world (machines) you are interacting with (Sendler, 2018). In this chapter some of these technologies will be briefly explained, namely Internet of Things (IoT), Cloud computing, Artificial Intelligence (AI) and Machine learning. In figure 3 below a short summary of the four different chapters in Industry 4.0 are given.

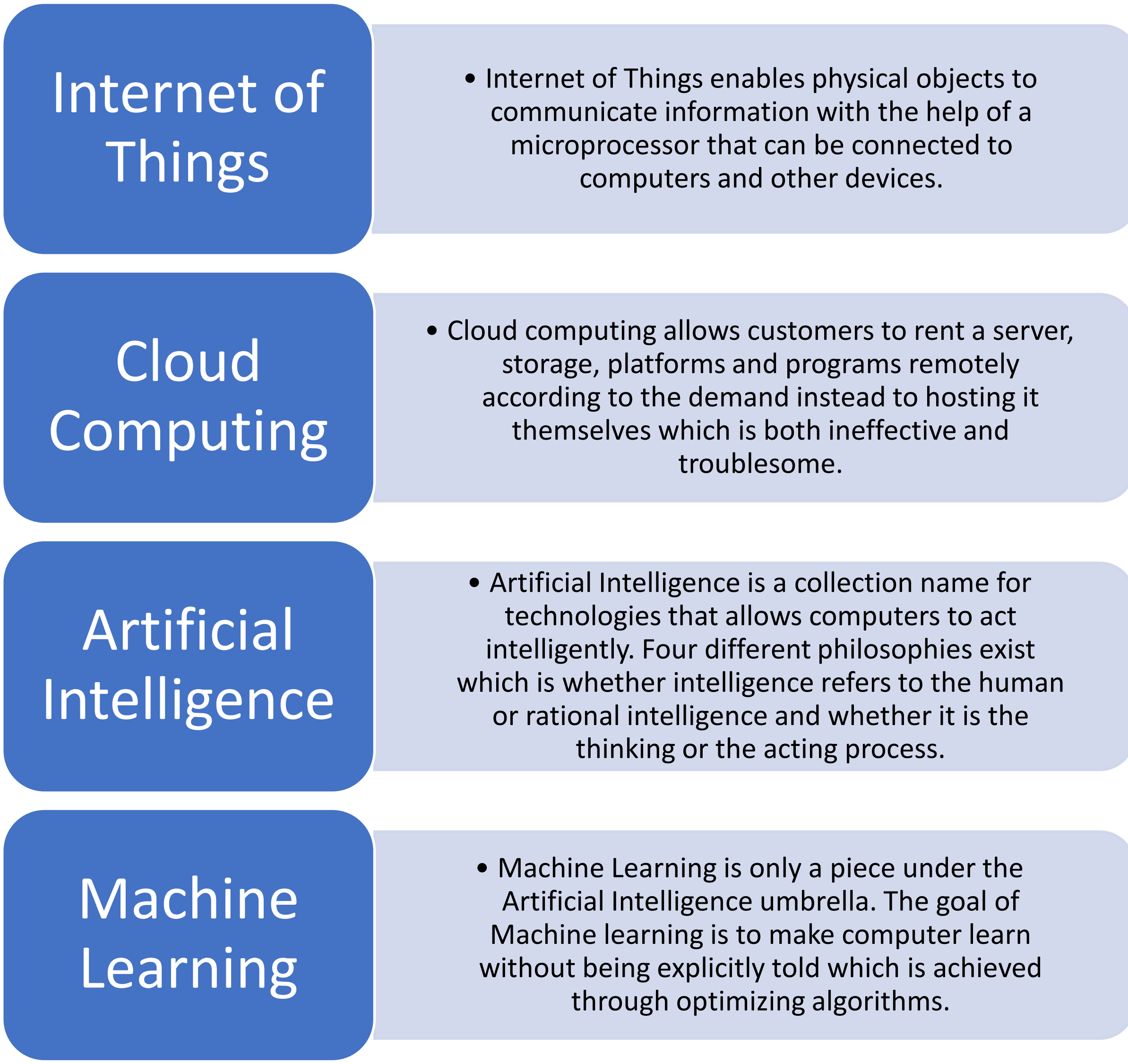

Figure 3 - Summary of the four technologies in Industry 4.0

3.4.1 Internet of Things

The number of devices that are connected to the internet is growing exponentially every year. In 2010 the number of devices connected to the internet exceeded the entire human population and the number is expected to reach 212 billion by the end of 2020 (Al-Fuqaha et al., 2015). The technology that made this possible is called Internet of Things (IoT). The following quote is Al-Fuqaha et al. (2015) own words.

> *"The IoT enables physical objects to see, hear, think and perform jobs by having them "talk" together, to share information and to coordinate decisions. The IoT transforms these objects from being traditional too smart by exploiting its underlying technologies such as ubiquitous and pervasive computing, embedded devices, communication technologies, sensor networks, Internet protocols and applications."*
>
> \- Al-Fuqaha, 2015, p. 2347

When breaking down what IoT is, Al-Fuqaha et al. (2015) argues that IoT consists of six elements (see figure 4); identification, sensing, communication, computation, services and semantics. Identification includes separation between different devices through an Internet Protocol (IP) address so that information can be sent and received from a specific device. Identification methods are used to provide a clear identity for each object within the network. The sensing refers to devices that transforms the environment around them into data which is sent to the database or cloud. The sensing is made through sensors which provide data to understand what is going on within a facility. Sensors can be wired or wireless, sensors can amongst other things measure; motion, Proximity, temperature, CO_2, VOC (Volatile organic compounds), Noise level, Light level, Power usage, Humidity, Barometric pressure, vibrations (Weng & Agarwal, 2012; Yanzi, 2018). Cameras can also be used to measure and for example count the amount of people moving through a door (Sangogboye et al, 2017). The next element is communicating the data which can be achieved through various communication protocols such as Wi-Fi, Bluetooth, Z-waves and LTE. There are also alternative communication protocols such as RFID, Near Field Communication (NFC) and Ultra-Wide Bandwidth (UWB) for close range machine to machine (M2M) communication.

Figure 4 - the six different elements of IoT (Al-Fuqaha et al. 2015, p. 2350)

Now that all the data is accessible the next step is to process it through computation. There are many different microprocessors that does that, Arduino and Raspberry PI are the two most well-known. In addition to the hardware, software is needed. There exists many third parties that provide these kinds of services such as IBM Watson and Microsoft Azure. The computing can be managed both locally and, on the cloud, which will be covered in more detail in the next section. Through the computation of data there are new possible services such as aggregating raw data into convenient tables and graphs and base decisions on facts. The last element is semantics which refers to the ability to extract the information the user needs on demand. Semantics also consists of analyzing and recognizing the data, so that a good decision can be made.

3.4.2 Cloud computing

Cloud computing is one of the key components that enabled the digitized world we live in today. A few decades ago when computers were the size of a room and cost a fortune, only big companies could afford them. Later when computer shrunk in size and price, small and medium sized companies and even private people could also benefit from computers. But there were still a big problem remaining, it is expensive and complicated to host and store a website. Before cloud computing every website needed to have their own server and storage. Hosting an own server is complicated for a company, especially if the website is public. A server can only handle a certain amount of request per second. So, if a company grows or puts out an advertisement it is likely that their website will attract more visitors, which would demand that the server can manage the increase in traffic and if it does not, it will crash. This is problematic for every company if they need to buy a server that meets the temporary demands. On top of that, servers also need maintenance and updates and many companies does not possess this knowledge, which is where cloud computing comes in (Sendler, 2018).

Cloud computing allows customers to rent a server, storage, platforms and programs according to the demand. Cloud computing can be divided into three different layers known as Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS) as shown in figure 5 below. IaaS allows customers to rent virtual servers and storage space on demand according to their needs. This allows everyone to run their own websites without the hassle of hosting one's own server. The IaaS service has developed very fast and is today taken for granted by many. Amazon Web Service is an example of IaaS service provider. The next service PaaS allows customers a platform where you can develop your own applications in addition to what IaaS services provide. Microsoft Azure is an example of a PaaS provider that offers a framework of developing application on their platform. The framework consists of previous application that already exist, so you do not need to recreate all the infrastructure as well as takes care of all licenses and updates so that the user can focus on their specific application. The last service SaaS provides the customer with already developed software program and application on their end device (e.g. their PC or smartphone), which is used by almost every application on smartphone´s. The SaaS service is very convenient for the end user since they do not need to develop anything themselves and can only utilize it for their needs. SaaS services is also used for Big Data application's where one example is IBM Watson which is a SaaS that allows the customer to upload data and process it using IBM's supercomputer Watson to analyze the data through machine learning, which is why cloud computing and Big Data Analysis are closely related (Sendler, 2018).

