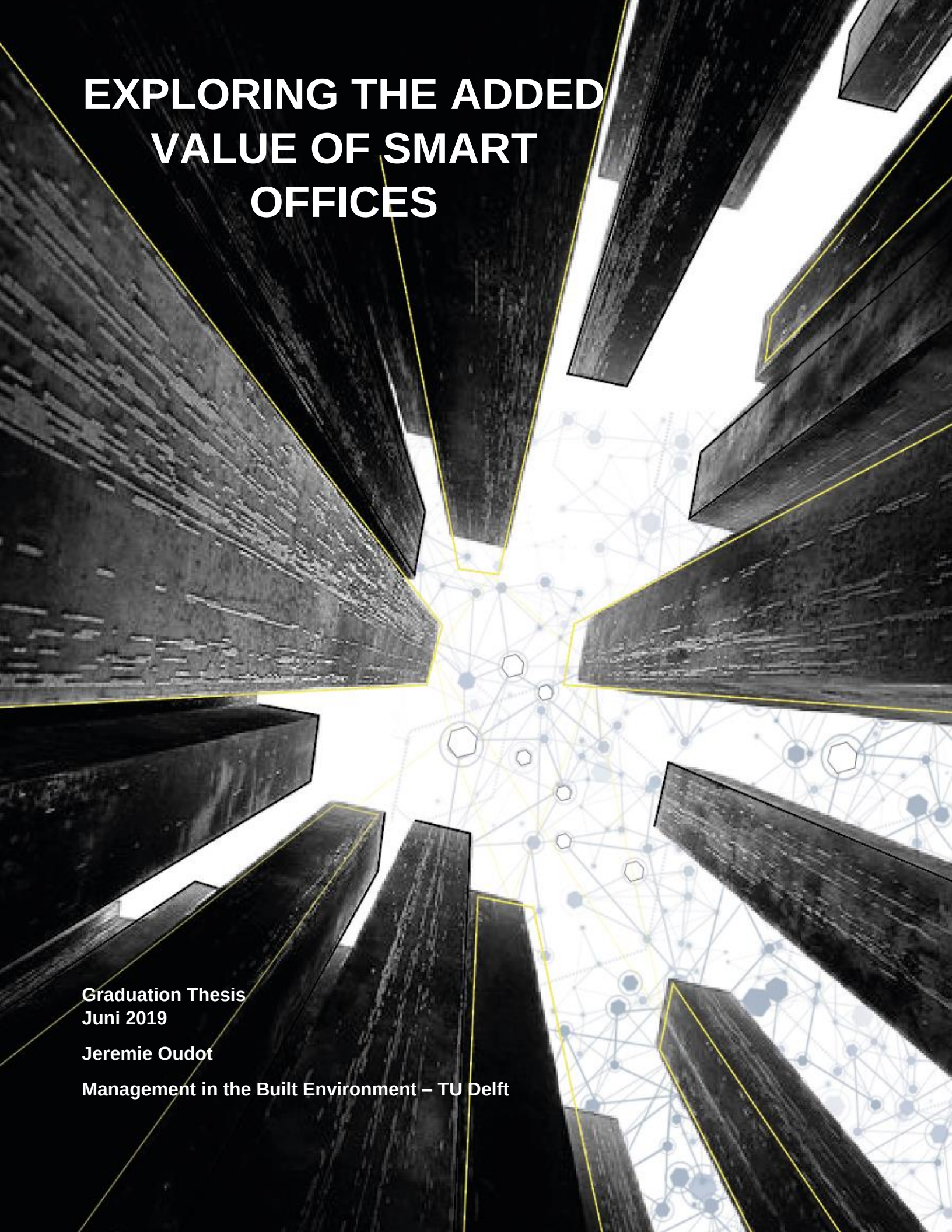
EXPLORING THE ADDED VALUE OF SMART OFFICES



Graduation Thesis
Juni 2019

Jeremie Oudot

Management in the Built Environment – TU Delft

Foreword

My interests in smart buildings were sparked by the famous Edge office in Amsterdam. The way office users gain control over their workplace, using the building as a data farm and increasing the efficiency through that collected data was something that interested me instantly the first time I heard about it. At the same time, real estate investment interested me as well. By combining the two topics, smart offices and real estate investment I wanted to touch upon two of my interest.

So, in the end I started to research *how* property technology could be of value for, specifically, the real estate investors. In the end, hopefully, even the most traditional investors can be convinced to invest in smart technologies making our offices, and everyday lives, smarter.

I would like to thank the following persons for helping me achieve the results of this graduation research:

Both my mentors, Hilde Remøy and Philip Koppels for the time they have committed to helping me and their feedback and advice they have given me in the past few months. Ilir Nase who jumped it at the end as a mentor for my P4 and P5 presentations.

All the interviewees that took time out of their busy schedules to answer my questions, specifically Imardo de Blok who set up the interviews I did for The Edge Olympic case.

The participants of my Expert-panel for their time invested in helping me during the last weeks of my research.

PingProperties, and especially Sander Rovers, for helping me improve and structure my graduation thesis.

Debby, for helping and supporting me throughout this whole process.

Lastly, I would like the thank the person reading this, thank you for being interested and I hope you like this research, good luck reading!

Kind regards,

Jeremie Oudot

Tutors: Hilde Remøy and Philip Koppels.

MSc. Management in the Built Environment
Faculty of Architecture and the Built Environment
TU Delft, The Netherlands.

Jeremie Oudot
4287649
jeremieoudot@gmail.com
+31614923946
Delft, The Netherlands

Image 1. Picture of Jeremie Oudot. Credits: Jeremie Oudot.

Table of contents

Chapter 0. Research summary

Abstract

Purpose. This research has two purposes. Firstly, by researching the added value of smart offices, the adoption rates of smart office in the real estate supply might be increased which will contribute to a future proof building stock. Secondly, this research fills the gap in existing literature through adding new insights on smart real estate which are currently lacking in the academic environment.

Aim. The aim of this research is to connect the core objectives of real estate investors to smart offices. This is done through combining investor objectives, added values and the effects of smart applications found in smart offices in one holistic Smart Value Map.

Main question. The main question of this research is: *How can the implementation of smart technology in office buildings provide added value to real estate investors?*

Methods: The investor objectives and added values are researched through literature review. The smart applications and smart offices are research through the analysis of three different smart office cases. The information for the cases is gathered through conducting interviews with stakeholders whom are involved with the smart office cases. Furthermore, a Expert-panel will explore the perceived usefulness of smart applications and the importance of the added values as a result of the implementation of smart technology in office.

Findings: The core objectives of an investor are either increasing income, decreasing costs or increasing asset value. Smart applications in smart offices either directly or indirectly contribute to the core objectives of an investor. For example, cost reduction can be achieved by gathering information on the current usage of a building through implemented sensors and then automatically adapting climate systems to the actual use. This means that climate systems are only consuming energy when necessary, improving sustainability and decreasing energy costs.

Limitations: Due to the fact that smart offices are a new phenomenon, and have only recently been developed, quantified information for analysis is limited and inadequate. The Smart Value Map therefore remains unquantified and somewhat based on assumptions and expectations. Interestingly however, some positive effects on for example the rental levels have been discovered.

Relevance: Employees and tenants are increasingly vouching for smart office space as their preferences steer towards workplaces where technology provides for better work environments. This results in the need to stimulate the adoptions rates of smart offices to contribute in the reduction of future obsolescence in the real estate supply.

Keywords: investor, smart office, smart applications, added value, user.

Introduction

Ever since around the 1760's large scale changes in the real estate industry due to major technological advancements have resulted from the so called 'Industrial Revolutions' (Crouzet, 1996). Currently, in 2019, the Fourth Industrial Revolution, marked by the integration of technology with physical and digital space is taking place, once again leaving its mark on the real estate industry (Schwab, 2016).

This revolution significantly impacts the daily lives of humans, making them increasingly advanced when it comes to technology. Slowly, but surely, the technological advancements influence the consumer demand, steering towards rising adoption amongst consumers until a plateau is reached and the instated technology becomes standard. As such these innovative influences also impact the demand and supply of the commercial real estate market and its leaders (figure 2).

Figure 2. the 4th industrial evolution influences supply and demand. Icons by PowerPoint.

Problem statement

The core of the problem is the risk of obsolescence resulting from a mismatch between supply and demand. Due to the negative consequences of obsolescence in the current real estate supply it is necessary to take steps towards a match between future demand and future supply. This match can only occur only if the supply follows the changing demand. If the demand of the consumers is increasingly implying for the need for technological advancements, which are driven by the popularity of smart technologies, the supply must follow suit and adopt smart building developments.

However, due to the innovative nature of smart technology the benefits are for the majority still unclear, unproven or undiscovered. This, in combination with the capital-intensive characteristics of real estate objects and the traditional and risk averse mindset of real estate investors leads investors to opt for a more known route instead of a new and uncertain investment in smart offices.

This brings us back to figure 3. The demand is changing rapidly but the supply is not, this results in functional or social obsolescence leading to vacancy and an unhealthy office supply. To avoid any obsolescence in the office supply stock and make sure that the preferences of the users are represented in the supply the smart office adoption rates must be increased. If this does not happen the chances are that tenants will leave their non-smart office behind and seek office space elsewhere, creating vacancy.

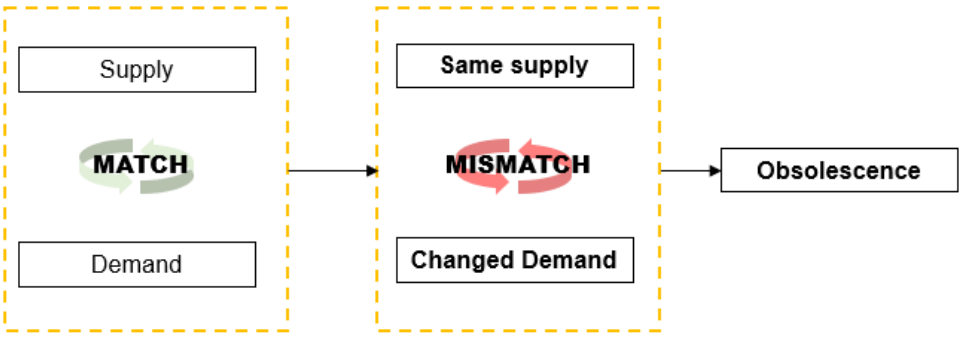


Figure 3. The mismatch that leads to obsolescence (Own ill.).

Aim

The aim of this research is to reduce the future risk of a mismatch in the office sector by potentially increasing the adoption speed of smart office. This can be done by providing information on the benefits of smart buildings in order to decrease the perception that technology is a risk instead of an opportunity, and to provide a substantiated foundation for informed decision. This research targets the investors, who represents the supply side (Remøy, 2010) in order to increasing the adoption rates on the side of the market where it is slowest.

Figure 4. The smart value map (Own ill.).

The deliverable of this research is a qualitative Smart Value Map that connects investor objectives to smart offices. This will be done in multiple steps, substantiated by multiple research methods. The figure above (figure 4.) shows connections that must be made in order to connected smart office to the investor.

The goal is for this map to be used by investors to see if a smart office contributes to their core objectives. This can convince or incentives them to invest in smart technology during redevelopment or new constructions.

Research Questions

To achieve the research goals, the following research question, and sub-questions have been formulated:

Main question: *How can the implementation of smart technology in office buildings provide added value to real estate investors?*

In order to answer the main questions of the research several sub-questions are asked to ensure that the relevant topics are covered and combined:

1. What is smart technology in relation to office buildings?
2. What is the effect of implementing smart technologies in office buildings?
3. What are the objectives and constraints of the real estate investor?
4. What is added value?

Methods

The value map will be constructed through the following research methods.

1. **Literature review**. Through the literature review a theoretical framework is constructed that will provide the first part of the value map. The relevant stakeholders and their objectives as well as the added value parameters will then be researched. This will result in the connection between stakeholder, objectives and added value. The literature review will also provide theoretical knowledge on the concept of smart buildings and smart technology.

2. **Case studies.** The case studies will provide the second part of the value map; the smart application and the smart technology. Furthermore, the case studies will be used to study the effects and results of the implementation of smart applications in office buildings. This will create the link between added value and smart applications.

3. **Interviews.** The interviews will be used to collect in-depth information necessary to construct the case studies and will therefore contribute to finding connections between smart technology and investor objectives.

4. **Expert panel.** A Expert panel will be organised to gather consensus on the importance and benefits of the value parameters and smart applications found in literature and the case studies. This will further substantiate the claim that smart buildings hold value.

Literature review findings

Theoretical framework

The theoretical framework consists of the findings obtained from the concluded literature review which is divided into three topics: technology and smart buildings, added value and stakeholders.

Technology and smart buildings

The literature review provides a theoretical overview of the key features of a smart building. Figure 5 shows this overview and highlights the four most important aspects.

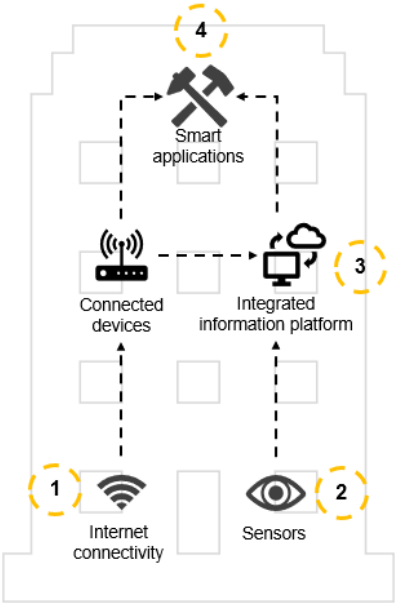


Figure 5. Smart office concept. Icons by PowerPoint.