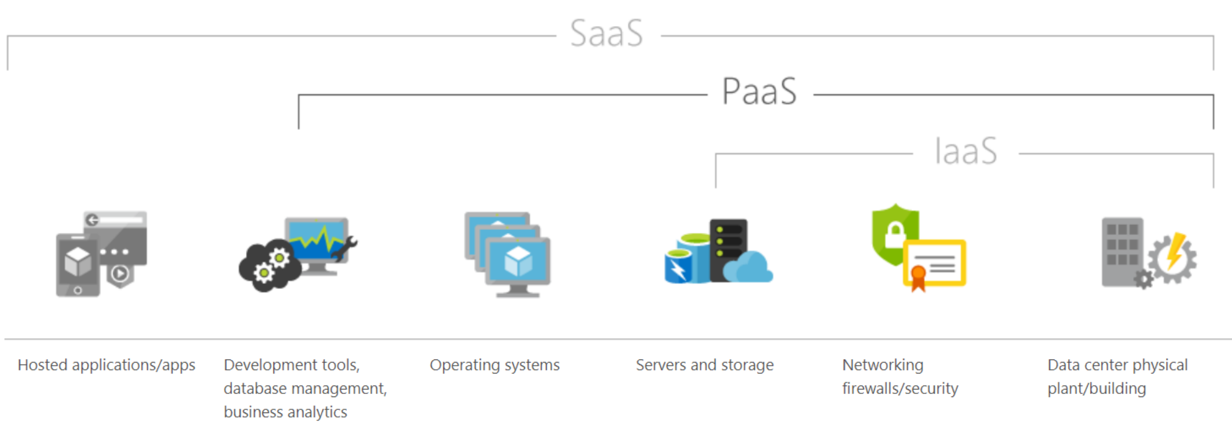

Figure 5 - Levels of service in Cloud Computing from azure.microsoft.com (2018)

3.4.3 Artificial intelligence

The concept of Artificial Intelligence (AI) has been around since the creation of the first computer and already then people began to speculate the potential of what the computers are capable to do. But back then neither the hardware performance nor the information science behind AI were developed enough to meet the expectations. It is only in the last decades where both the hardware and the knowledge have reached a somewhat mature level to utilize AI (Schaller, 1997). But what is AI exactly? To answer this question, first a definition of intelligence is needed, and there exist two different dimensions behind what intelligence entails. The first dimension focus on whether intelligence lies in the thought process and reasoning or if it lies in the actions performed. The second dimension focuses on whether ideal performance and rationality or to imitate human performance is intelligence. These are four different philosophies that AI can be divided into Russel

& Norvig, 2010). In figure 6 there are eight definitions of what AI is. The definitions of AI can be very different depending on what field it is applied to and what the desired outcome is. An example of where AI have been implemented is Google's search engine is an example of reaching mass adoption. Now that AI have been proven profitable the technology has again gained a boom in interest and the market is going to be 40 billion dollars in 2020 and 60% of those platforms will be running on Google, Amazon, IBM and Watson (Sendler, 2018). The race has begun on who will become the leading platform in AI.

Thinking Humanly	**Thinking Rationally**
"The exciting new effort to make computers think … *machines with minds*, in the full and literal sense." (Haugeland, 1985)	"The study of mental faculties through the use of computational models." (Charniak and McDermott, 1985)
"[The automation of] activities that we associate with human thinking, activities such as decision-making, problem solving, learning …" (Bellman, 1978)	"The study of the computations that make it possible to perceive, reason, and act." (Winston, 1992)
Acting Humanly	**Acting Rationally**
"The art of creating machines that perform functions that require intelligence when performed by people." (Kurzweil, 1990)	"Computational Intelligence is the study of the design of intelligent agents." (Poole *et al.*, 1998)
"The study of how to make computers do things at which, at the moment, people are better." (Rich and Knight, 1991)	"AI … is concerned with intelligent behavior in artifacts." (Nilsson, 1998)

Figure 6 - Philosophies of Intelligence (Russel & Norvig, 2010, p.2)

The Swedish innovation agency Vinnova conducted a study on AI development and performed a SWOT-analysis (Strength – Weakness – Opportunities – Threats) for Sweden. The study found some pitfalls, critical issues and applications where AI will be of use going forward (Vinnova, 2018). The expected benefits of implementing AI are to create autonomously controlled processes, to plan and follow-up with greater precision and speed, keep track of maintenance to avoid down time and specially for the construction sector to replace administrative tasks with AI. The use of IoT will also be given a boost when AI can take care of processing and presenting of all data being gathered. It was further assessed that there is plenty of data collected which is suitable for AI and machine learning, but there are several issues and potential pitfalls to take into consideration. One is the lack of competence in AI, both within companies and potential competence to recruit, this often leads to the development work to be less prioritized and the day to day operations are only being performed due to a current shortage of human resources. The coming implementation of AI in many sectors will lead to a change in manpower to meet the future demands, since long practical experiences can relatively easy be transferred to people with the needed education the workforce will either must be educated or changed out to keep up with the development. If companies and the country does not keep up with the competition there is a large risk of being left behind.

In the field of AI, there is an absence of rules, legislation and policies concerning standards of working to ease the implementation of AI technology, to handle ethical and safety concern, to handle the ownership of data which is especially difficult when different sources are aggregated and possibly hardest to solve when private and public data are combined. Further the study found that the control of data must be managed so that no one abuses the power of data or knowledge. The current IT infrastructure in Sweden are not stable enough to properly support AI services and the different systems which generate data are rarely able to communicate which is critical to continue the development as well as allowing technology from different generation to function simultaneously in the same environment and the data streams to be aggregated (Vinnova, 2018).

The study further concludes that the great risk of AI development in Sweden today is that the necessary sense of urgency might not appear due to the current boom, if that is the case there is a large risk of sectors to fall behind the development and be left behind.

3.4.4 Machine learning

Machine learning and Artificial intelligence are two terms that are often confused or believed to be the same technology. But machine learning is only a piece under the larger AI technology umbrella. According to Langkilde[1] machine learning is

"the goal of machine learning is for computers to learn without being explicitly programmed"

– Langkilde (2018)

According to Theobald (2017) machine learning can be broken down to three main categories including structured learning, unstructured learning and reinforcement learning. Some people are arguing that there are only two categories, structured and unstructured and all others are just different sub methods. The structured learning is based on a person feeding the computer with labeled data (e.g. a picture of a cat with the tag cat, or a sentence with every word labeled with its grammatical form) that goes through an "optimizing mathematical algorithm" or "neural network" and from that categorize the input to an output based on the labeled data that it used as learning material. In unsupervised learning there is no structured data. Unstructured learning tries to categorize data according to its properties. For example, if you have a big data set of all students that are 13 years old and you use unsupervised learning to analyze the relationship between height and weight, you will likely see two cluster emerge. One cluster with boys and one with girls since the weight and height relationship between the genders differ at this age. So unsupervised learning enables you to discover new patterns. This technique is called a k-means clustering, there are also other techniques for example, association analysis, social network analysis and descending dimensions algorithms. Reinforcement learning differs slightly from both structured and unstructured learning, since it learns from feedback from previous iterations. Reinforcement learning is mainly applied to videos games where the computer plays the game repeatedly and learn from previous iteration based on goals that could be score, time, level, etc.

3.4.5 Ethics in industry 4.0

With all information about individuals, organizations and their actions being stored today there are ethical considerations to be made. According to Acello (2010) who studies the storing of attorney information in the US, it is becoming even more important when utilizing cloud services to store and process data since the data are not stored locally by the actor. Instead it is stored globally by a service provider which means that the service provider is responsible for the security of your data, not the actor you have an agreement with. On the other hand, de Bruin & Floridi (2017) see that

[1] Presentation and seminar on Machine Learning "WTF is AI: The Next or Last Step of Evolution?", Gothenburg (2018-02-28)

some professions such as medical doctors, dealing with sensitive data should be banned from storing it in the cloud which could be vulnerable to attacks and legislative demands when data crosses borders. Some issues with gathering and storing data is according to AboBakr & Azer (2017) that individuals can be identified with the data, diminish the line between private and public life. They see three entities to be important, the privacy of information, the access to information and the integrity of the information.

3.5 Integration in FM

This chapter will dive deeper in to how BIM and BDA can be implemented in FM. Since this is a developing technology there are an infinite number of potential use cases but very few have been applied and tested in reality. The use cases range from installing sensors to optimize cleaning to buildings that will develop and adapt itself based on user behavior. This thesis will first present some general synergies between the technologies and then present two use cases that is most relevant to this thesis namely, energy optimization and space management.

3.5.1 Big Data Analysis in Facility management

Facility Management is not known for being high tech but is currently facing a trend toward new technology such as Internet of Things (IoT), Big Data Analytics (BDA) and Artificial Intelligence (AI). These new technologies will leave no market untouched and that includes FM. It is critical for companies to harness the wealth of knowledge from the corporate data to stay competitive, but many companies are still experimenting with this new technology and are gathering data without understanding the means or the possible benefits. But when implemented correctly BDA will provide tremendous value (Mawad & Al-Hajj, 2017).

The advantages of BDA in FM can be divided into two parts, operations and strategic. The former emphasizes the increase in efficiency and cost reduction on an operational level for example turning of ventilation when the room is not used or only to clean rooms that have been used. The operational benefits give quick indication on the outcome. The latter focuses more on gaining a competitive advantage by collecting data of the facility to use as a base when making decisions. An example is when deciding on if the company needs to expand their office space or not, with the support of collected data you might find that some big meeting rooms for 10 people only gets utilized for 2 and can be divided into a more suitable sizes and thus lead to the space being utilized more efficiently. This allows not only the manager to base their decisions on data, it also lets them take decisions faster since the data is always present and only need to be accessed or analyzed instead of having to investigate and starting to gather data (Atkins & Bildsten, 2017).

Currently many facility owners already have gathered a large amount of data but does not know how to handle and process it to be able to abstract value from it. Before BDA and AI this data was futile to work with since no human could process the vast amount of information being gathered. The Group Chief Commercial Officer of ISS, Price puts it as

> *"Buildings should work for people, using cognitive capabilities we will be able to provide places which are more efficient from an asset perspective, but more importantly more capable of supporting great service as we go forward. They'll be places where people will want to be rather than places they have to go to work. They'll be places where the human being part of us is retained. So these places in the future will be much more interactive. And to attract people to that interaction, we'll need buildings which are exciting, which create*

creativity, and really allow a business to come alive. The real value isn't the data, it's turning the data into knowledge which drives continuous improvement for our business"
-(IBM, 2017b)

3.5.2 BIM in Facilities Management

BIM have changed the way the AEC industry communicates, cooperates and allows knowledge sharing between all actors involved such as facility management and design professionals. BIM have been used for many years in the construction sector but mainly in the design phase for visualization and clash detections. The use by facility managers in the FM phase are uncommon, even though the greatest gain from BIM would be when it is integrated with the FM processes (Grobler, 2011; Liu & Issa, 2014). According to Shalabi & Turkan (2017) the whole FM process can be improved by connecting BIM-models to the systems and integrate the data from the information systems with the data from the model. An example is when an object is broken, it can be presented visually in a 3D-model and lead the technician to the actual object that is broken instead of a serial number in a list (Kelly et al., 2013). But there are some obstacles to get there, Shalabi & Turkan (2017) states the following

"However, current practices depend on manual data input during the Operation & Maintenance (O&M) phase. Therefore, the Facilities Managers is forced to master, operate, and gather data from multiple systems in their daily work. For example, when a new equipment is installed, or a repair occurred, related data need to be entered manually, which may result in inaccurate and/or incomplete information"
- Shalabi & Turkan (2017, p.2)

Another obstacle for implementation is that different systems are based on individual data structures which keeps them from communicating directly with each other. Further it is costlier to store data in multiple places and there is an uncertainty of validity if information is being stored in different places (Shalabi & Turkan, 2017; Teicholz, 2001).

3.5.3 Energy optimization with the help of BIM and BDA

With the increase in energy prices and awareness of CO_2 emissions having opened peoples and building owners' eyes to take actions against the cost of energy. In Europe the building sector accounts for approximately 40% of all energy consumption and 36% of all CO_2 emissions (European Commission, 2018), which have led to an increased interest to create more energy efficient buildings. Energy Management systems (EMS´s) job is to reduce the cost of energy in a building but it is important to not reduce the Indoor Environmental Quality (IEQ) (Habibi, 2016). Yuan & Yuan (2013) and Habibi (2016), state that Information and Communication Technologies (ICT) application such as sensor, mobile technologies, networks, big data, etc. can provide key contributions to sustainable growth. To create a comfortable indoor climate, sensor can have a significant impact by assisting to monitor user behavior as well as the metrics for indoor climate and supplies data to assess the comfort requirements from users and to identify possible retrofitting options. In addition, they offer a low-cost environmental monitoring and are flexible to install. However, it is still a complex task to implement multiple simultaneous sensors systems (Habibi, 2016).

BIM is another concept that is frequently mentioned when it comes increasing efficiency of a building in many aspects such as energy consumption over its life-cycle (Eastman et al., 2011;

Volk et al., 2014). There are also great benefits by combining Artificial Intelligence (AI) with BIM. According to Yuan et al (2013) it is possible to integrate mathematical algorithms to calculate and achieve the multi-objective optimization of building energy and Haymaker (2011) also states that AI will have a great impact on improving the sustainability of building and even provide optimum level of efficiency and automation. Further AI can be used as a decision supporting tool is proven to be viable approach in information and control systems. AI is rapidly developing new systems that is used to support BIM tools and may convey alternatives in the prediction of actual building performance and energy modeling without information loss (Habibi, 2016). But this is a new trend and still needs considerable progress and development (Haymaker, 2011).

3.5.4 Space management with the help of BDA and BIM

According to Teicholz (2001) space management are aiming to reach three goals; Increase productivity of the facility without compromising the performance of the staff; Minimizing facility cost, since every facility have an optimal level of maintenance and energy usage; and Providing information foundation for strategic planning with the help of data. The second goal was covered in the previous section, but the first and third goal can be reached with the help of BDA. According to Levi (2016) with the help of IoT, information can be gathered about how a space is being utilized over time and when applying BDA detect patterns over time to provide valuable information of how the space can be improved and used in the future. By providing workspaces that are more efficiently planned in combination with surveys, interviews, workshops, pilot projects or post-occupancy evaluations will lead to an increased rent per sqm (Teicholz, 2001).

In a research carried out by American Society of Interior Designers in 1999 listed what the staff needed from its workspace to be productive.

1. A neat and clean workplace
2. Visually appealing or pleasant looking
3. A well-lit and bright environment
4. New furniture and equipment
5. A private and quiet workspace
6. A workplace that provides easy access to people and equipment
7. Comfortable furniture
8. Air quality
9. Windows and/or a nice view

IoT and BDA can help solve many of these criteria's by providing real-time data when there is a breach of any of the criteria's and send instant alarm to be fixed. This according to Steiner (2006) will provide a competitive advantage when attracting and retaining talents.

4 RESULTS AND ANALYSIS

In this chapter the empirical data that was gathered will be presented from the five interviews with two property owners, two consultancy firm where one primarily focuses on Facility management and one Facility manager. The different sub-chapters will be ended with an analysis comparing the empirical data with the theory presented earlier.

4.1 Introduction to the interviewed companies

During the work for the thesis, five companies have been interviewed and to keep the focus on the content and not the identity they have been anonymized. In this section a brief introduction to the companies are provided where their focus in BDA and other related technologies are brought up before the results are presented in different sub-chapters.

Company A is one of the larger property owners in Sweden, they are working with sensors in their properties together with a consultant who are working solely with their project to enable BDA for their facilities. The interviewee was one of the co-founders of the consultancy firm who was developing the systems internally in the company, the authors also attended a meeting with the consultant, project owner, facility managers and facility developers. The authors see company A and their consultant as a single entity as far as the thesis is concerned since they are working on the project together.

Company B is one of the larger property owners in Sweden and have installed sensors in their HVAC-systems one of their properties that enables them to control the systems remotely. For example, there are motion sensors in every room and the ventilation only goes on if the room is booked and the motion sensor is activated. The Interview was with an Operations Manager together with a Facility technician who brought specialized knowledge about the facility.

Company C is a large consultant and Facility management company in Sweden, they have installed sensors in their office that visualize what workplaces and rooms that currently are vacant. They have also installed sensors in every room that is measuring the indoor climate parameters such as temperature, CO_2, VOC, humidity and noise. They are also helping other companies install similar setups. The interview was performed with their Innovation manager.

Company D are a large consultancy firm active in the AEC industry in Sweden. They have done a pilot test where they installed over 1000 sensors in their office to work with BDA to find out how to make their office more efficient. The interview was performed with their Innovation manager.

Company E is one of the larger property owners in Sweden and are working with developing a new facility which will be a test bed to for utilizing BDA to optimize facility management. Interviews were performed with their IT infrastructure Engineer.

4.2 Services and Applications

A common opinion between all interviewees is that digitalization of the Facility Management sector is necessary. Company B and C however emphasized the importance of only implementing the technology that is necessary to fulfills the people's needs and not for the sake of the technology. The technology is a tool to help people, not to make it more complicated. Another common thread was sensors, BIM, IoT, BDA, machine learning and AI that was mentioned by all the interviewees and that these new technologies will create new services. Company A & E see the shift from the traditional view of property owners only providing of steel and concrete towards providing services to the tenants. These services are achieved through digitalizing the facilities with sensors to gather data to provide the tenants ether as raw data for the companies to analyze themselves or already analyzed data about the tenant's usage of the building. A more general acknowledgement was that BDA would help in the decision process. For instance, Company D used data gathered from over 1000 sensors in their current office when designing their new office. Company B uses data generated from sensors that is integrated in their Air diffusers when investigate complaint reports to see if it is the HVAC system that is the problem or if it is something else. The target of implementing these technologies is however always economical, either to reduce cost or to increase profit which can be achieved either by working with the building control systems or enabling the people to perform better. However, the companies have different thoughts on how to focus their efforts today and the discussions have focused on four areas where BDA in can be implemented in FM, these are 1) Hard to calculate returns, 2) Lack of competence, 3) Lack of standards, 4) Maintaining the digital twin, and 5) Ethical and regulatory questions.

When comparing the gathered information from the companies with the theoretical framework, the shift towards a more service-oriented business model that are expressed by some companies to fulfill the needs of the people using the building are in line with how Högberg & Högberg (2000) see the FM sector by focusing on the customers value creating processes as well as Atkins & Brooks (2015) view on the FM sector being a service sector in itself. The view of BDA to be helpful to increase the efficiency, help make decisions and perform proactive maintenance is supported by the 2018 Vinnova report which expect AI to take over many administrative tasks, to provide information to base decisions and planning on as well as keep track of expected maintenance. The view on having the technology solve issues for people and not for the development of the technology could in some instances be conflicting with the urge from Vinnova in their report to find the sense of urgency to work actively in the development to not fall behind. Although company A and E were in line with Vinnova´s (2018) conclusion and saw the need to not only fall behind but to also lead the development and expect competitors to survive unless they do keep up. The concept of selling data to one's tenants have not been addressed in literature, but the concept of refining the data to information are the concept of a service which is not unlike other services provided by the FM sector.