A smart office collects and sends data (Shulman, 2014) by using:

1. **A Communications network** (Zsebik, no date)
   To enable connected devices to send and receive data. This creates a network of devices that can interact with one and other.

2. **Sensors** (Zsebik, no date)
   The sensor technology is used to detect and respond to input from the physical environment. This provides environmental processes (Arditi, 2015)

And enable the improvement of efficiency (Shulman, 2014) with:

3. **Intelligent controls** (Zsebik, no date)
   These controls are required to manage the whole system. These intelligent controls are complex software that gathers, processes and transforms data into information.

4. **Smart applications** (Zsebik, no date)
   These are the features that have impact on the building processes. These applications use the information provided by the intelligence controls. The use of smart applications is what makes a building smart (Nouveau, 2017).

Added value

In total 11 added values are defined through analysing existing literature. These value parameters can directly or indirectly contribute to the objectives of stakeholders. The way to increase or impact the values has been researched for each of the added values in order to 'connect' them with the effects of the smart applications. Figure 6 shows an example of one of the eleven added values, and how it can be increased or impacted.

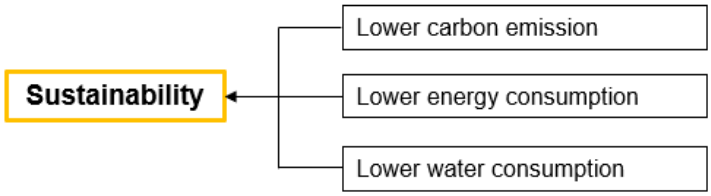


Figure 6. the added value 'sustainability' (Own ill.).

As seen in figure 6, sustainability is seen as an added value and can be improved by lowering carbon emission, energy consumption or water consumption. If one of the smart applications can achieve any of the three improvements, it is of benefit for the sustainability objectives of an investor.

The Investor

Since an added value is essentially only valuable if it contributes to one of the core objectives of a stakeholder it is important to research the main objectives of the investors and other relevant stakeholders. The core objectives of an investor, who is the stakeholder that represents the supply side, are the increase of asset value, the increase of income or the reduction of costs.

The User

The demand side of real estate is represented by the user. In this research the user is defined as the employee and the (corporate) tenant. Both are very important to the investor. The tenant is vital to the investor since it provides the rental income, which is the investors main source of income. The employee executes the core business of the tenant and is therefore vital for the tenant. The investor has to keep the tenant satisfied in order to guarantee his long term income. The tenant has to keep the employee satisfied in order to keep it's business running.

Conclusion of literature review

Figure 8 shows the part of the value map in which the added values that have a direct impact on the investor's core objectives can be found. Figure 8 is read from right to left and illustrate how a certain measure or process influences an added value. The added values are marked in orange.

An example of how the map can be read follows. As is seen in the value map indicated by the black arrow in figure 8 achieving higher tenant attraction will decrease the risk premium of an asset. A lower risk premium increases the asset value. If a certain measure can increase the attraction of tenants, it can ultimately contribute to a higher asset value which is a core objective of the investors.

As is seen in Figure 8, the investor core objectives can directly be linked to the following added values: Adaptability, Sustainability, Satisfaction, Risk and Branding. Improving any of these 5 added values will, in accordance to figure 8, either reduce costs, increase income or increase asset value. Therefore, linking investor objectives with added values.

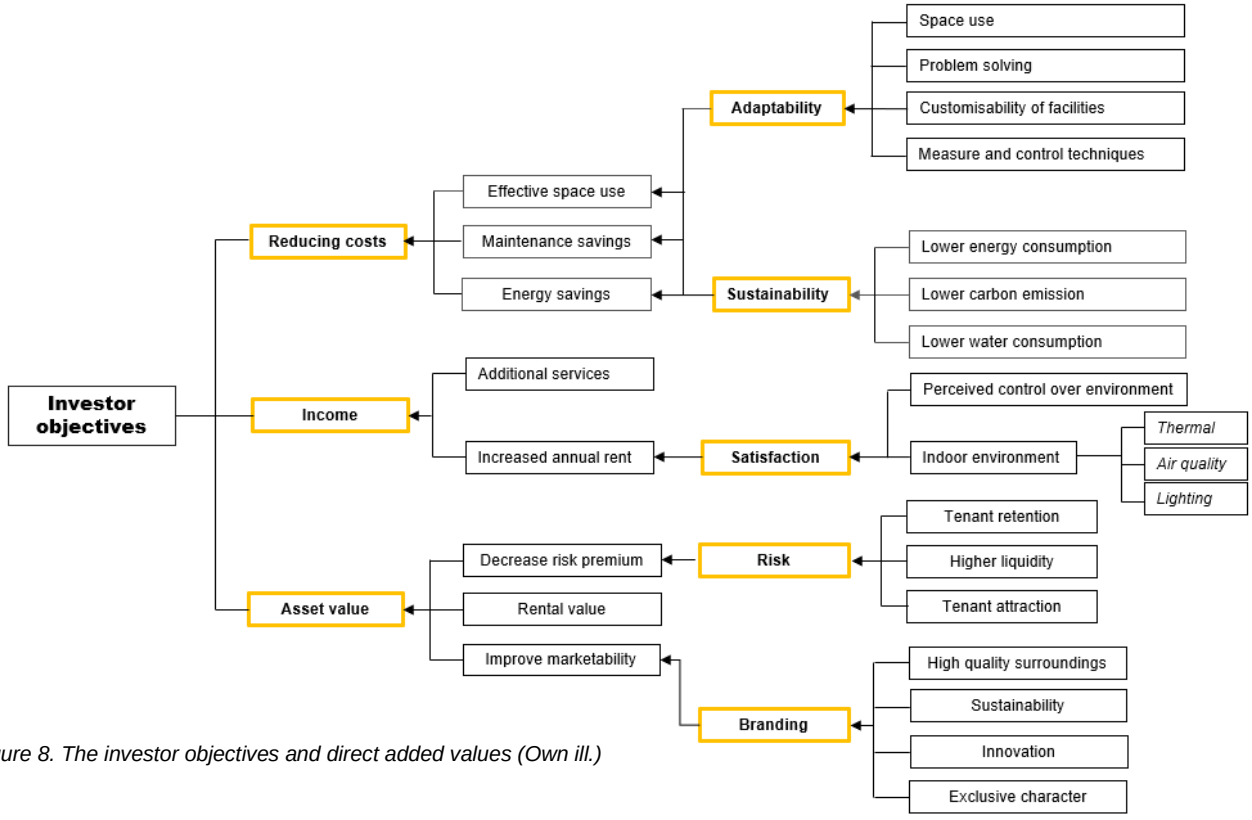


Figure 8. The investor objectives and direct added values (Own ill.)

Case study results

In total, three cases have been extensively research through conducting interviews and through reviewing case documents. The findings of the cases can be found below.

Figures 9, 10 and 11 show the findings of the three cases. The Outcome column shows the smart applications that are found in the cases and the Output column shows the added values that are impacted or improved through the smart applications.

The Edge

The smart applications are enabled through the use of sensors and internet connectivity. The data that is collected by the sensors, connected devices and external sources is stored in a Data Lake. The data in the Data lake is then analysed by various smart controls (software) that transform the data into legible information. This information is then used to improve building processes through the smart applications. Simultaneously, the connectivity network allows users to directly interact with building systems and installations, enabling even more smart applications.

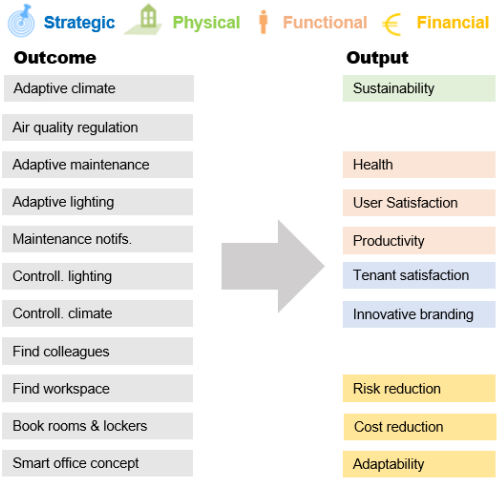


Figure 9. Findings of The Edge Case. Icons by PowerPoint

The Outlook

The processes and smart applications in The Outlook are similar to those found in The Edge. The main difference is the fact that The Outlook does not use a data lake but directly uses the collected data through the smart controls. The smart applications are similar, but less varied.

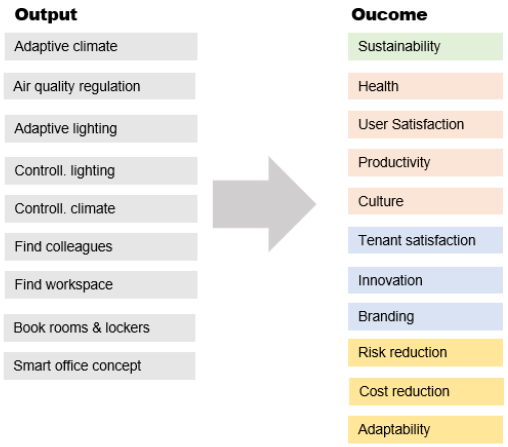


Figure 10. Findings of The Outlook Case. Icons by PowerPoint

The Edge Olympic

The Edge Olympic is, according to its developer, the first of a new generation of smart offices. This is mostly seen in the inside processes. The smart applications are mostly the same as those seen in the Edge and The Outlook. The processes in The Edge Olympic are more integrated and use one single software application together and analyse the data.

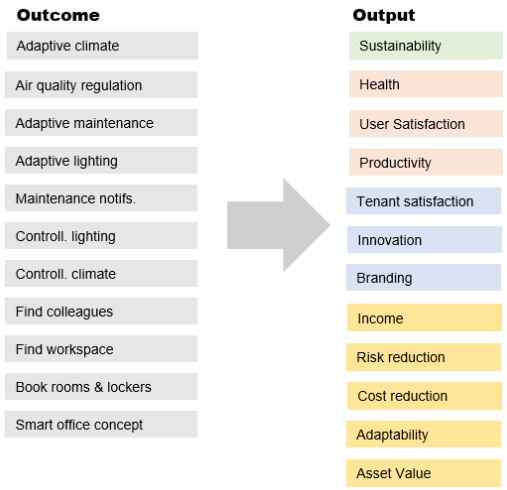


Figure 11. Findings of The Olympic case. Icons by PowerPoint

Cross case analysis

The findings of the three cases are compared and combined through a cross-case analysis. This has resulted in one overview that covers the three cases. The overview has the same structure as the case summaries. This complete overview is then compared to the findings extracted from the earlier carried out literature review and Expert-panel.

Figure 12 and 13 show the results of the cross-case analysis. Figure 12 shows the overview of the smart applications, and figure 13 the overview of the added values impacted by the smart applications. The numbers indicate the frequency in which the applications or values have been identified in the cases.

The Edge	The Outlook	The Edge Olympic	The smart applications	
Adaptive climate	Adaptive climate	Adaptive climate	Adaptive climate	3
Air quality regulation	Air quality regulation	Air quality regulation	Air quality regulation	3
Adaptive maintenance		Adaptive maintenance	Adaptive maintenance	2
Adaptive lighting	Adaptive lighting	Adaptive lighting	Adaptive lighting	3
Maintenance notifs.		Maintenance notifs.	Maintenance notifs.	2
Controll. lighting	Controll. lighting	Controll. lighting	Controll. lighting	3
Controll. climate	Controll. climate	Controll. climate	Controll. climate	3
Find colleagues	Find colleagues	Find colleagues	Find colleagues	3
Find workspace	Find workspace	Find workspace	Find workspace	3
Book rooms & lockers		Book rooms & lockers	Book rooms & lockers	2
Smart office concept	Smart office concept	Smart office concept	Smart office concept	3

Figure 12. Findings of the cross case – smart applications. Icons by PowerPoint

Strategic Physical Functional Financial

The Edge	The Outlook	Edge Olympic	Added values	
Sustainability	Sustainability	Sustainability	Sustainability	3
Health	Health	Health	Health	3
User Satisfaction	User Satisfaction	User Satisfaction	User Satisfaction	3
Productivity	Productivity	Productivity	Productivity	3
Culture	Culture		Culture	2
Tenant satisfaction	Tenant satisfaction	Tenant satisfaction	Tenant satisfaction	3
Innovation	Innovation	Innovation	Innovation	3
Branding	Branding	Branding	Branding	3
Risk reduction	Risk reduction	Risk reduction	Risk reduction	3
Cost reduction	Cost reduction	Cost reduction	Cost reduction	3
Adaptability	Adaptability	Adaptability	Adaptability	3
		Asset Value	Asset Value	1
		Income	Income	1

Figure 13. Findings of the cross case – added values. Icons by PowerPoint

Expert panel findings

The most important Expert panel findings are found in figure 93 and figure 94. The participants of the Expert panel were asked to rank, in two different rounds, the added values found in the literature review based on their importance.

Figure 93 shows the results and as is seen the added values 'Satisfaction' and 'Sustainability' are perceived as most important by the participants of the Expert-panel. The differences between round 1 and round 2 are due to the participants having the opportunity to change their own answers of round 1 when confronted with the group average of round. As can be seen the top two spots remain unchanged but there is a slight switch between health and productivity and risk and culture.