4.2.1 Energy saving

Company A see the initial main use of sensors and BDA being energy savings, they stated that energy savings is the application that they can prove will pay back the initial investment needed. They had a goal to reduce the energy consumption from 100 kwh/m^2/year to 50 kwh/m^2/year in all their building. They are also put up monitors in the entrance in their facilities that have solar panels installed to visualize how much energy they have generated to increase the sustainability awareness. Company B also sees energy saving as one of the greatest applications, but also stated the new systems needs a lot of steering, it is great when everything works but troublesome when it breaks down. It is hard to find out which part that is broken and whose fault it is, and there is also a lack knowledge for the operations technician to solve it on their own since it often needs IT-competences.

Company D & E also acknowledged the potentials of energy saving but was not the most important application of the technology to focus on. For instance, Company D conducted a pilot project in their headquarter and found out that 40% the electricity was wasted when no one was in the room due to not turning of the light and computer screens, leaving phone chargers plugged in, etc. but it was not worth remedy since the cost of changing the employee's behavior would far exceed the gains from energy saving. Company D instead stated that if this could be made automatically there are great gains to be made. And for this to be possible they need data of people's preferences to create algorithms to solve this. Company E mentioned that the energy cost of a building is a relatively small amount compared to for example the revenue from rent. However, all companies mentioned the potentials of integrating weather data with the HVAC systems to automatically adapt to save energy, for example pre-heating or cooling. Some companies also mentioned integrating booking systems, event, user behavior and price of energy with the help of machine learning and AI. Company C was however a bit skeptical and see user data collected from a facility as far too specific to be used as analysis material for another facility. Company E argues the opposite, if the data is well categorized, facilities and people are often quite similar no matter the company or business. Company A, B and E are currently experimenting with integrating weather data with the HVAC systems.

Comparison with literature

When comparing the gathered information from the companies with the theoretical framework that have been published, the general acknowledgement is that BDA is a great tool for energy savings. However, the main focus of energy saving was financial incentives, while the theoretical researches main focus was the sustainability gains which is exemplified by Company D (see above). Another aspect was that all companies had the user experience in mind when talking about energy saving and Company C prioritized user behavior above energy saving while the other companies had a more balanced view. Habibi (2016) states that user behavior has a large impact on the energy consumption and that there cannot be any accurate simulations or calculations without taking this into consideration. The companies all have somewhat taken this into consideration, but the matrix was employee productivity rather than energy saving. And the approach all companies are taking is combining sensor data with soft data from surveys and interviews. Related to this all companies drew the parallel to machine learning and artificial intelligence with very high expectations. However, they all agreed that it is still in an early stage.

4.2.2 Better indoor climate to increase productivity

All companies have mentioned to create better indoor environment, both the physical environment such as cleaning, furniture and overall comfort, but also indoor climate such as Air Quality, lighting and noise. Company C sees this integration of people and technology, to help the people work more efficient and be more productive as the greatest gain possible with BDA. They state that the cost of employees account for around 90-95 % of the cost under during the FM phase while the remaining 5-10 % are rent and services. Therefore, the greatest gain is to increase the productivity of the staff, since making the building more efficient will have a smaller impact on a company's budget.

Even though all companies see a great value in increasing the productivity of the people in the building no on accurate solutions of achieving this. The main reason is that there is no accurate way to measure productivity. But all companies lean towards that self-assessment of productivity is the most accurate measurement available today and are therefore conducting surveys and interviews of their employees and customers experience. Company E are however conducting some experiments in test environments with sensors and observers to find out which environments that people work best in. There are still no conclusions to be drawn from these tests, but they believe that when there is proof of some environments are more productive than others, they can offer these to tenants.

All companies are however looking towards creating an ideal indoor climate to give people the best opportunities to be as productive as possible by working with mainly temperature, CO_2, Organic particles (VOC), humidity, sound level, lightning and cleaning. Company C have developed a package where they help facilities to obtain good air quality. They state that it is relatively easy and cheap to install a green organic wall, vaporizer or air filter that could make a huge impact for the user experience. For example, having pollen free rooms during spring and summer.

All companies also believed that machine learning and AI will make sure that the optimal indoor climate are maintained in the future. The opinion on whether these systems should be customizable or fully autonomous differs especially between company D, who believes that the systems should adjust to the people in the room (maybe through their smartphones), while Company E believes that it should be fully autonomous with the possibility for manual override until when the systems are developed enough, it shows in this quote from the interview:

"If we can build autonomous cars today, it should not be so hard to build an autonomous building"
- Company D

Related to this there are also different opinions if the systems should be optimized from an individual perspective or from a whole facility's perspective. All companies have also states that it is in an early stage with the development of machine learning and AI for FM uses and it will take at least several years until systems like this are functioning in an efficient manner. Company A and E are however going to start implementing machine learning solutions already this year.

Comparison with literature

When comparing the gathered information from the companies with the theoretical framework, the statement that productivity is a complex area to accurately measure is agreed upon both by the companies and the theory. Company E are however experimenting with ways of measuring productivity and believes that it is possible to create and prove that some indoor environments help people to be more productive than others. This research is being done in a laboratory environment with observers and specific sensors which measure individual people. Other than that it is generally agreed by all the companies that self-assessment is probably the most accurate measurement available just as Haynes (2008) stated in his research. The companies are also working with creating better indoor climate since they all see great benefits in providing comfortable work environments with good air quality which have been proven by Atkins & Brooks (2015) to have a positive impact on employee's self-assessment of productivity. Cleaning and finding/booking suitable meeting rooms is something that all companies also touched upon. BDA can make both these tasks more effective. By only cleaning rooms that have been used does not only save time for the cleaners but also provides the employees with cleaner rooms and by visualizing which meeting rooms are free considerable time could be saved from employees running around to find a last minute room. These are similar to the findings by American Society of Interior Designers in 1999 that found what constitutes a pleasant office where clean areas (rank 1) and workplace that provides easy access to people and equipment (rank 6) are in the top 10 list.

4.2.3 Space Optimization

Finding ways to optimize the usage of space or more specifically usage rate both in regard of reducing rental space for the tenants or recreating the areas that people like to work in. Company

C is working with optimizing the office space for their clients by measuring current usage with sensors in room and individual seat level. They believe that a substantial amount of space can be saved but it is essential to look at the tenants needs. If you space optimize an office without considering the business and the people, it will lead to more harm than saving. They also combine the data gathered from the sensors with surveys and interviews conducted quarterly or every year.

Space optimization was also brought up by company A, D and E as an important application of sensors and BDA, which company D and E saw as one of the most worthwhile applications of the technologies. Company A and D focused on the aspect to use BDA to find out which area people prefer to work in and recreate similar areas to leave no areas with low occupancy rate. Company D has also performed a study on their office during business hours and found that their space utilization was approximately 38 % while company E have found the utilization in their facilities to be around 40 % during business hours. Company E see substantial saving to be made for their tenants if the facility they are renting is used for the right purpose and the possibility to multiple tenants for the same facility during different time periods such as evenings and increase rental time instead of price per sqm. With the help of BDA, they can show their tenants that there are possibilities to optimize and lower their rent by allowing them to rent it out to another tenant which will also increase their revenue. If the space can be utilized more, the need for constructing new buildings will not be as great as it is today, which is beneficial from a sustainability perspective. In the same sense they are looking at co-workings solutions to for example improve office environments where larger meeting room rarely are used normally, and several tenants can share one instead of all paying for a permanent one. Meanwhile company C see the possibility to increase the number of tenants in the same area if each tenants use is optimized but only see the gain if the owner can increase the price per sqm that the total revenue becomes higher. Otherwise they only see more work with handling more tenants for the same pay as fewer tenants in the same area.

Comparison with literature

When comparing the gathered information from the companies with the theoretical framework, the opinions of the companies of how to utilize BDA in space management it is very similar to the three goals Teicholz (2001) mentioned which is 1) increase productivity of the facility without compromising the performance of the staff; 2) Minimizing facility cost, since every facility have an optimal level of maintenance and energy usage; and 3) Providing information foundation for strategic planning with the help of data. One of the companies looked at all three of the goals but the other companies mention all these goals but tend to focus on one or two of these goals. All the companies also saw the importance of combining the hard data that the sensors provide with the soft data from surveys and interviews like Levi (2016) and Teicholz (2001). Except for company E, all companies believe that benefiting from BDA could and should lead to higher rent per sqm, while company E rather believe that reducing the price per sqm and instead allowing multiple tenants to utilize the same space and increase the total rental time.

4.2.4 More effective maintenance and operations

By collecting and combining information about the objects in a building which require maintenance or can break, such as HVAC-units, lights, projectors and door shutters, with the hierarchy and positioning of BIM, company D and E see the opportunity to streamline the maintenance process for buildings. The information would be able to be combined, visualized and analyzed together. By having a simple method and interface where a user of a building can orient themselves and an object in need for care where they can report the object to the facility management the information path from the people noticing and being affected by the issue to the ones responsible for the issues are more streamlined and clearer since there would be no guesswork as to which object that is reported. The next phase is that the facility management know what objects and have the information about the specific object that needs care, and a description of what is wrong. Therefore, they can dispatch or order the correct technician to mend the issue. The last step is when the technician arrives to mend the issue and have a guide to find the object in a BIM-viewer where they can see which object they are present to amend. Lastly when the technician has replaced or serviced the object they send the information to the system of replacement part or what they have serviced on it to the database so that the information on the objects in the building always are up to date. Company D see potential in having sensor detecting how much different facilities are used to align the available cleaning resources most efficiently. An example given was to install motions sensors in a buildings bathroom, these sensors count the amount of times each bathroom has been used, the statistics are then used to make sure the most used bathrooms are cleaned more often than the ones barely used. The use of sensors mean that the distribution can be changed easier since current and accurate data is available. Meanwhile, company C and E do not currently see viable options to install sensors in trash cans, towel dispensers and similar places to notify when the action of emptying or filling is needed. This due to the cost of implementation are much larger than the savings in labor costs are for an overseeable future, although company E believe that it will change in a year of two with decreasing cost of implementation.

Comparison with literature

When comparing the gathered information from the companies with the theoretical framework, most of the companies brought up the benefit of having detailed, accessible and visualizable information regarding the buildings for the maintenance and operations processes. This benefit has also been supported in literature by Nordstrand (2000), Shalabi & Turkan (2017) and Atkins & Brooks (2015) who see information, and especially information that can be visualized as favorable. By having the data and information accessible in a single interface the companies see the same possibilities as Shalabi & Turkan (2017) propose where they can aggregate, analyze and visualize the information for increased understanding. The suggestion of easy to use error-reporting by company D to increase the efficiency in maintenance are supported and similar to the idea from Kelly et al. (2013) who see increased efficiency when the technicians can be led to the object visually. Further the method of having sensors steer the allocation of resources for example cleaning were also proposed by Atkins and Bildsten in their 2017 paper, although they did not discuss the current profitability.

4.3 Infrastructure of Big Data Analysis

The use of IoT, BDA and AI are emerging as a trend in Facility Management and there is no standardized framework or infrastructure out in the market yet, so every company must develop their own. One issue that Company A & E mentioned is that there is no ontology in place to enable work with BDA since different data streams are coded in unique ways. For example, some sensors send out data and names it temp and another temperature, while some might measure in Fahrenheit and some in Celsius. Real Estate Core is the ontology being developed by company A, E and one more company in consortium, which works as a translation module which makes sure every different input is in the same standard language, so it can be managed and processes in a single platform. The consortium plans to release the ontology as open source for other actors to use and implement while hoping it will help develop a standard in the industry. Since there is no standard and infrastructure currently in place there are many uncertainties regarding how this new technology will impact work roles in the FM sector. All companies have stated that there will either emerge new job positions or that the current role of the operation technician will be broader or changed. Other concerns that was mentioned was the cost distribution, ownership of systems and data as well as privacy and ethics.

4.3.1 Sensors and communication between systems

To perform an analysis on the usage of a buildings, the data need to be gathered and collected. The gathering of data is usually performed with sensors either built into other infrastructure such as air-diffusers or using separate sensor systems aside from the other infrastructure in a building. Company A currently believe the built-in systems as a simple and good solution when building new or renovating building, while company C and D only have used separate sensors in parts of a building to collect environmental data, utilization rate and electricity usage from specific plugs. Company D however does not believe that mobile sensors are the right route forwards due to increased complexity and managing battery time. Meanwhile the mobile sensors are advocated by company E who see the built-in sensors as useful but the common choice today, an air-diffuser with built in motion, temperature and CO_2 sensors are more expensive than installing simpler diffusers and a separate sensor system which provides a broader output of data. A further argument brought up is that the sensors being locked into the HVAC-system have a shorter lifespan than the HVAC-system itself which Company E estimate to have a lifespan of 15-20 years while the lifespan of the sensors being around 5 years before they are changed or updated due to advances in technology or changed needs. But to be able to use several systems together they need to be able to communicate with each other and the data being received from the different systems must be comparable. But one topic that all companies do agree upon is that wireless solutions is better the cables since it is costly to install cables and it is less flexible.

With the usage of several systems from different manufacturers, a building ontology to translate the communication from all different systems is needed, one being developed by company A and E are Real Estate Core. The ontology being developed are a collection of “dictionaries” between the standard and the protocol of the brand, as well as each brand having different “dialects” which change depending on age, designing consultant and installation technician. These differences mean that it need to exist a large amount of different translations, company A themselves have over 30 different brands and many dialects within each brand and without the ability to read the data in the same standard they would not be able to aggregate and analyze the data together. Company B, C and D are ether developing their own tailor-made solution for each application or just utilizing the manufacturers platform which is not compatible with sensors from other manufacturers.

The gathered information is in the solution being developed by company A and E stored in their cloud service where the ontology, Real Estate Core, is housed together with the platform used to control the flows of data and information. The platform allows the owner to control which data that is streamed or accessed by which actor to make sure that sensitive data is safe and not accessed by the wrong actor. For example, to allow streaming of data from the use of a building to a screen in the lobby where they can see the indoor temperature for different rooms and which rooms are occupied but not information regarding the number of customers entering a store. Company C & D are also utilizing the cloud services to gather, store and analyze data. Company E further discusses the development of allowing third parties to access data through API’s to create software services for customers that solves needs not tended to by traditional facility managers. They draw parallels to the banking sector which today allows third party developers to create application for their customers to use. To allow third parties there need to exist a gateway for the information to be accessed and information of how to access it available which can be serviced by their platform in the cloud.

All companies see the need to not get locked into a software environment such a certain cloud provider or platform. Company A goes as far as saying that a supplier using proprietary software's are very unlikely to win a bid with them and that they more of less demand non-proprietary solutions from their suppliers while company E says that they are only using non-proprietary systems and platforms which allow them to bring everything a move it to another cloud provider if needed. The same positions were also found in company D who want to keep their options open and not be locked in to a choice.

Another common opinion that all companies have is that BIM-models are an excellent tool in combination with sensors mainly due to the easy and effective visualization it brings, with it being a carrier of information and being a Digital Twin which is a digital representation of the physical building. The ability to visually connect information from sensors to position in the BIM-model where the sensors can provide real-time data about the usage of the facility because it provides precise localization of data for easier maintenance and analysis. Company D also stated that one of BIM-models great benefits is that it is a universal language that everyone can understand no matter where you from or background, for example

"...a red room means bad or occupied and a green room means good or vacant"
- Company D

Meanwhile company C see the possibility to include technologies to visualize the information in a more advanced way such as Virtual Reality (VR) and Augmented Reality (AR). Company E emphasizes more on the importance to integrate the planning of sensors already in the design phase. They focus on utilize BIM as an information carrier to connect the intended sensor through BIM-Objects (which is a platform where manufacturer can upload modules of their products) to the position it is to be placed and later is placed. This method would give a detailed structure and collection of the information regarding each sensor and its properties and during the installation process only the serial/identification-number of the sensor need to be added.

Comparison with literature

When comparing the gathered information from the companies with the theoretical framework, the statement that BDA and AI in FM is in an early stage and still lacks standards of application was quite agreed upon among all companies even though all of them already were working with it and had different business models and services in use or on the market today. Company C & D are expecting standards to emerge within the near future while Company A and E is trying to develop these standards with an open source project. This is necessary since it according to Vinnova 2018 there needs to be a stable infrastructure that can handle technologies from different generation to function simultaneously in the same environment and for the data streams to be aggregated. It is also evident that cloud computing plays an essential role for IoT and BDA to function, all companies rely on Microsoft Azure or the IBM Cloud. However, Company A, D & E emphasized the importance of not being locked up in one of them because if one goes down it needs to be possible to migrate to another platform. Company A, D and E also believed that it is essential invite third parties to create SaaS solutions since there are not enough resources within a single company which Sendler (2018) states is the direction the world will be moving towards. All companies also brought up the great potentials of the integration of sensors and BIM models to locate and visualizer the facility which Eastman et al. (2012) also pointed out to be one of the major strengths of BIM.

Eastman et al. (2012) also points out that BIM provides a more detailed handover of component information and located which Company E believes in and will be implementing.

4.3.2 Ownership of data and privacy

Ownership of data is a question that the companies had a slightly different view upon. The general reasoning was that the one that pays for the installation owns the data. The property owners (Company A & E) argues that they should own the data since it is their building and they want to have control over it. They both are also willing to pay for the installation and then sell the data to the tenant as a service. Company A argues that it is more beneficial for both parties since tenants tends to switch office more and more frequently and having every tenant set up their own sensor system would be both costly and inefficient. Company D however presented a more radical view and believe that it is not important who owns the data since data in itself does not hold any value, but rather the knowledge of how to process and analyze the data that holds value. Company D continues to argue the value of having open data since it could let others develop solutions to problem known or unknown by the owners and thereby improve their company faster. Company A & E agrees that there are many benefits of having the data accessible and are willing to share some of it publicly but they as property owners have a responsibility to protect their tenants and cannot share the tenant's data without their permission. But Company A & E states that data holds value and companies are willing to pay for it. Company A also gave a very futuristic example of property owners in the future might offer free rent just to be able to collect the data that the tenants are providing, just like how Facebook is free to use, but collects data on us. They are already starting to witness some examples where shopping malls are offering companies like Starbucks free rent in exchange for setting up their shop since it will generate a lot of customers to the mall. Company E have divided data into three different categories namely, tenant data that they will sell as a service to the tenants, research data that could be public to depending on the research and the parties involved and public data such as energy consumption and data that the tenant decides to release.