Ranking round 1	(Geomean)	**Ranking round 2**	(Geomean)
Satisfaction	**7,1**	Satisfaction	**7,3**
Sustainability	**7,0**	Sustainability	**6,9**
Health	**5,7**	Productivity	**6,7**
Productivity	**4,8**	Health	**5,9**
Adaptability	**4,8**	Adaptability	**4,0**
Branding	**4,7**	Branding	**3,9**
Risk	**4,2**	Culture	**3,8**
Culture	**2,8**	Risk	**2,8**

Figure 93. Expert panel-results: importance of values. Own ill.

In line with these results, keeping tenants and employees satisfied and achieving better sustainability have been important values that have led to the development of the smart office researched for the case studies.

The second questions that the participants answered led to the results found in figure 94. The participants were asked to score the smart applications based on the perceived usefulness. As can be seen in the figure, the adaptive lighting and climate applications are seen as most useful. The applications to find colleagues throughout the office is seen as least useful. Due to the fact that not a single participants changed their scoring in the second round of the Delphi panel, there is no change in ranking between the first and second round.

Smart application	**Score**	**Geometric mean**
Lighting adapt.	92	8,4
Climate adapt.	89	8,1
Controll. climate	71	6
Maintenance adapt.	68	5,8
Controll. lighting	63	5,4
Maintenance notifs.	63	5,3
Room & Locker booking	55	4,2
Workplace finder	57	4
Colleague local.	48	4

Figure 94. Expert panel-results: usefulness of applications. Own ill.

Most important take-aways

The most important take always of the expert panel is the fact that satisfaction is seen as most important out of the eight values the were presented to the participants. This resulted in the conclusions being adapted towards showing how smart offices can increase the satisfaction of the user; the employee and the tenant.

The theoretical framework showed the importance of asset value and cash flow, but the expert panel and the cases showed the importance of keeping the tenant satisfied.

Conclusions – Answering the sub-questions

Sub question 1: What is smart technology in relation to office buildings?

Through the performed literature review and the findings of the case studies the following description of smart technology in office buildings has been made:

Smart technology in smart office refers to the integration of sensor technology and internet connectivity throughout the building. The sensor technology gathers environmental data on the states and activity in the office building. The internet connectivity creates a network between systems, installations and devices that allow for interaction and the sending and receiving of data. The collected data is then gathered and processed by integrated software platforms that are used to analyse the data and transform it into information. This information can then be used through smart applications to influence building processes. Furthermore, through the connected network user can directly interact with installations to influence their environment. The smart applications that enable the interaction and influence the building processes are what ultimately provides value, and are listed below:

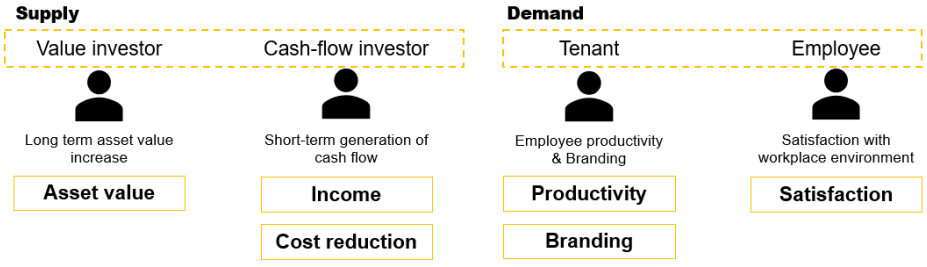
- Climate systems that adapt automatically depending on whether space is being used.
- Lighting systems that adapt automatically depending on whether space is being used.
- The automatic regulation of ventilation based on carbon dioxide concentration in the air.
- Maintenance notifications sent by devices before they need maintenance.
- Lighting installations that can be controlled by users through a smart phone application.
- Climate installations that can be controlled by users through a smart phone application.
- A colleague localisation function that enables users to find co-workers throughout the offices.
- An empty workspace function that enables users to find empty workspace throughout the office.
- A function that enables users to book rooms and lockers through their smart phones

Sub-question 2: What are the objectives and constraints of the real estate investor?

Through performing the literature review an investor profile has been set up that captures the objectives and constraints of the investor. The objectives will be used as the endpoint of the smart value map.

The investor

The investor objective and constraints are seen in figure 98. The main driver of real estate investors is profit. Investors either achieve profit by optimising and improving the cash-flow of their investment assets or by realizing long-term asset value increase (Geltner et al., 2001). Investors are mostly constrained by risks, such as not being able to rent out their assets or not being able to sell their asset. But also, by capital constraints that limit the investment possibilities due to limited available monetary funds (Geltner, 2006). These capital constraints are mostly due to the capital-intensive characteristics of the real estate objects and are related to the long life cycles of real estate objects and the fact that retrofitting or altering a real estate object is capital intensive and time consuming.



Sub-question 3: What is added value?

Something is of value when it aligns with objectives. Added value therefore means that it contributes to achieving the objectives. Through literature a list of added values has been compiled. Table 25 shows an overview of the 12 added values that have been found through literature.

Additionally, the table also shows if the added value is a core objective or contributes directly or indirectly to the core objectives of the investor and in what way.

	Added Value	**Contribution**	**Explanation**
1	Health	Indirectly	Health contributes to the satisfaction of tenants as a higher indoor environmental quality is achieved.
2	Satisfaction	Directly	Satisfaction can lead to higher income potential through higher rental value. If tenants are optimally satisfied it can result in higher rental income.
3	Sustainability	Directly	Improving sustainability means better energy efficiency, this means that energy costs are lower and therefore overall operational costs also.
4	Productivity	Indirectly	Contributing to better productivity increases satisfaction and branding.
5	Adaptability	Directly	Adaptability of installations can save energy and maintenance costs.
6	Culture	Indirectly	Improving the culture of an organisation through real estate can increase satisfaction.
7	Branding	Directly	Branding can increase marketability and rental value.
8	Cost (reduction)	Core objective	Cost, or reducing costs, is a core objective as it is a part of cash flow.
9	**CAPEX**	*This added value is the only value that is negatively impacted by the implementation of smart technology, as it is increased due to higher investment costs.*	
10	Asset value	Core objective	Asset value is based on income and a core objective of the investor.
11	Risk	Directly	In valuations, risk premium is used to determine asset value, which is a core objective.
12	Income	Core objective	Income is an integral part of cash flow and therefore a core objective.

Table 25. Overview of all the added values. Own table.

Sub-question 4: What is the effect of implementing smart technologies in office buildings?

The smart applications improve many of the building processes making it more efficient, increasing sustainability, health, productivity while enhancing culture, tenant satisfaction, branding and innovation. Smart applications also indicate that they can be used to reduce costs, risk and increase income and asset value.

The answer of this sub-question is best illustrated by figure 101. Figure 101 shows not only the smart technologies; sensors and connectivity, but also the processes and smart applications that lead to the actual effects of the implementation of smart technology.

The implementation of the smart technologies, as defined in the answer of sub-question 1, lead to an improvement of the outcomes as seen figure 101.

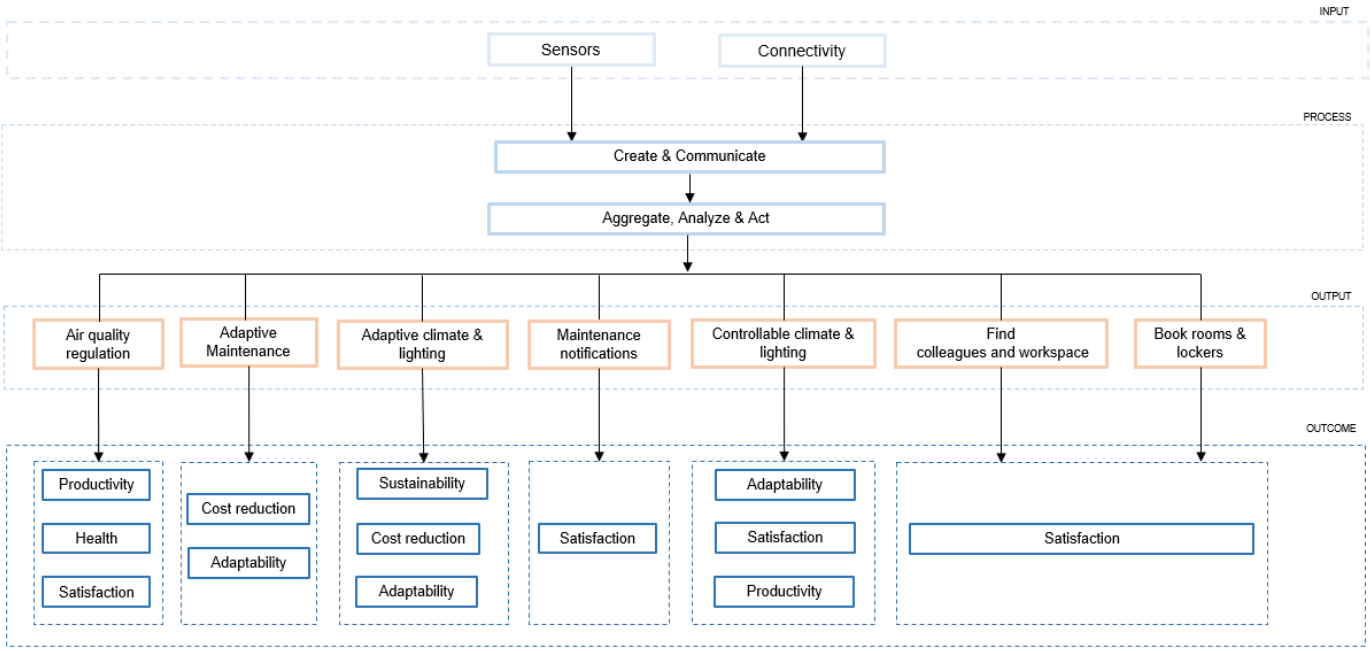


Figure 101. The holistic overview of how smart technology in office building can impact several added values. Own ill. (2019)

Conclusions – Answering the main question

Through effectively carrying out the research methodology and answering all the sub-question, the main research question can be answered. As is seen in figure 101 there are multiple ways that smart technology can provide value for real estate investors. Therefore, the main questions will first be answered with a specific example of how smart technology can positively impact a core objective of an investor. After the specific answer, the complete Smart Value Map will be shown. The main question of this research was:

"How can smart technology in office buildings provide added value to real estate investors"

An answer that can be given to this question is:

"Smart technology can improve the satisfaction of the employee by providing interactive control over the environment and a higher quality indoor environment. Tenant satisfaction, retention and attraction increase as a result to increase the investor's guarantee for long term income."

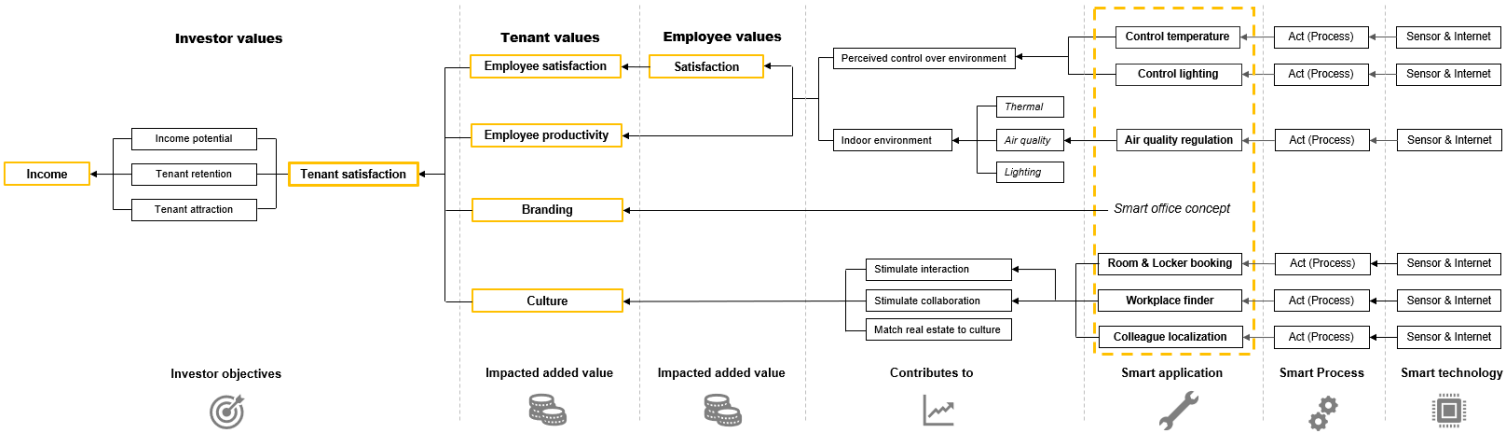


Figure 14. The smart value map: from technology to a decrease in operational costs. Own ill.

The answer given above is substantiated by figure 14, which combines all the findings of the research to create a connection between smart technology and a core objective of an investor.

Step by Step:

1. The first step is the implementation of sensor technology and internet connectivity.

2. The next step is the process; the sensors and the connectivity are used to collect and analyse data that is transformed in information and acted upon by the output.

3. In this example the outputs are the smart applications that allow employees to control the climate and the lighting, regulate the indoor air quality and allow employees to localise each other and workplaces and book rooms and lockers through their smartphones.

4. The implementation of these smart applications provide the users with the perception that they can control their environment which increases satisfaction and productivity. The optimal regulation of air quality improves the indoor environment which also contributes to satisfaction and productivity. The smart applications also stimulate interaction and collaboration. Lastly, the implementation of smart technology provides a certain level of branding to the users.

5. As was concluded through the literature review, culture, branding, employee satisfaction and employee productivity are all added values that contribute to the core objectives of the tenants. Improving these values contribute to the satisfaction of the tenant.