Privacy is a topic that that all the companies emphasized the importance of. There is strict regulation regarding Personal Identifiable Information (PII) and new regulation regarding PII being introduced. However, Company C and D does not see themselves collecting PII in the current way of working and therefore does not need to take any action now. Company A and E does not either see themselves gathering PII now but are considering the possible aggregation of data from several sources in combination could be classified as PII. Apart from regulatory concerns there are also concerns on an individual level where some individuals do not feel comfortable knowing that they are being monitored. Company D have experiencing this concerns from individuals when they were installing sensors in their office, and especially whether it was acceptable to install sensors in bathrooms and fixed offices. Company D believes that this could be overcome with good communication and explaining that they are not looking at individuals but the general usage and behavior at the facility. All the companies also said that there needs to be an agreement on how personal data can be stored and used if it would be gathered. Company C & E stated that the individual must be able to agree to the storing and using of their PII. Company A see that it will be standards in tenant agreements, Service Level Agreement (SLA) or other agreement for which data can be stored, how the stored data can be used and shared, but that this standard has not yet been agreed upon. Company E also looks further into using heat and video cameras which they see creating interesting concepts, one example being a fire alarm emergency where it can be seen how many people are in the building to focus the rescue efforts where needed. But this will raise a discussion around what we as individuals will accept in the future, if decreased privacy will increase the overall and personal safety and draws parallels to project with extensive camera surveillance to increase safety and company E predicts that we as individuals will accept to trade a lot more of our privacy in exchange for increased safety.

Comparison with literature

When comparing the gathered information from the companies with the theoretical framework, the statement that data hold value is agreed upon by all companies, even though Company D stated that data does not hold any value in itself, that only the analysis has any value. But without the data there is no analysis to be made. But the analysis is defining how much value that can be extracted from the data. This is similar to the fourth V in BDA that Sendler (2018) brought up. The different actors have had different views on the ownership of gathered data, the lack of standards is in line with the Vinnova report which see the lack of standards as a current weakness which need to be addressed. The different views include having data public or private and the ethical aspects of contract and agreements on how the data can be gathered, stored and processed which need to be agreed upon. The issue is seen in the literature where Eastman et al. (2012) see legal issues with documentation, AboBakr & Azer (2017) see it as necessary that individuals cannot be identified with the data without consent and Vinnova again see a lack of regulations and standard in how data can be stored and that the ownership is unclear and more difficult when different data sources are combined. Vinnova also see a risk with potential abuse of stored data due to uncertainties and knowledge advantages for some parties. The two property owners A & E have brought up the need to protect their customers data from others and to be vigilant in controlling who can access which data. The issue of private data where the companies in large do not see themselves collecting PII, although company A & E see the possibility of aggregated data streams to be considered PII where individuals can be identified. Acello (2010) and Bruin & Floridi (2017) argues that sensitive data should not be allowed to be stored in the cloud due to security concerns where they see hacks and legal demands from authorities when data crosses borders as threats.

The use of gathered data to analyze the behavior of people are another area where the companies are seeing issues, as some companies see the usefulness of having data on the facility and the people using it which they compare to how large IT-companies today use data as payment method as described by Sendler of the business models of companies like Google, Facebook and Amazon. Company E further reason on future intrusions in privacy by looking at facial recognition solutions appearing for example in China where the people by limiting their privacy has reached a safer environment and believe that there will be an increase in solutions giving us humans benefits in return for our privacy.

4.3.3 New ways of working

The use of IoT and BDA is in an early stage since all companies see a need for the current role of facility technicians to change and Company A, B and E are also witnessing some technicians starting to face difficulties in maintaining the control systems. The lack of competence is one of the biggest concerns among all companies regarding the implementation of sensors and BDA. All companies have all also stated that the current role of facility technician will be changed when this technology is introduced. But the view on the development of the facility technician's role is not the same between the companies. Company B sees that the role of the facility technician will lean more towards the role of a Control engineer who will focus on the digital systems and optimizing the building systems. While Company D believes that the role of the facility technician will remain similar but instead introducing a new role "facility information technician" similar to how the facility technician have the knowledge about the physical systems the facility information technician will have the knowledge about all the information of the systems. Company D believed in a similar to what Company B mentioned but that the role of facility technician will be more centralized and managing more facilities each and focusing on optimizing the building systems for the janitor or third party to physically be in the facilities to implement and fix things.

Another concern that was brought up by Company A and E regarding lack of competences is that they are struggling to recruit employees with enough competences that can work with interpreting the information being generated from the sensor. And to further add to the lack of competences Company A and E are also struggling to find people capable of developing the infrastructure for BDA and AI since they are recruited by the big companies such as Google, Facebook, Amazon, etc. according to Company E.

All companies also raised the concern of keeping the digital twin of the facility correct and updated. If the digital twin is not correct there is a risk of the gathered data being used incorrectly since it is coupled with the wrong location or that the information might be outdated which will lead to incorrect analysis. The question of who should be responsible for updating the digital twin and how it should be done is yet to be decided. Company C gives an example, if some employees start to move some chairs and tables around then the sensor placement in the model where the information is presented in real-time will be incorrect. So, someone needs to constantly update the digital twin and no good solution yet exist for this. Similar examples have been given by the other companies as well and none of the have a solution to this. But Company D envision a model where everyone in the building can send in an error report stating that some furniture's have been moved and the maybe the janitor or whoever will be managing the digital twin goes and checks that the information is correct and then in an easy drag and drop interface can update the model. Company E presented a solution that when dealing with retrofitting buildings with sensors it needs to design and place the sensors in a model for positioning and information placement. One method they believe is effective is to make a laser scanning of the building and create a point cloud that is added to the BIM model to provide an exact replica of the physical environment. All the furniture and systems can then be collected from BIM-objects and added to the BIM model. But that all companies are certain that BIM-model needs to be easy to use for everyone and that the people in the building should be able to make error reports through their smartphone or desktop and the janitor or someone similar should be able to make changes in the model. And there is a concern that the BIM software's are too complex to use without any education in it.

Comparison with literature

When comparing the gathered information from the companies with the theoretical framework, the concerns and uncertainties brought up by the companies regarding lack of competences and updating the digital twin of the physical build in a straightforward way. That there is lack of competencies in a new emerging technology is evident since very few have adopted it yet and it is not a unique problem for adopting BDA and AI in FM. Vinnova (2018) states as one of the biggest challenges for the development in AI and this is also the case for the companies working with the development in Sweden. When it come to the concerns of implementing BIM-models with sensors to create a digital twin and how to effectively update it the companies does not have a complete solution but only embryos of solutions. This can be correlated with Eastman et al. (2012) statement that BIM is a complex process and education in BIM is needed for it to be implemented correctly otherwise it will just lead to more trouble than benefits.

5 Discussion

In this chapter we, the authors, are highlighting some discussions that we have paid some extra attention to, which were brought up from the interviews and literature study, and as well what we think is important when working with Big Data Analysis in Facility Management.

5.1 Competitiveness with Digitalization

The statement that BDA and AI will leave no market untouched and that the FM sector would soon be changes was clear when conducting out interviews. All the companies agreed upon that the implementation of BDA and AI is necessary for companies to maintain their position in the market just like Manyika et. Al. (2011) have stated. We agree with the notion of digitalization being a necessary step forward for FM sector and for the facility owners to succeed and still have a relevance to meet their clients' needs not lose market shares and only becoming a supplier of concrete and glass. The digitalization and especially BDA will give the property owners an important tool and business intelligence to continuously improve their position in the market and taking on the service market and gain new revenue streams.

5.2 Productivity

A discussion that became very central as the thesis went along was how to measure productivity. It was agreed upon by both the companies and the theory that self-assessment is the most accurate measure we have today. But we are certain from our experiences that indoor environment does have an impact on the experienced productivity. For example, it is widely known that high level of CO_2 makes you tired or that high noise makes you stressed and problems to concentrate etc. We also agree with the companies that by making sure to provide good indoor climate there is great gains to be achieved both on productivity but also less complaints from the employees which hopefully will increase the overall atmosphere among the employees. Since it is proven and acknowledged by everyone that good indoor environment is good for the employees we see the use of BDA as a good tool for guaranteeing that the facility always provides good indoor climate. BDA will increase the competitiveness since with data the tenants can complain to the property owner that they are not providing good enough condition or for the property owners to guarantee that they are providing the tenets with good conditions to gain a competitive advantage.

It also became clear that the Swedish companies we interviewed saw four main areas where the implementation of BDA and AI would bring great benefits and gains which is 1) energy optimization, 2) indoor climate improvement, 3) space optimization and 4) more efficient maintenance. The first discussion that was brought up was the balance between energy saving and indoor climate improvement. It is easy to show that by optimizing the energy consumption such as turning off ventilation and lighting when no one is in the room would save the companies money but that could lead to a worse indoor climate that would have a negative impact on the employees. In general, we believe that indoor climate should be prioritized above energy saving since the cost of salary exceeds the cost of electricity. However, according to Company D, 40% of the electricity is wasted while no one is in the room and there are examples mentioned by IBM (2018) of similar cases. So, the main focus should not be to balance the energy saving and user experience, but rather optimize user experience while people are present while saving energy while it is unused. This needs to be autonomous to remove the impact of human behavior, since it is easier to install new technology that solves our built-in laziness than changing the behavior of humans. Thereby the facility management can optimize the indoor climate to receive the most gain from giving the people the best opportunities to perform while also saving energy when the facilities are not being utilized.