6. As was seen in the expert panel, the cases and also the literature, tenant satisfaction is very important and valuable for the investor as it can lead to tenant retention, tenant attraction and possibly higher income and longer lease terms.

7. All the factors mentioned in step six (6) contribute to the long term income guarantee of the investor which, through the literature review, is seen as a core objective.

As was said, the example above is not the only answer to the main question, it is an example of how the findings of this research can be combined to create a part of the Smart Value Map. In line with figure 14, the connections between smart applications and investor objectives can be explored. This results in the Smart Value Map seen in figure 103. Figure 103 shows a more complete overview of the connections that can be made between smart technology and value for the investor.

Figure 103 shows the direct connections that can be made between smart application and investor objective.

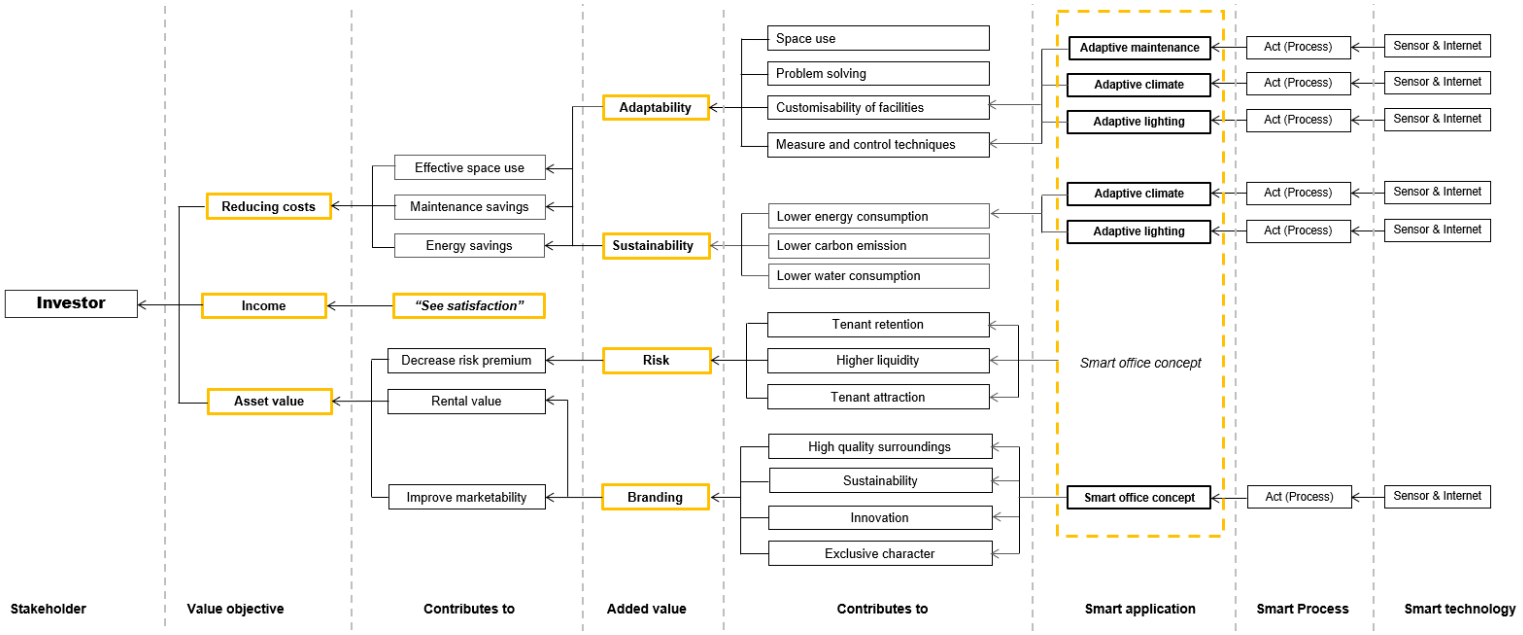


Figure 104. The Smart Value map that connects smart technology to the investor. Own ill. (2019)

By exploring the Smart Value Map in figure 103 and 104, smart technology can be traced back to a contribution to investor objectives. The smart applications that positively contribute to one of the three value objectives of the investor are shown in figure 103, therefore showing how smart technology adds value for investors.

Discussion

The methods that have been used to conduct this research have for the most part been effective. The literature review provided a good theoretical framework, especially on the topic of the added values. Many literature sources were available which resulted in a well substantiated added values. The added values played a key role in connection the smart offices to the investor, so the substantiation of the added values was vital. The case studies provided for insightful practical findings that could not be obtained through the literature review. The conducted interviews provided the necessary information to complete the cases. The interviewees were very helpful and even though the interview protocols were not strictly followed the necessary information was still gathered successfully. However, the lack of information available on smart technology and smart offices have lead to conclusions that rely almost entirely on the findings of the case studies, especially when researching the smart applications.

This does mean that the validity of the Smart Value Map is debatable as the smart applications might be very different in five years due to technological developments. Furthermore, other smart offices might have additional smart applications that might provide better value for investors.

The use of the Expert-panel provided good alignment of the importance of values and the usefulness of the smart applications. Both the findings of the cases and the Expert-panel substantiated the importance of sustainability and satisfaction.

The findings of the Expert-panel and the case studies are in line with the definitions of Buckman et al (2014) and Shulman (2014) who state that smart offices contribute to sustainability and user experience. The only gap that can be determined is that some of the user oriented smart applications, such as colleague localization, are not as user friendly as expected and are perceived to be less useful compared to other smart applications. The most useful smart applications are the ones that contribute to the sustainability of the object, which is in line with the importance of sustainability.

Recommendations

The findings of this research can be useful for investors and other decision makes to determine what types of smart applications can contribute to the achievement of their objectives. If a certain stakeholder wants to improve the sustainability aspects during a redevelopment, the Smart Value Map can be used to see which smart applications can contribute to improved sustainability.

The findings of this research can also be used as a starting point for future research. For example, a particular path of the Smart Value Map can be isolated and quantified. By using the smart value map as a staring point, time could be saved as it already maps out the substantiated connections between smart application, added values and investors objectives

Chapter 1. Introduction

Technological innovation has driven humanity forwards for several millennia now, dating as far back as the Stone Age where stone tools advanced humanity significantly. Ever since around 1760 large scale technological driven changes have been referred to as 'Industrial Revolutions' (Crouzet, 1996). By now, in 2019, the Fourth Industrial Revolution is happening (Schwab, 2016). Unique to this revolution is the fact that is predicted ahead of time instead of in retrospect meaning that the future can be actively shaped (Drath, 2014).

The fourth industrial revolution is characterized by the fusion of technology with physical, digital and biological spheres (Schwab, 2016). The innovative developments in this revolution include advanced robotics, artificial intelligence, quantum computing, 3D manufacturing, 5G wireless technology, autonomous vehicles and the internet of things.

All these developments influence the daily lives of people, making them increasingly advanced when it comes to technology. Slowly the technological innovations influence the expectations and preferences of people, steering towards adoption amongst consumers until the innovation becomes 'standard'. These influences are seen in the increasing growth of technology (IDC, 2017; IDC, 2018; Statista, 2019). As such, the technological innovations across the world also influence the real estate sector.

1.1 The real estate sector

The real estate market is one of the largest markets in the world. Savills (2017) estimates that the value of all real estate developed in the world is approximately 228 trillion US dollars, which is around 60% of all global assets. And like most capitalistic markets it is regulated by the dynamic between supply and demand, shown in figure 15. The 4th industrial revolution impacts the real estate market and therefore influences both the demand and the supply side of the real estate sector.

Figure 15. Innovation influences on real estate. Icons by PowerPoint

The real estate market is an imperfect market. Manganelli (2015) states that this is largely due to the heterogeneity of the properties, but also due to a lack of transparency. Furthermore, the real estate sector is characterized by a very traditional culture, long operational life cycles and high capital intensity. These four aspects mean that new innovations, such as those of the fourth industrial revolution, are slower at being adopted compared to most other markets, sectors and industries.

Innovation in real estate

Notwithstanding the slow adoption rates in the real estate sector, the amount of knowledge and technological possibilities available thanks to all the industrial revolutions led to buildings constantly progressing in the following four aspects (Buckman, et al. (2014)):

1. How building operation information is gathered and acted upon.
2. How the users and the building interact with each other.
3. They physical form of the building.
4. How the building uses information to improve the performance of the occupants.

By now the influences of the industrial revolutions have led to a point where some of the newest developments in office buildings are seen as **smart offices**. This concept will be described in-depth later

in the report in the 'smart building' section. Buckman et al. (2014) state that a smart buildings, compared to the previous building iterations, are interactive, have integrated data and systems, have more control and high efficiency, use a IP backbone to reach integration between building systems and provide real-time optimisation of building systems with the use of the building. In line with Buckman et al., Wang (2012) agrees that the next generation of buildings will be smart buildings.

Consequences of innovation

What is seen in the world now is that the Fourth Industrial revolution also influences people; changing their expectations and preferences and making them more and more technologically advanced. Simultaneously we see that real estate is also influenced and the next generation of buildings, the smart buildings, are starting to pop up.

However, due to the changes caused by innovation there is constantly a gap between real estate demand and real estate supply. The real estate demand constantly changes while the real estate supply remains static and is subject to deterioration (de Jonge et al., 2009). The field of corporate real estate management (CREM) is especially focussed on research methods, models and strategies that improve the process of matching supply and demand (de Jonge et al., 2009).

The differences in real estate supply and real estate demand are key to the problem and are summarized in the figure below (figure 16.)

Figure 16. Characteristics of supply and demand. Icons by PowerPoint

The next section will dive deeper into the problem that results from the fundamental differences in real estate supply and demand in relation to the influences of the fourth industrial revolution.

1.2 Problem analysis

To illustrate the problem of this research the DAS-framework (De Jonge et al., 2009) will be used, describing each step along the way. The DAS-frame is a framework that is used as a guide to steer towards alignment in order to increase the match between supply and demand both now and in the future. While the DAS-frame is often used for CREM, Remøy (2010) states that it can also be used to describe the commercial office market, where the investor represents the supply side and the user the demand side. Indirectly, a

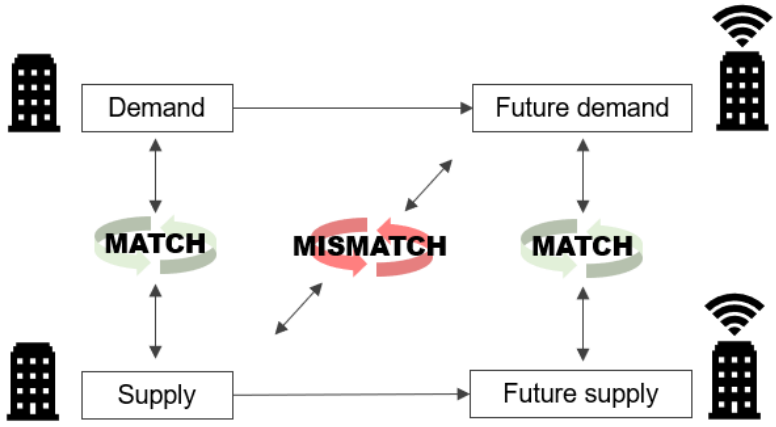


Figure 17. The DAS-frame, adapted from (De Jonge et a., 2009)

match between supply and demand is equal to a healthy office market and is therefore advantageous for investors (Remøy, 2010). The problem is shown in Figure 17. and will be described per quadrant in the following sections.

Demand

In the DAS-framework, the demand side consist of two boxes (figure 18.) The current demand, represented by the 'normal' office icon, and the future demand, represented by a 'smart office' icon. The future demand is an assumption of the preferences and expectations of real estate consumer; their demand. In line with previously mentioned sources (Wang, 2012; Buckman, 2014; Baum, 2017) Kejriwal (2017) states that user requirements in regard to real estate are shifting towards smarter and more sustainable buildings that provide higher performance through the use of smart technologies.

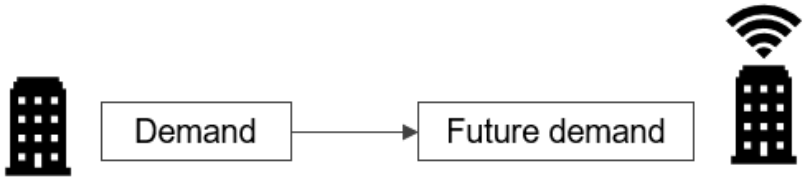


Figure 18. Part of the das frame, adapted from De Jonge et al., (2009)

Manganelli (2015), further supports the claim that technological innovations impact the demand side of real estate. Technology is one of five key macro-factors that drive the real estate demand. These factors are also often used in tools such as the PESTLE- and DESTEP-analyse, which are used for strategic or market research. A quick overview of the macro factors can be found in table 1. below.

PESTLE	*DESTEP*	*Manganelli (2015)*
Political	Demographical	**Technological**
Economic	Economic	Economic
Social	Social-cultural	Sociological
Technological	**Technological**	Political
Legal	Ecological	Demographical
Environmental	Political	

Table 1. Macro factors as found in literature. Own table.

All three mention **technological** as a market influencing factor. The rapid growth in technology is constantly changing the daily lives of people, whom represent the demand side (IDC, 2017; IDC, 2018; Statista, 2019. Furthermore, one of the fastest developing Internet of Things market, is the consumer market. This is seen in the rise of smart phones, smart wearables and smart home devices. (IDC, 2017).

The change in demand towards 'smart' services is supported by many other sources and predictions, table 2 shows an overview of different sources with claims that future demand will shift towards smart technology adoption.

ValuStrat (2019)	"Real estate experts have reported that the local market is already requiring more smart offices. Companies are now focusing on office designs and technology to accelerate business and reduce operating costs"
Dell & Intel Survey (2016)	70% of 18 – 34 years old expect to work in a smart environment over 5 years.
Allied Market Research (2018)	"The demand for intelligent building is on an increase since the past few years due to constant increase in awareness about energy conservation throughout the world"

Ullah et al. (2018)	“A boom in the demand for ‘sustainability’ and ‘smartness’ has led to these terms often being used in conjunction’
Dell & Intel Survey (2016)	44% of surveyed millennials were likely to quit a job with substandard technology.
Future Workforce study (n.d.)	80% of millennials cited workplace tech as a deciding factor for taking a job.
Markets and Markets (2018)	“Factors such as increase in demand for smart office solutions and sensor networks for energy efficiency, advancement of IoT in smart office offerings, [……] are driving the growth of the smart office market.”
Baum (2017)	“there is an oversupply of activity in real estate financial technology….but a real need for smart buildings”
KPMG (2018)	“As the way in which people interact with the built environment evolves, customer requirements for technological features and increased flexibility will become standard”
GII (2018)	“higher levels of technological innovations are required on diverse fronts including smart cities, homes and buildings.
KPMG Survey (2018)	93% Agree with the statement “Traditional real estate organizations need to engage with PropTech companies in order to adapt to the changing global environment”
Contractor (2018)	“Today, 43 percent of those who own smart homes are between the ages of 18 and 34. Builders and contractors who want to stay relevant in the coming years may want to prepare now to offer homes and devices that are better connected to their owners in the future.”

Table 2. Perceived changes in real estate demand. Own. ill

With the future demand in mind, the supply side must also be considered, as the real estate market consist of the dynamic between the two.

A recurring theme is the preferences and expectations of the new generation, the millennials. The studies done by Dell and Intel (2016) and the Future Workforce (no date) indicated that millennials place much importance on the workplace environment. To attract new talent, a majority of which are a millennial, companies will have to meet the demands of the new talent (Lovinus, A., 2018)

Supply

In the DAS-frame (Figure 19) the supply and the future supply represent the other side of the framework. This part of the framework is actually the necessary steps the supply must take in order to match the future demand. In order to determine the match, the current supply must first be understood before a certain strategy is made to determine the future supply.

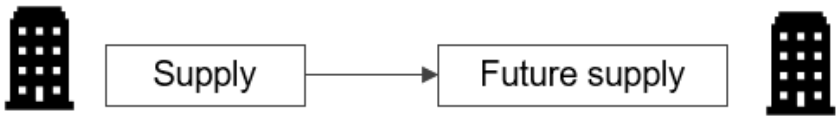


Figure 19. The supply side of the DAS-frame. Own ill.

In the context of this problem, figure 19 shows that the current supply, represented by the 'normal' office icon will still be the same as the future supply, also represented by a 'normal' office icon. Compared to other large industries and sectors, the real estate industry is lagging behind when it comes to the adoption of new technological innovations (Ferren et al., 2015). The supply side being slow is clearly something that is not new and is not just seen with smart technology. GII (2018) states that, in terms of sustainable solutions the supply has not been able to match the growing need and demand for sustainable solutions.

Constraints slowing adoption

The slow change in supply and the consequences thereof are substantiated and supported by multiple sources as seen in table 3.

Shulman (2014)	"Much of the existing office stock is technologically obsolete.
BPIE (2017)	"The European building stock and energy system are at the initial stages of a journey towards becoming smart"
GII (2018)	"Supply has not kept pace with demand, and there is a growing need for sustainable solutions"
BPIE (2017)	"The explosion of smart technologies [….] will inevitably redesign the built environment [….]. The existing building stock was not constructed for this purpose - what is now technologically possible was only speculation just 10 years ago"
Global Real estate expert (2018)	"[….] Installing sensors to collect data was costly and time consuming. And so, most commercial real estate (CRE) companies still use manual methods to collect and confirm the data they rely on to manage building temperature, layout, and maintenance schedules"
Global Real estate experts	"In fact, as tenants come to expect a smart experience, buildings without them may have difficulty filling space and may need to lower their prices."
KPMG (2018)	"it is evident that the real estate industry has made a start on the road to realizing the opportunities that technology and innovation can bring. But there is still some way to go"
KPMG Survey (2018)	Only 30% of traditional real estate companies say they currently invest or plan to invest in PropTech start-ups
KPMG Survey (2018)	66% do not have a clear enterprise-wide digital and technological innovation vision and strategy
KPMG Survey (2018)	56% rate their business 5 or below out of 10 in terms of digital and technological innovation maturity.
Dell & Intel Survey (2016)	44% think their workplace is not smart enough
Ullah et al (2018)	States that the traditional mindset of real estate leads to slow adoption of technological innovations.
Research and Markets (2018)	"It is important to note that roughly 90% of legacy buildings in developed economies have issues that will require substantial retrofitting"

Table 3. Perceived changes in real estate supply. Own. ill

As was mentioned in section 1.1 'The real estate sector', the traditionalism in real estate plays a big role in slowing down the adoption rates. According to Wang et al (2016) one of the barriers that slow down the

adoption of technology in real estate is the risk-averse nature of real estate organisation representing the supply side. The new technological innovations are threats and risks instead of as opportunities (Wang et al., 2016). Further elaborating on the factors that lead to slow adoption in the real estate supply, Ullah et al. (2018) substantiates the fact that the traditional mindset where information is withheld is a key factor halting technological adoption.

Due to smart buildings being a recent development, there is a lack of academic research on smart building technologies (Ullah et al., 2018). Ullah et al. (2018) states that to increase adoption speed it is imperative to improve information dissemination. Scientific and academic research is needed to convince stakeholders that smart buildings are worthwhile investments and not a risk or a threat.

A third important constraints are the characteristics of real estate objects themselves. As seen in figure 20 real estate objects have very long lifecycles. The structure can last up to 300 years and the space plan up to 30 years. Due to the capital-intensive nature of the sector, the layers seen in figure 20 are not often retrofitted unless the layer's lifecycle is at its end. The layer in which the smart technology is to be applied is the 'services' layer. This means that it can take up to 15 years for the service layer needing retrofitting. Also, to save costs, most of the retrofitting of layers happens during one single renovation when multiple layers are at the end of their lifecycle. Which also slows down the adoption rates since retrofitting occurs less often.

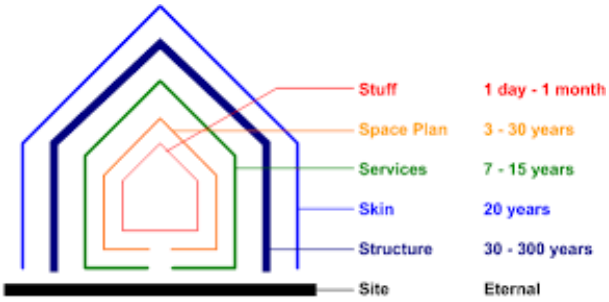


Figure 20. Brand's shearing layers (1994)

Summarizing, the slow adoptive nature of the supply side (figure 21.) is due to high capital intensity, a traditional mindset, risk, a perception that new technologies are risk instead of opportunities and due to a lack of available information.

Figure 21. Reasons for slow adoption. Icons by PP.

The mismatch

So far, the expectations are that the demand for smart offices will rise, while the supply will stay behind due to the constraining characteristics of the supply side. The DAS-frame compares the current supply and the future demand in order to determine any possible gaps between supply and future demand and limit the consequences of any gaps. A gap between supply and future demand is referred to as a mismatch.

As shown in figure 22. the fast adoption of smart technology in the demand compared to the slow adoption of smart technology in the supply side results in a mismatch. The current supply consists mostly of traditional offices, while the future demand is for smart offices.

Figure 22. Mismatch in supply and demand. Icons by PowerPoint

The mismatch means that real estate stakeholders, and therefore real estate assets, who resist to change or refuse to adapt, run the risk of becoming obsolete (Ferren et al., 2015). In line with Ferren et al. (2015), Remøy (2010) states that the changing user preferences, combined with the development of new buildings, result in obsolescence amongst the older buildings that cannot meet the preferences anymore. Thus, I line with both Ferren et al. (2015) and Remøy (2010) the mismatch increases the risk for obsolescence.

Obsolescence is the diminishing usefulness of a building with respect to the function the building was designed for. Obsolescence in a building leads to lower revenues, higher costs and vacancy (Remøy, 2010). Three very big threats for real estate investors that should absolutely be avoided.

The mismatch caused by the changing demand influenced can lead to the following forms of obsolescence:

Functional obsolescence

Functional obsolescence means that the building is unfit due to the changing ways of working in the sector (Remoy, 2010). Even though the condition of the building is good, the building is functional obsolete since it does not fit the expectations of the user. If the ways of working change and require smart office space the function of office space will have to change accordingly. If an office cannot support the new ways of working, it becomes functionally obsolete.

Social obsolescence

When it comes to offices, social obsolescence can lead to functional obsolescence. Social obsolescence results from both figure issues and increased demand of the occupiers. If tenants and users demand but cannot obtain a smart working environment it is likely that other accommodation will be searched for, leading to vacant office space. Also, occupiers looking for smart office space will not consider renting non-smart office space.

Future demand and future supply

The last step of the DAS-frame is creating a strategy in order to reduce the future mismatch and create a match. The match between future demand and future supply is shown in figure 23. For this match to occur in the future the currently supply must change accordingly and towards, the future demand. Influencing the current supply to better match the future demand is one of the core tasks of CREM.

The alignment of future supply and future demand requires stimulation of the supply side to adopt smart offices. By showing that smart buildings are opportunities instead of threats, the adoption speed can be increased and the future match between demand and supply can be improved. Simultaneously this will contribute to filling the gap in knowledge on smart buildings.

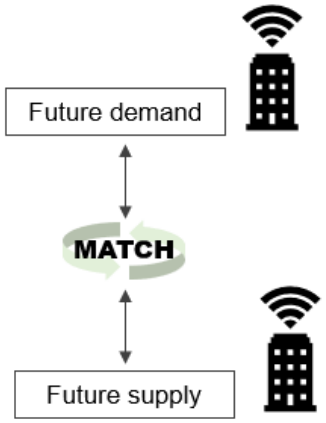


Figure 23. Match between future demand and supply

1.3 Problem statement

The core of this research is the risk of obsolescence resulting from a mismatch between supply and demand. Due to the negative consequences of obsolescence in the real estate supply it is necessary to take steps towards a match between future demand and future supply. This match occurs only if the supply can follow the changing demand. If the demand of the consumers is increasingly technologically advanced and driven by smart technologies, the supply must follow suit and adopt smart building developments.

However, due to the innovative nature of smart technology the benefits are still unclear, unproven or undiscovered for the majority. This, in combination with the traditionalism and risk-averse nature of real estate investors, not choosing for the development of smart offices. This brings us back to figure 24. The demand changes fast but the supply does not. The result of this is functional or social obsolescence leading to vacancy and an unhealthy office supply. To avoid any obsolescence in the office supply stock and make sure that the preferences of the users are represented in the supply the smart office adoption rates must be increased. If this does not happen the chances are that tenants will leave their non-smart office behind and seek office space elsewhere, creating vacancy.

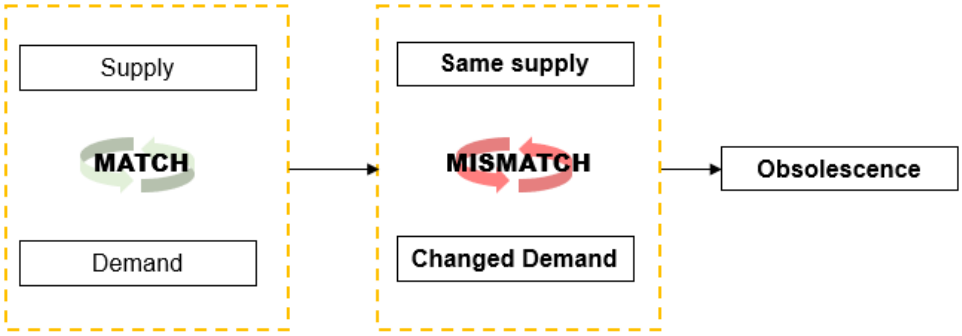


Figure 24. The mismatch that leads to obsolescence (Own ill.).

1.4 Research aims

The main goal of the research is to show that smart office can provide additional value to real estate investors. Many investors seen technology as a risk and are unconvinced of the benefits of smart offices. Convincing the investors that smart offices are not a risk but an opportunity, will in turn increase the adoption rate of smart offices.

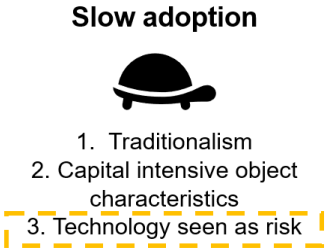


Figure 25. constraints targeted by this research. Own ill. (2019)

In order to accelerate the adoption rates of smart technology in the supply side information dissemination must be improved (Ullah et al., 2018). Since the supply side is represented by the investors, they are the key stakeholder to target to increase the adoption speed of smart offices (Remøy, 2010). The future risk of obsolescence can be minimized, by illustrating the benefits that smart buildings can offer to the decision makers of the supply side. As such, the commercial real estate investors will be targeted by this research. The aim of this research is providing the investors with rationale that show that smart buildings are worthwhile investments. This will enable the investors to make more informed decision and will contribute to accelerating the adoption of smart buildings and decrease the future risk of obsolescence.