Space optimization and more efficient maintenance are also two applications that were brought to change the physical space to better fit the activities and people in the space to increase their productivity and money. The most common example that was brought up was optimizing the use of meeting rooms, that employees often complain that there is a lack of them but at the same time many examples have shown that the utilization rate of the rooms are very low. BDA could provide real time data over to help decision making of optimizing the size of the meeting rooms. This would increase the utilization rate of the office which would save the companies money since they might not need to rent more space. BDA could similarly be used to prove that some areas in a facility have a higher utilization rate and in combination with surveys and interviews with the employees recreate them. When it comes to more effective maintenance the most common example was more effective cleaning. That instead of manually walk around and clean all rooms according to a schedule to only clean room if they have been used which would save time for the cleaners and reduce the times when employees would enter a dirty bathroom or meeting room. Another common example that was brought up is the possibility for employees to submit error-reports in an easy interface “BIM-model” which is an effective visualization tool to specify the location of the error which would save a lot of time for the facility manager or janitor when fixing the error. The use cases and potentials were generally agreed by all parties; however, these have been discussions on how these services would affect the price model for space. The first view is that by providing better indoor climate the tenants will be more productive and therefore be willing to pay more for each sqm and the other view is that with the help of BDA show that the tenant have low occupancy rate and be able offered lower total rent in return for sharing space with other tenants such as big meeting rooms when needed or others utilizing the space on evenings. We see that both of prize models are great use areas of how BDA is can be utilized in FM since they are not conflicting with each other and that different companies will be preferring different price models.

We want to highlight the different approaches the companies have taken to utilize BDA. The general mentality is that BDA can be used as proof and support decision making to strengthen their hypothesis such as low occupancy rate and energy saving. But one of the benefits of BDA that brings up is finding problems that the company did not know existed and that BDA´s main strength is providing accurate data over time to continuously develop over time. We think it is important for the companies to have this in mind when working with BDA. The information that BDA provides should be used for decision making and not making decision and use BDA to prove it was correct.

We also want to highlight the high hopes of machine learning and AI that was mentioned by all the companies. When asking how they viewed the future or how to solve a specific problem it was often referred to “AI will solve it”. We think that there is too high hopes of machine learning and AI, there is a mentality that these technologies will solve all problems and all uncertainties is gathered under “AI will solve it” could be dangerous. Machine learning and AI is not magic and will not suddenly work if we do not actively work with it. For machine learning and AI to function the way we hope great amounts of data sets needs to be collected and algorithms developed that can optimize the data sets into usable business intelligence and control systems. Most of the companies did however experiment with the technology which we believe is essential to stay competitive. With the critical view on expectations we can only agree with company E who stated the following when discussing the autonomous vehicle industry, *"If we can build autonomous cars today, it should not be so difficult to build an autonomous building"*

- Company E

5.3 Property owners manage the technology

After conducting this thesis, we believe that the most reasonable business model for the implementation of BDA in FM is that the facility owners will be the one who pushes the development forward and install the infrastructure necessary in their facilities. We also find it most reasonable for the facility owners to pay for all the installation of the sensors and infrastructure and then the tenants pay for the data. Our reasoning is that it is more scalable and effective approach. A comparison would be to imagine that every tenant would need to install their own ventilation systems for the space they are renting, it would create a chaos and suboptimal solutions. We believe that the inclusion of sensor infrastructure in the rent will be as obvious as ventilation and plumbing going forward. However, there is a counter argument that it is possible for the tenants to be responsible and pay for the installation of sensors since all sensors could be mobile. For this to be possible to be utilized the facility owners needs to allow the tenant to get access to the BIM-model (or Facility Information Model, FIM-model) and the ventilation system to utilize the benefits of creating better indoor climate and energy saving. This could be possible, but both the property owners we interviewed clearly stated that they do not want to have external parties interacting with their systems to improve and adjust the HVAC or other systems. However, both companies are big property owners and are both willing and can pay the for the initial investment while this might be an issue for smaller property owners and for those cases the second alternative might be a more suitable solution.

There have been discussions whether the services that BDA and IoT brings is profitable or not. Some companies argue that energy optimization and space optimization is the applications which could be profitable while others argue that every investment that could increase the productivity or well-being of the employees are profitable. When it comes to services such as installing sensors in trash cans and other equipment's the companies believed that it most likely is not profitable yet but there will be a break-even point in a few years which will lead to us seeing such "small" applications as well. It has also been mentioned in the literature from Sendler (2018) that there is interest from manufacturers to provide services such as subscriptions of refilling and repairing equipment. So, it might not be the property owners that will be providing these services. However, we believe that services such as creating better indoor environment and energy saving will begin to find traction and be rewarding within the coming year. Further we fully agree with one of the interviews stating that

"we first need to focus on developing the infrastructure and the use cases that could pay off the initial investment to fund future developments"

- Company A

5.4 Communication

We also want to highlight the importance of having an infrastructure to support IoT that enables BDA. The gathering of data in facilities are being done with a variety of sensors, data from HVAC systems, sensors integrated in HVAC-systems and mobile sensors creates the need for the ability to communicate between systems. The communication has proven to be necessary to be able to combine data from different sources as well as collecting all data in one single place for storing and processing. Without the ability to communicate the people working with buildings would be as limited as they are today working with several different systems to perform their job as described by Shalabi & Turkan (2017). The two property owner interviewed working with the development of BDA in FM are therefore developing an ontology, Real Estate Core, which translates the data from different sources into a standardized “language”. When looking at the different ways of working we see no other way other than using an ontology to be able to combine data from the different sources present in a facility. We think that it is essential that the path chosen by company A & E to develop their ontology as open source since this allows for broader adoption. This also invited other facility owners to getting started working with sensors and BDA in their facilities to reach wide adoption. The ontology and surrounding interfaces are being developed with open standards and completely free of proprietary technology or software, the basis is developed and coded so that it can be moved to different cloud platforms if the need or circumstances change and requires that.

The software that Company A & E are developing allows third parties to develop application from the ontology through APIs. It is proven by many industries that it is impossible to develop all services on their own and that letting third parties help in the development. An example is the web, every web service providers such as Amazon Web Services (AWS) could close down their service and develop every web page themselves, which would lead to them owning a lot of web pages. But by doing that the development would slow down and the web would not be as widely adopted. We are certain that if the FM sector want to reach a broad adoption it needs to invite their parties to develop application for it. So, if more facility owners utilize this open standard with standardized API´s for accessing data, having a standard way of naming and denoting data then these third-party service providers can sell their service to customers renting from different facility owners without having to develop a completely new product solving the same issue.

Another question where the companies interviewed had differences was whether gathered data should be made open or be protected. When breaking down the arguments and reasons for the different views, it turned out that very little actually differentiate them. All see the benefit of releasing data so other can help them find actions which could increase efficiency or to help other realize issues with their properties in comparison. The critical thing brought up is which data cannot be open and accessible? That question is certainly difficult to generalize on and will have a unique answer in every instance, but the solution presented to be able to control each data stream going out from the closed interface and being able to stream any and all data if it is wanted is an excellent solution to be able to share and to protect the data.

5.5 Uncertainties

Some other discussion that have come up during the interviews is whether it is more beneficial to have integrated or mobile sensors. The main arguments for integrated sensors is that it is convenient and there is already some infrastructure provided for it from the manufacturers. On the contrary it is more expensive and harder to repair/replace if something does breaks. There is also the argument that the sensors are developing in a more rapid pace then the systems they are installed in which creates a lock in effect of being stuck with older technology. From our perspective we believe that integrated sensors will be more common in the future simply because of the convenience. But as for now when the technology is still under rapid development it would be more economically beneficial to install mobile sensors until the development rate of integrated sensors have slowed down enough and since it brings more flexibility.

We also want to highlight a controversial view that have been brought up in during the interviews which is integrating sensors with the BIM model. All companies are the theory is mentioning that BIM is excellent at visualizing and transferring information. However, all companies have stated that the BIM model needs to be easy to interact with for everyone without any knowledge of BIM. That model would then not a traditional BIM model according to Eastman et al. (2012). Our interpretation of what the companies refers to is a second's layer of BIM where the user does not need to interact with the BIM model but a separate layer that is sending the information to the BIM model or a separate model that is used only for the FM phase which could low level of detail but keep a high level of information. We see a close relation to what the companies are describing with the solution Zynka BIM refers to as the FIM model. We do not believe that the BIM-model is necessary in the FM phase but only a simple 3D-model that can be integrated with BIM. We also believe that laser scanning is an easy solution that allows facility owner to easily create a FIM-model even if they do not have a BIM-model which most older buildings does not have, which could be a solution to otherwise a major hindrance.

The lack of people with the competences is as for so many other industries one of the greatest hindrances for the development and implementations of BDA and AI in FM. This will always be an issue for all industries that is new. The solution that we see to this is the traditional model of supply and demand. BDA and AI are two emerging technologies that will leave no industry untouched, so to attract the skilled people with the right competences you need to provide something more than other industries does which could be either financial instruments, challenges or some other soft factor. So, it is understandable that the bigger and more disruptive industries such as software companies attract the skilled employees compared to the construction and FM sector which is well known for being conservative. Another area of competence that are changing is the one of the facility technicians working physically with the building and its systems and the development of digital tools and BDA which have been discussed by the companies and literature. Vinnova (2018) see that the technicians handling the building need to acquire deeper knowledge and understanding of how to work with AI and BDA in facilities, they saw the easy way being to teach engineers from technical colleges with education in AI and BDA practical knowledge of how to manage buildings. The companies interviewed have seen the need to upgrade the competence but in different ways, from replacing the person with one carrying higher competence to creating new positions which manage the information and digital aspect of the current and future tasks. We believe that there is a place for a new role managing the information and "soft" sides of the buildings, that could be to have an information/digital technician responsible for maintaining the information and digital control of the building.