Figure 25 shows the main constraints that result in the slow adoption rates on the supply side. While this research might not change the traditionalism and risk averse nature of real estate, it will tackle the constraints of asymmetrical (lack of) information and the fact that technology is seen as a risk instead of as a benefit (figure 25.)

To achieve the main goal two commonly used theoretical frameworks will be used to structure and substantiated the end produce. The first framework is that of Corporate Real Estate Management (CREM) and the second is that of Value Adding Management (VAM). Both frameworks will be introduced before describing the end product of this research.

Corporate real estate Management

As was mentioned in the introduction, CREM specialised in models and strategies that improve the match between supply in demand, which fits well with the problem of this research. Corporate real estate management theory was already introduced in the problem analysis by using the DAS-frame. In the rest of the research CREM theory will be used to further categorised the findings of the research. A common categorisation found throughout CREM theory are the four perspectives: strategic, financial, functional and physical (Den Heijer & De Jonge, 2012). Using these perspective to categorise the findings will help to compare the findings and will place the research outcomes in a known environment and enable better structured future research

Value adding management

Jensen and Van der Voordt state that changing the physical environment of an office is a Corporate Real Estate management (CREM) intervention that can be used to add value to an organisation. This intervention is in line with the research where the implementation of smart technology is used to change the physical office environment and can therefore be used to ultimately create added value. Jensen & Van der Voordt introduce a value adding management (VAM) model that can be expressed in the following ways:

Decision or reason for change → implementation → result of effect → value

This model can be applied to the context of this research. Where the decision for change is the decision to implement smart technology, the implementation is how the smart technology is used and the results or effects are the impacts on the value.

In line with the Value Adding Management (VAM) approach of Jensen & Van der Voordt (2017) the investor objectives will be linked to smart technology by connecting both to added value parameters. Based on the results of this research any observable rationale can be explored on the added value benefits of smart offices. The connections that need to be made in order to connect smart technology to value for the investor are shows in figure 26.

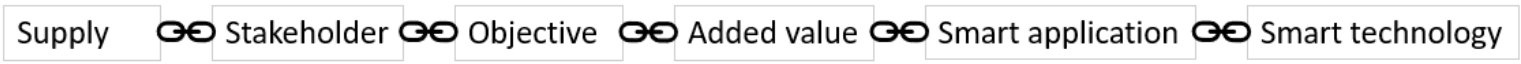


Figure 26. the design of the smart value map. Own ill. (2019)

The results of this research are combined in a qualitative value map that makes the connection between smart buildings and investor objectives. This value map (figure 26) can be used to convince real estate investors that smart buildings hold additional value and make clear that investing in them can be beneficial. In line with the VAM method, the value map structure follows the input, output and outcome order where technology is seen as the input and the contribution to investor objectives the outcome.

Secondary aims

Convincing investors to invest in smart offices is key to breaking the Circle of Blame (Cadman, D., 2000). Real estate investors are the stakeholders that oversee decision making, they are the ones with the capital and therefore often the ones that take the decision whether or not to invest in property technology. By breaking the circle of blame, the other stakeholders are also influenced positively (figure 27.) further boosting adoption. The findings of this research will impact the unclear benefits that investors might have therefore contributing to breaking the circle of blame that slows down innovative adoption. Figure 27 shows that the constrains of the investor is, again, the fact that investors are unsure of the benefits and perceive, in this context, smart technology as a risk.

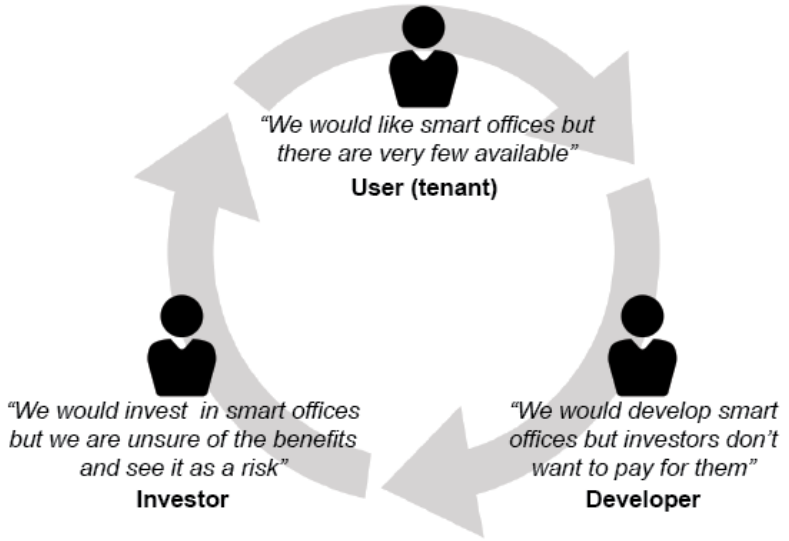


Figure 27. Circle of blame. Adapted from Cadman (2000).

1.5 Research questions

To attain the research goals, the following research question, and sub-questions have been formulated:

Main question: *How can the implementation of smart technology in office buildings provide added value to real estate investors?*

In order to answer the main questions of the research several sub-questions are asked to ensure that the relevant topics are covered and combined:

1. What is smart technology in relation to office buildings?
2. What is the effect of implementing smart technologies in office buildings?
3. What are the objectives and constraints of the real estate investor?
4. What is added value?

1.6 Conceptual model

The conceptual model of this research is seen in figure 28. This research explores the concept of smart offices as an investment opportunity. In the traditional cycle, real estate investors invest in office building to achieve a certain return on investment or more broadly speaking real estate investors have certain objectives and investing in offices is a way to achieve those objectives.

With the advent of smart offices a new investment opportunity or cycle presents itself for the investor. Instead of investing in traditional offices the investor can now chose to invest in smart offices. In line with Buckman et al. (2014) the smart offices are more advanced compared to office buildings and therefore provide a certain level of added value.

The added value can contribute to the core objectives of the investors. By exploring the added value provided by the smart offices and how those added values impact the core objectives of investors, the benefits of smart offices can be shown and the risk aversion towards technology can be reduced. The research framework indicated in figure 28 is the focus of this research.

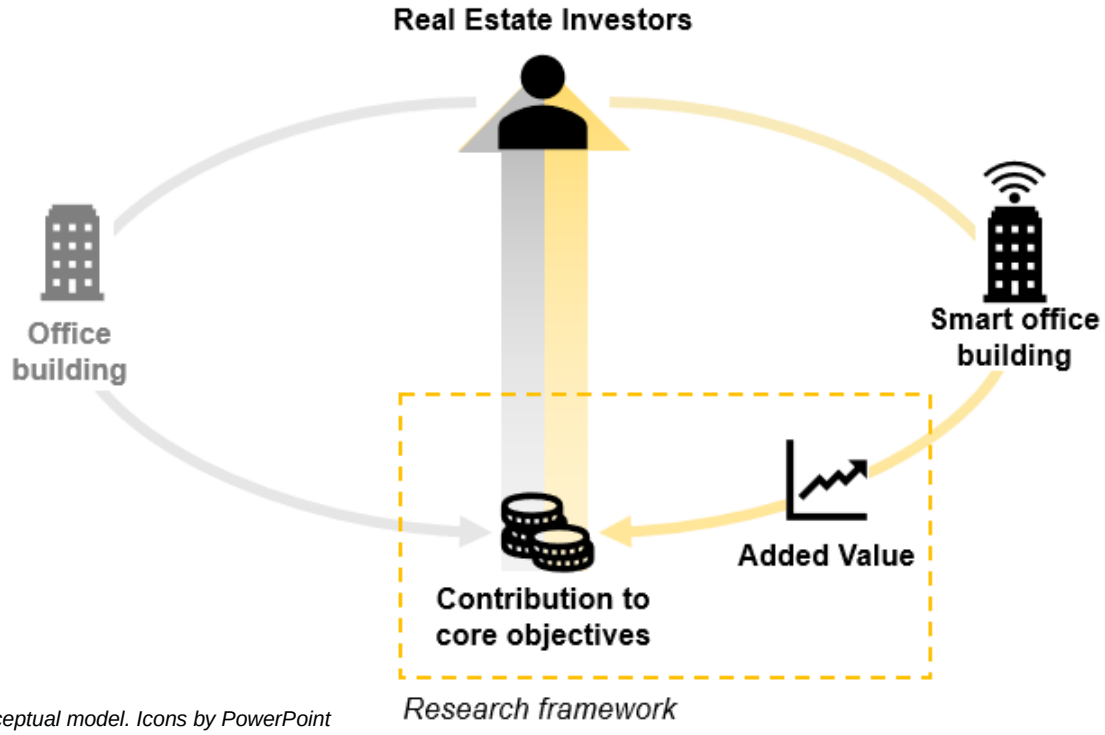


Figure 28. Conceptual model. Icons by PowerPoint

1.7 Relevance

Societal

User preferences in real estate or slowly shifting towards more smart and sustainable environments, that, by using technology, provide higher quality and performance (Kejriwal, 2017). These solutions will play a more and more important part in the daily lives of employees. The aim of this research is to promote the development of smart buildings that meet the future preferences of real estate users. Thus, it aims at keeping the office stock healthy and future proof. A healthy building stock prevents obsolescence and vacancy.

According to Baum (2017) and several other sources (Buckman et al., 2014; Wang et al., 2012) smart buildings are more efficient. This increased efficiency often goes hand in hand with higher sustainability, contributing to a more sustainable and healthier built environment. If smart technology can contribute to reaching the ambitious climate goals, such as the Paris Agreement it is important that it is researched and adopted as fast as possible.

Based on an 8 working hours per day, people spend on average 25% at the office during a typical workweek. Functionality and comfort of the workspace score very high on important workspace environments (Rothe, P. Beijer, M. van der Voordt, T.J.M., 2011). Meaning that it is important that workspaces are optimised to the needs, habits and preferences of the employees. If smart buildings indeed improve workspace environments, it is beneficial to stimulate their developments.

The consequences of the slow adoption of smart office are mostly economic and mostly borne by the more traditional investors and corporations. Office users, employees but also tenants, will at one point base their real estate choice on whether or not an office is technologically advanced. As was seen in the problem analysis, the newer generations are increasingly asking for smart office space. Offices that are not smart enough will become obsolete as other more fitting options will be chosen whenever available. For investors this means loss of income in the form of vacancy but also a dwindling rent levels as the property might not be regarded as high quality anymore. Furthermore this might also results in many new developments where a relatively simple retrofit of an older office might suffice.

Academic

As mentioned by Ullah et al. (2018) the amount of available literature on smart real estate is very low. The amount written on specifically smart offices and their value for investors is even smaller. Therefore, this research provides information on a subject that is under researched compared to other topics.

BFP (2018) states that there is need for a PropTech library that combines PropTech with needs and drivers to create more understanding in the benefit and value of smart buildings. The value map created through this research combines current smart office applications with the objectives of real estate investors and creates the understanding necessary according to BFP. Furthermore, by using a CREM approach the current corporate real estate management knowledge base can be extended with research on smart buildings.

The value map can be used as starting point for further research. Research can be done on parts of the value map to enrich it with deeper and more quantified information. For example, with additional research the actual contribution of the smart technology to the sustainability of the office can be measured. Also, from a CREM-perspective it can be used by organisations to target specific values that meet their organisational goals. For example, if an organisation wants to improve collaboration in their office culture the value map can be used to see which smart applications improve collaborative culture. Thus, the value map can be used as a strategic tool to align real estate with organisational goals.

1.8 Research Design

This section describes and discusses the research design. In order to go from the problem statement and research aims to the end results many steps must be made. The starting point is the formulated research questions: How can smart technology in office buildings provide added value to real estate investors?

To answer this question the topics framed in orange in figure 29. must be research first. Information on smart buildings, smart technology, added value and the real estate investor will be gathered through literature reviews (1) and result in a theoretical overview of the topics.

How to enrich the theory and research how smart buildings provide value to investors in reality and not in theory more methods are used. Through interviews (2) and case studies (3) multiple smart offices will be analysed in their real-life environment. The case studies will provide the scope and the setting, the interviews will provide the information. Combined, the interviews and cases provide the practical knowledge and answers to the question.

Lastly, a Expert panel (3) will be conducted to gauge the usefulness, importance and validity of the findings of the research.

The combination of all the methods will ultimately be the value map that shows how smart technology used in office can provide value to real estate investors.

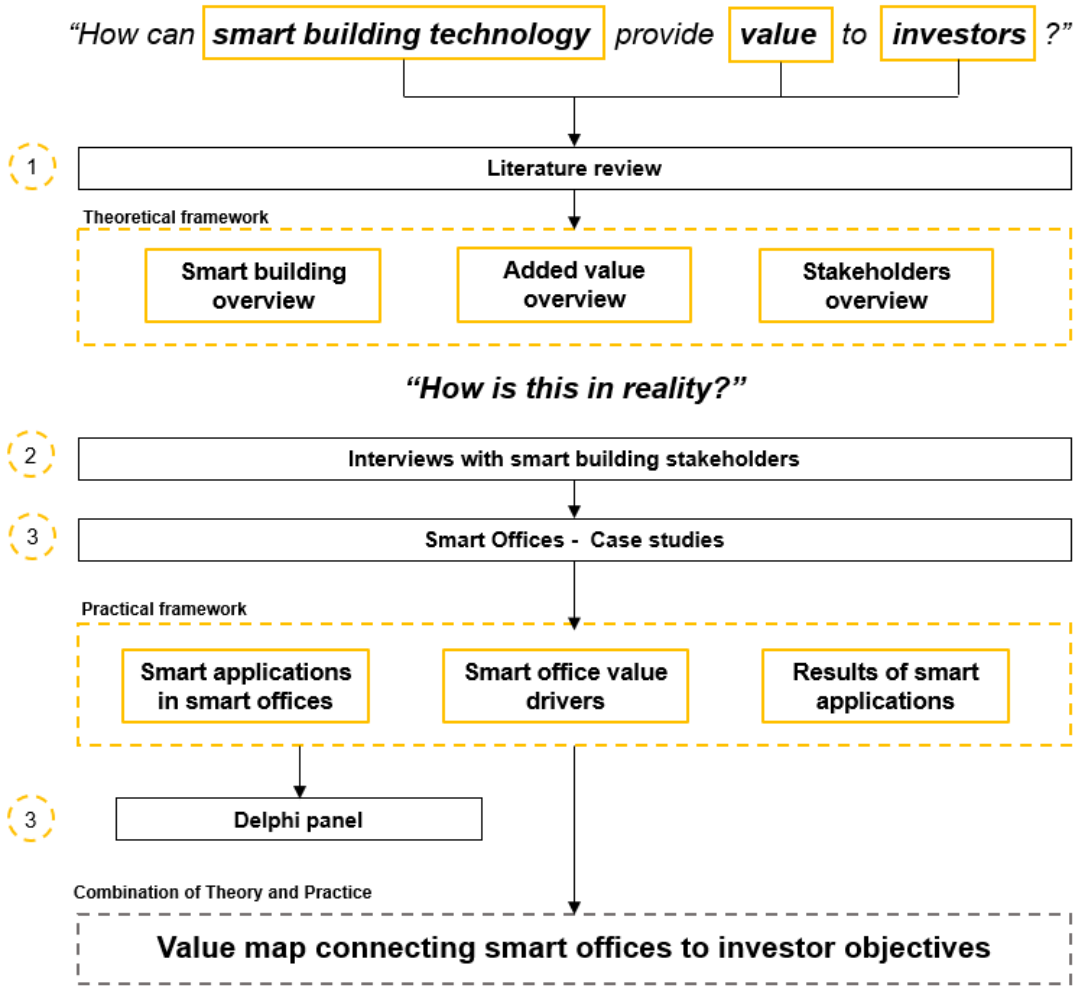


Figure 29. Research design. Own illustration.

Chapter 2 – Methodology

2.1 Method overview

In line with the research design scheme mentioned before (figure 29) the methods of research that will be used to answer the research questions will be described in this chapter. The used methods are as follows:

1. Literature research
2. Expert interviews
3. Case studies
4. Expert panel

Figure 30. shows a quick overview of the four methods and their goals and research results. The case studies, interviews and Expert panel will mostly be used to enrich the research done in the literature review with practice and more in-depth and case specific information. The following sections will describe in depth the four methods and how they will be executed. Furthermore, the goals and objectives of the methods will be described with the expected results and the contribution they offer to the research.

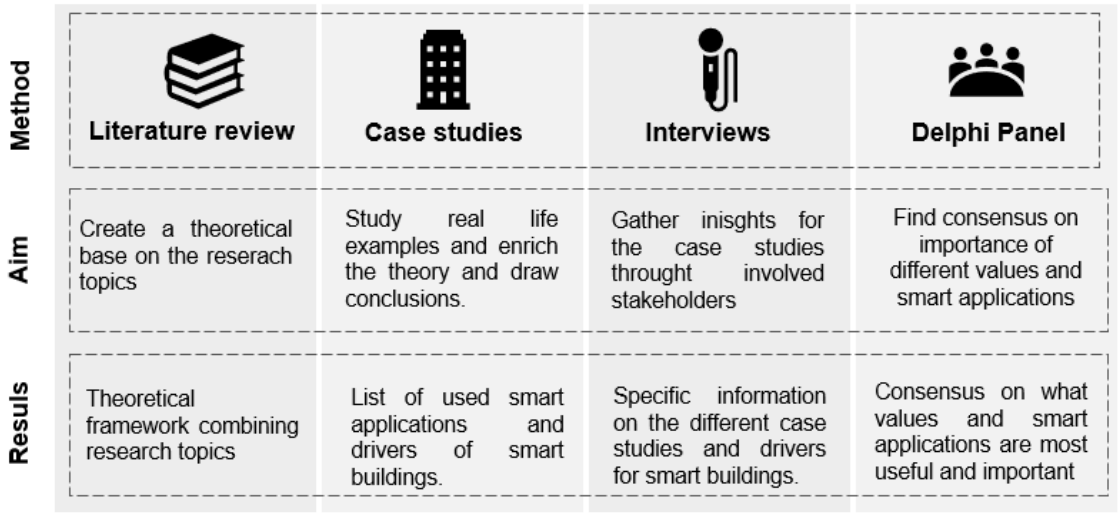


Figure 30. Method overview. Own illustration. Icons by PowerPoint.

2.2 Literature review

The literature review is the first part of the research. In this phase as much information as possible is gathered on the main topics of the research: Smart technology/buildings, added value, real estate investors and other stakeholders. The literature review is also used to substantiate the problem statement. The literature review will be used to give preliminary answers to the following questions:

1. What is added value?
2. What is a smart building and smart technology?
3. What are the objectives and constraints of the real estate investor?

Method

The information gathered in this part of the research will also be reviewed in order to collect and combine the most valuable information into the theoretical framework. The main methods will be as illustrated in figure 31.

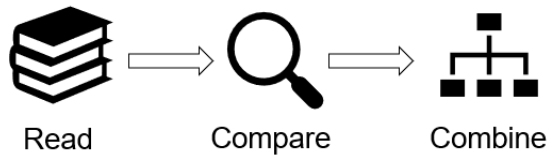


Figure 31. Literature review scheme. Own illustration. Icons by PowerPoint.

By combining information for multiple sources and reviewing them the theoretical framework can be well substantiated. The sources will be reviewed on relevancy and on accuracy. At the same time different information will be compared to see if there is overlap. By combining the different sources that have been compared a complete overview can be created that take into account multiple sources and therefore reduces biased and one-sided information. An overview of the sources can be found in table 4.

Value	Smart technology	Stakeholders
Jensen & van der Voordt, 2017	Donovan et al. 2018	Nase, 2018
Esfandiari et al., 2017	Ullah et al., 2018	Manganelli, 2015
Van der Voordt, 2016	ING, 2018	Keeris, 2008
CoreNet, 2016	Deloitte, 2018	Van Gool, 2007
Ticleanu et al. 2015	KPMG, 2018	Geltner, 2006
Manganelli, 2015	Linder, 2017	Geltner et al., 2001
Jensen et al. 2012	Baum, A. 2017	
Den Heijer, 2012	MIPIM, 2017	
Ristaniemi, 2011	Dijkstra, M. 2017	
Van Meel et al., 2010	Kejriwal, 2016	
Lindholm, 2008	Zsebik, no date.	
MacMillan, 2006	Li, C.Z., 2016	
Roulac, 2001	Zhilong et al., 2015	
Greer, 1997	Arditi, 2015	
De Jonge, 1996		
Nourse & Roulac, 1993		

Table 4. Overview of used sources. Own table.

To answer the sub-question on added value, multiple sources on value will be reviewed. For each sources an overview will be created with added value parameters described in that source. After this process has been repeated for multiple sources the overviews are compared to each other and a new list will be made. Similar parameters will be merged and added to the list and unique points will also be added to the list, resulting in an overview based on multiple sources. This overview will be a complete set of ways to create added value or provide added value. The overview of added value point will contribute to the 'added value' part of the value map (in orange in figure 31.)

Figure 31. Part of the smart value map – added value. Own. Ill.

This same process will be repeated for the types of smart technologies. Firstly, the different sub sectors of real estate in which the property technologies operate will be gathered. Then the gathered information will be compared and combined to create an overview of the types of smart technologies (figure 32). This overview also provides clarification and categorisation on a topic where that is lacking (BFP, 2018). The actual effects that the smart technologies have will be studied through the case studies.

Figure 32. Part of the smart value map – smart technology. Own. Ill.

Lastly, to answer the question on the investors objectives the relevant stakeholders will be researched by reviewing literature. This will result in an overview of the relevant stakeholders, their objectives and any constraints. In the value map this will provide the part on the stakeholders and their objectives (figure 33.)

Figure 33. Part of the smart value map – stakeholder objectives. Own. Ill.

2.3 Case studies

The goal, the research design and the contribution to the research of the case studies will be described. The case studies are done to observe smart office and their processes in practice as compared to in theory. In total three case studies will be constructed and finally a cross-case analysis will compare and combine the three cases to create one holistic overview of smart offices.

Goal

A Case study is an empirical research method that is used to investigate a case by addressing the 'how' or the 'why' questions that are relevant to the research (R. Yin, 2012). Also, according to Yin (2014) case studies are a method that set a certain phenomenon in real life context. In this research context, the phenomenon is the integration of property technology with office buildings.

Through the case studies one can study why certain decisions were made, how these were implemented and led to what results (Schramm, 1971). By performing the case studies real life results can be researched and documented and new insights can be collected.

The case studies will be used to answer the following sub-question:

1. What is smart building technology?
2. What is the effect of implementing smart technologies in office buildings?

The case studies will provide additional and more in-depth answers to question (1) as the preliminary answers will be give after the literature review. Question (2) will be answered through the three cases and

the cross-case analysis. Figure 34 shows the research design for the case studies. This model is based on the case study research model developed by Yin (2014). During the define and design phase the theoretical background, the case study protocol and the selection of the cases according to criteria are done. During the second phase, the prepare, collect and analyse phase, the case studies are performed and an individual report for each case is made. The last phase is the analyse & conclude phase, in which the cross-case analysis, the conclusions and the case study summaries are made.

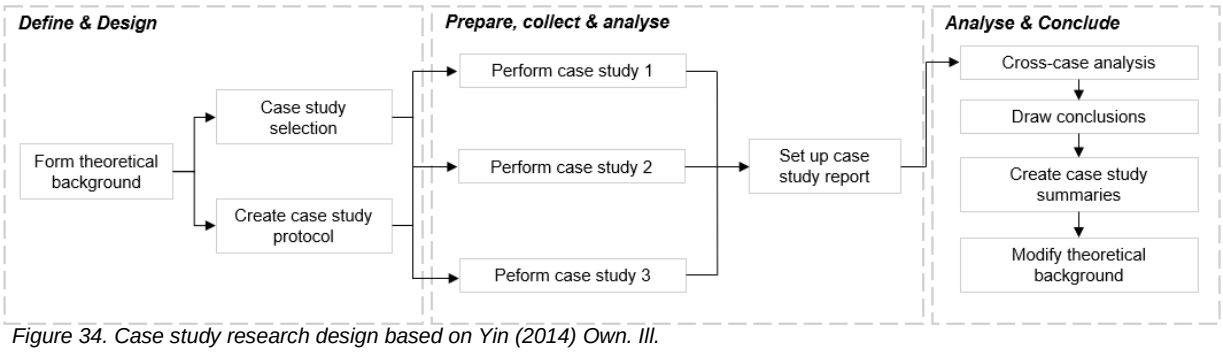


Figure 34. Case study research design based on Yin (2014) Own. Ill.

Define and design

Based on the theoretical background formed through the literature review the cases can be selected and the case study protocol can be created. The cases are selected based on the 4 criteria found in figure 35. To narrow the selection of cases the first criteria is that the case must be an office building. This is necessary as the main research aim targets the office market and there might be significant differences in the smart technologies used in offices compared to other buildings.

The second criteria ensure that the building is a 'smart building'. Measuring objectively if an office is smart or not might be difficult due to the innovative nature of smart offices. But if multiple sources claim that the office is smart, the assumption can be made that, according to current standards, it is a smart building.

1. Must be an office building
2. Must be branded as a smart building
3. Preferable located in The Netherlands
4. Different developers

Figure 35. Case study criteria. Icon by PowerPoint.

The third criterium is that it must be in The Netherlands. This makes the available information easier to gather and limits the research to the Dutch office market.

Lastly, to avoid too much repetition and similarities the office must be developed by different developers or development consortia.

To gather enough information to draw substantiated conclusion and answer the sub-questions three cases will be studied in total. The selection of the cases will be made in the 'Case study Results' chapter. To answer the sub-questions and contribute in answer the main question topics will be researched:

1. The types of smart applications used in the case.
2. The way these smart applications work.
3. The reason and motivation for implementing smart applications.
4. The expectations and results in regard to the implementations of the smart applications.

To structure the different cases and create a case study protocol will be created to improve the comparability of the cases. The full case study protocol can be found in the appendices (Appendix II). The protocol will be constructed following the four topics; the used smart applications, the way they work, the drivers for the

Figure 36. Part of the smart value map – smart application and technology. Own ill.

implementation thereof and the expectations and results. This will contribute to the part of value map seen in figure 36.

Prepare, collect & analyse

To gather the information for these topic three different methods will be used, all three identified by Stake (1995) and Merriam (1998) as methods to gather data for case studies. The interviews, however, will be the main method of information gathering. This is due to the lacking amount of in-depth information found on the cases. By conducting interviews with stakeholders that were closely involved in the development and use of the cases, precise and in-depth information can be retrieved.

1. Document review
2. **Interviews**
3. Observations

Due to their importance the interviews will be explained further in the 'Interviews' section the document review will be done through desk research. Observations will be performed through a tour of the case.

The results of this phase are found in the 'Results' section. For each case a short summary will be made that can be used as input for the cross-case analysis.