Issues with privacy is always an important topic to take seriously since the reaction and opinions of humans usually are what decided if something will thrive or even survive. Data being gathered from people which can identify and reveal things about this person is important to safeguard and we think the organizations which collects and process the data have a responsibility to safeguard it and to be open and honest about the implications and uses of it. The shift between closed and open data are perhaps not as dramatic as it can seem, our overall view is that the data must be protected and secured so that sensitive data cannot be unauthorizedly accessed. But the idea of safeguarding data for the sake of it might be contra-productive since the benefit of having others to use your data to compare and analyze to help you find solutions for streamlining processes and systems. The literature has been quite clear in that some information are more sensitive and therefore important to safeguard than other, where information from facilities would fall is somewhat unclear. We see that a shift could be where the facility owners drew the line, can you identify an individual or is all data anonymous and still would be anonymous if aggregated with other sources.

6 CONCLUSION

The purpose of this thesis was to investigate how Big Data Analysis (BDA) can be implemented in Facilities Management (FM) and what challenges it is facing. This was achieved by conducting interviews with companies in Sweden that are either developing implementation areas or are working with project related to BDA in FM. The aim of the thesis was to answer the two research questions which are summarized in this chapter, the questions are answered in separate paragraph.

How can Big Data Analysis be implemented in Facility Management?

The companies developing or working with BDA implementations in the FM sector in Sweden and the literature found connected to the topic have led the authors to the conclusion that there are 4 implementation areas of BDA in FM which are 1) Energy optimization, 2) Better indoor climate, 3) Space optimization and 4) More efficient maintenance. The main goal behind the implementation for the companies have been financial incentives either through decreased expenses of energy, increased revenue from rent or new services, but the main argument was in increasing the productivity of employees. It is known that employee cost is the greatest expense in a building (often around 90-95% while rent, energy and other costs only represents around 5-10%. Therefore, the greater gain will be in creating a workspace where employees can work more efficient. Consequently, the main focus in Sweden are indoor climate by utilizing sensors, BDA and AI in combination with the HVAC-systems to automatically maintain a good indoor climate. There are in the industry high hopes for utilizing Artificial Intelligence (AI) to control the process of maintaining the indoor climate in the future, however there is a general understanding that the AI development is in an early stage and have a long way to go before being adopted broader.

What challenges does the implementation of Big Data Analysis face in Facility management?

The thesis has uncovered 5 main challenges in the implementation of BDA in FM which are 1) hard to calculate returns 2) lack of competence, 3) lack of standards, 4) maintaining the digital twin and 5) ethical and regulatory questions. The first concern deal with the inability for actors to calculate the returns from different applications for BDA in FM to argue for the investment since it is hard to prove the gains mainly from the increasing productivity and well-being. The second concern is the lack of competence which refers to both the knowledge among people that are working with the new technology such as the facility managers as well as people that are capable of developing the systems. The third concern is that the implementation of the technology is in an early stage so there are no standards to follow, which creates a situation where each company are developing their own. However, the interviewees are certain that standards will appear as the implementation continues. The fourth concerns are how to visualize and update information, the BIM-model was frequently mentioned as a tool to store and visualize the information in, but the BIM-model is difficult to update for someone without experience or training, so a user-friendly model, a Facility Information Model (FIM-model), where everyone could submit error reports and for someone like a janitor or facility managers to make the updates need to be established. The last concern is regarding ethics and regulation of storing and handling information about individuals. Generally, no information about individuals are stored, only about the usage of the building, but more advanced sensors and cameras where individuals can be identified will raise discussions in the future.

6.1 Future research

At the time this thesis was conducted we did not come across any published research that could prove the real value for BDA in FM, there were however a few case studies that indicate that there where gains to be made. We expect that there will be many more studies published with in this area the coming few years. This thesis was mainly focusing on identifying implementation areas and trends are in the Swedish market and what challenges the technology faced during implementation. Future research could include studying different methodologies within each use case and compare the result to establish standards and finding optimal solutions. Some examples of topics could be: Integrated sensors in the building vs mobile sensors; Make calculations on energy saving achieved by including external data such as weather or schedule data; Case studies to study how people are reacting to different indoor climates and its impact on productivity.

7 References

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8 Appendix

8.1 I – Interview questions to Company B

Introduktion

1. Berätta om din roll på Akademiska Hus?

Dagens system i Fastighet A

2. Hur fungerar systemet i fastigheten idag? (ventilation, belysning, elförbrukning och användandegrad av rum)
   a. Samlar ni in data, i så fall vilken data?
   b. Annars. Varför samlar ni inte in data?
   c. Hur styrs systemen idag?
   d. Hur analyseras den insamlade datan?
3. Vilka problem finns det med förvaltningen av SB idag?

Förvaltning och Digitalisering

4. Vad saknar du för att kunna förvalta mer effektivt och med bättre resultat?
   a. Vilken information saknar du för detta?
   b. Hur skulle denna information kunna samlas in?
   c. Varför samlar ni inte in informationen?
5. Vad är dina tankar kring digitaliseringen av byggnader och hur det påverkar förvaltningen?
   a. Fokus på mätdata från byggnader?
   b. Vilka för- och nackdelar ser du?
   c. Vilka problemen finns det med processen att anpassa byggnaderna till dina slutanvändare?
6. Vilken data samlar ni in?
   a. Hur samlas datan in?
   b. Hur används den datan?
   c. Hur analyserar/sammanställer ni den?

Framtidens system i Fastighet B

7. Berätta om hur förvaltningen kommer fungera i Fastighet B? Med fokus på det vi pratat om.
   a. Vad är målet men projektet?
   b. Vilka jobbar ni med?
   c. Vilka problem stöter ni på?
   d. Vilka sensorer kommer att användas?
   e. Vilken information kommer sensorerna samla in?
   f. Hur kommer informationen presenteras?
   g. Hur kommer informationen analyseras?
   h. Hur kommer information användas?
   i. Vilka problem stöter ni på?

Framtiden

8. Vilka användningsområden ser du för datan från sensorerna samt analysresultaten?
    a. Är det rimligt att se den insamlade datan som en tillgång? (pengar)
    b. Är det något som kan säljas
    c. Effektivisering användandet av byggnaden?
    d. Beslutsunderlag?
    e. Lära känna användarna? (Integritet?)
    f. Säkerhet?
    g. Konkurrensfördel?
9. Vilka hinder/problem finns det för sensorer i byggnader idag och i framtiden?
    a. Finns det några lagar/regler som måste tas i beaktning med tekniken?
    b. Integritet, moral, etik?
    c. Möter tekniken motstånd?
10. Vilka områden inom bygg tror ni kommer implementera tekniken först (konsulter, fastighetsförvaltare, byggare, fastighetsägare eller användaren)?
    a. Vilka aktörer är kritiska för att tekniken ska nå en bred användning?
11. När tror ni att vi kan se bred användning av tekniken?
    a. I organisationen
    b. I branschen
    c. I samhället

8.2 II – Interview questions to Company A, C, D and E

Introduktion

1. Berätta lite om din roll på företaget
2. Hur jobbar ni med digitalisering inom FM?
3. Vad är problemen ni försöker lösa genom digitalisering / IoT
    a. Vad tänker ni att kan tekniken kan lösas?
    b. Hur kan insamlad data användas för att lösa era problem?

Digitalisering och IoT

4. Berätta om ert projekt.
    a. Varför startades projektet?
    b. Vad är målet men projektet?
    c. Vilka jobbar ni med?
    d. Vad gick som förväntat?
    e. Vad upptäckte ni som ni inte tänkte på innan?
    f. Vilka problem stötte / stöter ni på?
    g. Ifall ni fick göra om projektet vad hade ni gjort annorlunda?
    h. Vilka lärdomar tar ni med er?
    i. Vad har ni haft för nytta / värde av projektet?
    j. Hur kommer ni gå vidare med projektet?
5. Vilka sensorer använder ni?
    a. Vilken data samlar ni in och planerar att samla in? (Vad mäter sensorerna)
    b. Hur fungerar sensorerna?
    c. Är systemen/tekniken öppet eller slutet?
    d. Kostnad/prisvärt
    e. Lätt att installera och använda?
    f. Vilka problem stötte ni på med sensorerna?
    g. Vad kan förbättras med sensorerna?
    h. Vilka begränsningar har ni identifierat
        - I Hårdvaran
        - I organisationen
6. Hur hanterar och analyserar ni datan?
    a. Vilken plattform används?
    b. Hur fungerar användargränssnittet?
    c. Vem äger datan? Operatören eller fastighetsägaren?
    d. Är den datan öppen för alla eller stängd?
    e. Är plattformen kompatibel med andra datainsamlingsverktyg?
7. Har ni andra projekt där ni jobbar med sensorer?
    a. Är det någon skillnad mot tidigare projekt?

Framtiden

8. Vilka användningsområden ser ni för datan från sensorerna samt analysresultaten?
    a. Lärdomar som andra kan dra från er data?
    b. Effektivisering användandet av byggnaden?

c. Beslutsunderlag?
d. Lära känna användarna? (Integritet?)
e. Säkerhet?
f. Konkurrensfördel?

9. Vilka hinder/problem finns det för sensorer i byggnader idag och i framtiden?
   a. Finns det några lagar/regler som måste tas i beaktning med tekniken?
   b. Integritet, moral, etik?
   c. Möter tekniken motstånd?
10. Vilka områden inom bygg tror ni kommer implementera tekniken först (konsulter, fastighetsförvaltare, byggare, fastighetsägare eller användaren)?
    a. Vilka aktörer är kritiska för att tekniken ska nå en bred användning?
11. När tror ni att vi kan se bred användning av tekniken?
    a. I organisationen
    b. I branschen
    c. Vad kan tekniken göra för samhället