Analyse & conclude

Once the cases have been completed and summarized, conclusions can be made. This starts with a cross-case analysis where the three cases will be compared and analysed based on the findings. Figure 37 shows the design of the cross-case analysis. In line with Yin (2014) the three cases will result in a list of smart applications that are found in smart buildings. This list is the 'Why' of the case, as in: why is this office seen as a smart office? The second overview that will be made is the 'What' of the case, as in: What is the result of the implementation of smart technology.

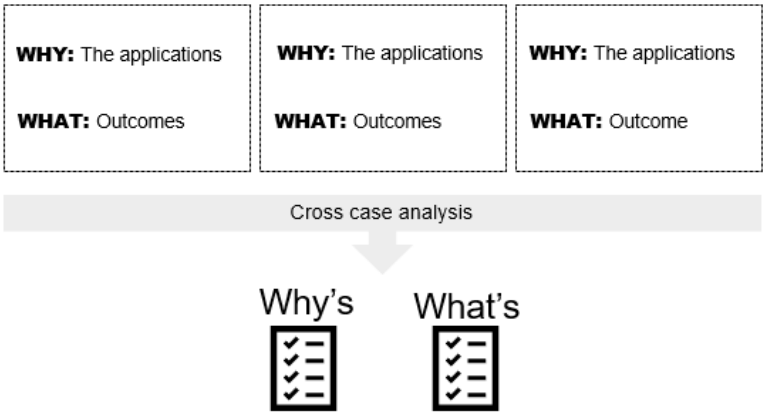


Figure 37. Cross-case analysis research design. Icons by PowerPoint.

The conclusions drawn based on the cross case analysis will result in the part of the smart value map seen in figure 37 The smart applications and the technology that drives them will provide the 'smart application' and the 'smart technology' part, while the results of the implementation will link the applications to the 'added value' part of figure 38.

Figure 38. Part of the smart value map. Added value, smart applications and technology. Own. Ill.

2.4 Expert Interviews

As mentioned at the beginning of this chapter the third research method of this research is the conduction of interviews. This section will discuss the way the interviews are set up, the reason for conducting the interviews and the contribution of the interviews to the overall research. By holding interviews with stakeholder that are closely involved with the three cases in-depth information not found through desk research and observation can be gathered.

Method

The interviews will be semi-structured interviews (Edwards & Holland, 2013). Semi-structured interviews allow for some flexibility in the responses of the interviewee but are still structured or guided by directional questions to stay on topic. To make sure information is gathered on the four topics there will be four guiding questions to steer the semi-structured interview, as seen in figure 39.

Figure 39. Guiding questions in interviews. Icons by PowerPoint.

The four guiding questions are as follow and are in-line with the four topics of the cases studies:

1. What are the different smart applications found in this office building?
2. How do these smart applications work and what do they do?
3. What were the reason or the drivers for implementing these applications?
4. What were the expectations, and what are the results in regard to these applications?

For each interview a specific interview protocol will be made (see Appendix I). This is due to the different roles that the interviewees have in regard to the case. The guiding questions will mostly be the same but depending on the interviewee the focus might change.

Goal

The interviews will mainly be done to gather concrete and specific information on the three different cases contributing to the gathering of the necessary information on the four topics discussed in the ‘define and design’ section of the ‘Case Studies’ chapter. Interviews allow for more in-depth and specific information. Due to the technology, and therefore the smart buildings, being new, it is expected that there is not a lot of documentation or research on these buildings. The knowledge is often kept internally and undocumented to the ‘outside world’.

Result

The interviews with the stakeholders that are involved with the cases will provide new insights on the value of smart technology and how offices and their stakeholders can benefit. While interviews with investors yield barriers that must be overcome and drivers that can be used to linked property technology to investment value. The interviews with the managers will mostly be used to gather insights into the actual use and performance of smart buildings. This can be used to gather hard values, such as cost reduction in percentages or earn back times, that can be added to the framework.

Interviewees

The interviewees are selected based on their role or position in relation to the three cases. For each case multiple interviews will be done. To get answers from multiple perspectives interviews will be done with persons with the following background:

1. **Investor**
   Investors are often the decision makers (Hermans et al., 2014) and can therefore give insights into the drivers behind the development the smart building. Investors (or decisions makers) can also provide insights into the expectations.

2. **Manager**
   Managers, and especially facility managers, are closely involved with the daily processes of the building and can provide insights into how the smart buildings work and what the results of the implementations of smart technology.

3. **User**
   The end users of the building are the ones in direct contact with some of the smart technology. Interviewing the user side gives insights in what works and what does not work when it comes to smart technology.

Table 5. shows on overview of the interviewees, compiled *after* conducting the interviews. For each interviewee the background has been listed after their name. As can be seen, for almost all the cases the three backgrounds have been covered.

The Edge	The Outlook	The Edge Olympic	Other
CBRE Facilities Manager	Schiphol Real Estate Project Manager	OVG Development manager	Bouwinvest Asset Manager
Deloitte employee	Microsoft employee	Edge Olympic IoT engineer	
(additional input provided by Edge Olympic interviewees)		Edge Olympic employee	
		CHOP Fund manager	

Table 5. Interviewees. Own table.

For each of the interviewees in table 5 an individual interview protocol is made (Appendix I). The questions are based on their roles in relation to the case and their expertise. The questions guide the interview and make sure the four case study topics are discussed.

In the discussion in section 5.2 the diversity of the roles the interviewees will be discussed.

2.5 Expert panel

A Expert panel is a qualitative research method that is typically used to achieve a consensus on a certain problem by using a panel of experts that are relevant in the field of the problem (J. R. Avella, 2016). The Expert panel is often used in cases where there is limited evidence or prior research available on the topic of interest, which fits well with the topic of this research since academic research is scarce.

Method

Figure 40 shows the research design of the Expert panel. The method starts with the researcher setting up the Expert panel protocol (found in Appendix III). This protocol consists of three questions that ask the participants to evaluate their perception on certain theme's related to this research. The three questions will be elaborated later on in this section.

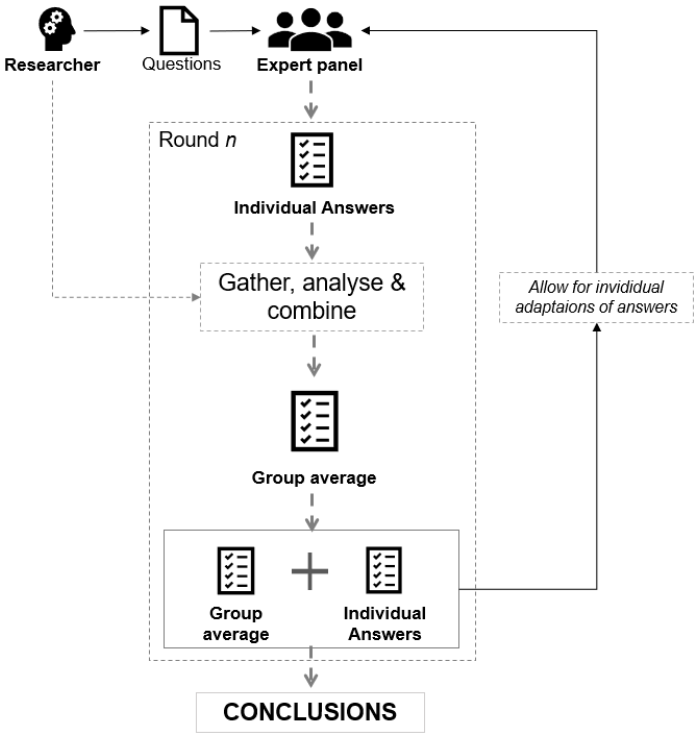


Figure 40. Expert panel scheme. Own ill. Icons by PowerPoint

A group of experts is then assembled, the expert panel. The panel is asked to, individually, answer the questions of the expert panel protocol. The answers give by the participants is then gathered by the researcher. The researcher analyses and combines the answers and creates a 'group answer'. The group answer is the average answer given to each of the questions. The researcher ends up with an overview of the individual answers given by the participants and the group average. This concludes the first round, indicated by 'round *n'* in figure 40.

The second round presents the same participants with their own individual results and the group average. In the second round, the participants are asked if, based on the group results, they want to change or adapt their answer. The objective is that, after each round, some response change according to the average answers given by the expert panel, until the answers are completely 'set' and a certain level of consensus is reached.

To ensure that the debate is independent of individual personalities and influence of professional experience or reputation the Expert panel must be anonymous. This means that each panel member only has direct contact with the researcher. By keeping the panel members isolated ensure that influence of strong personalities is eliminated and that there is no group pressure.

The Participants

The Expert panel participants will consist of several real estate stakeholders that are closely involved with real estate assets. Most of the participants will be the interviewees, as they have background information on the topic. The participants can be either involved in smart assets or in normal assets. Although it is important that experts of both 'sides' are present in the panel.

Goal

In this research the goal of Expert panel is to reach consensus on the importance of the value parameters, the usefulness of the smart applications found in the case studies and the perceived connection between value and smart applications. To reach this goal the following questions will be asked of the participants of the panel:

Importance of values

1. Out of this list of values, which one is the **most** important? *Place that one on position 8*.
2. Out of this list of values, which one is the **least** important? *Place that one on position 8.*
3. Rank the remaining values as compared to the values places on position 1 and 8.

Each response will result in a score given to each value and smart application. The more important the value and the more useful the smart applications the higher the score. Figure 41 shows a part of the Expert panel where the participants are asked to rate the importance.

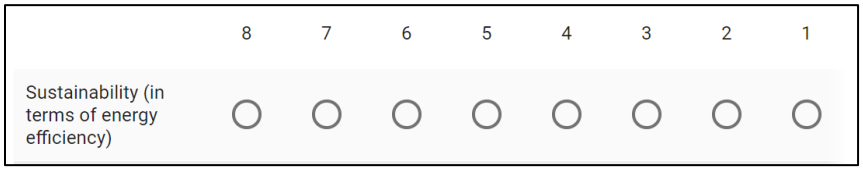


Figure 41. First Delphi panel question Own ill. Icons by PowerPoint

This is done for all the 8 values listed in the 'added value' section of the previous chapter. After enough responses are collected a ranking can be made and conclusions can be made on the perceived importance of the different value drivers.

Usefulness of smart applications

1. Out of this list of smart applications, which one is the **most** useful? *Place that one on position 9*.
2. Out of this list of smart applications, which one is the **least** useful? *Place that one on position 1*
3. Rank the remaining applications as compared to the applications places on position 1 and 9

The same applies to the usefulness of the smart applications. Figure 42 shows the second questions the participants will be asked. Like with the value, after the responses are collected a ranking will be made indicating the perceived usefulness of the different smart applications found in cases.

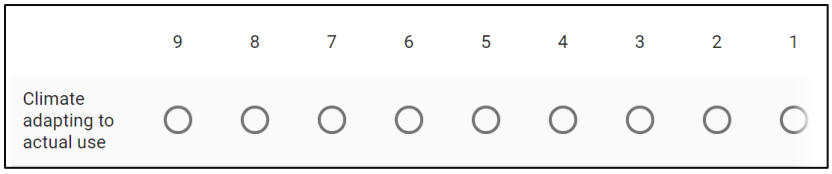


Figure 42. Second Delphi panel question Own ill. Icons by PowerPoint

Perceived relation between smart applications and value

The third question asks the participants to identify any connection they see between the value and the smart applications. Figure 42 again, shows the question. For each smart application, the participants can check whether or not they think that particular smart applications are associated with a certain value.

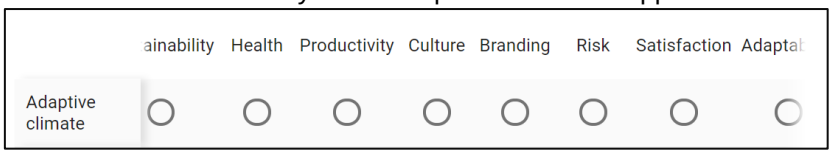


Figure 42. Third Delphi panel question Own ill. Icons by PowerPoint

Results

If the results are very divided after round 1, and consensus is not reached, the results are added to the questionnaire in the form of a ranking. This way the respondents can see what the other participants answered as a group and might change their answers based on these results. As seen in figure 42. on the previous page, this process is repeated until the desired level of consensus is reached. This means that approximately 70% of participants agreed on the importance of the value and the usefulness of the applications. The results of the Expert panel are found on in Chapter 3.4 on page 89.

Chapter 3 - Research results

3.1 Literature review results

In this section the results of the literature review: the theoretical base, will be described. As discussed in the 'literature review' section of the 'research methods' chapter the aim of the literature review is to create a theoretical base by reading, comparing and combine sources relevant to the research topics as seen in figure 43. The three topics are as follows and contain the following sub-topics

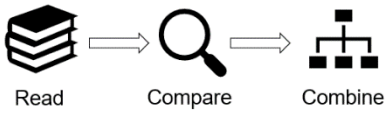


Figure 43. Literature review design. Icons by PowerPoint

Topic 1: Technology

This topic dives in deeper into the technological trends and cycles behind smart technology. It explores the world of Property technology in which smart buildings reside. Furthermore, the different categories within property technology and smart buildings are research and finally the concept of smart building as defined by literature is described.

Topic 2: Added value

The second topic defines and described added value according to various sources in literature. The added values are described one by one and the way to contribute to those added values are explored. Furthermore, the interrelationship between the added values, if present, are also discussed.

Topic 3: Stakeholders

This topic researches and explores the relevant stakeholders of this research. The investor and it's objectives are research through various sources. Furthermore, the real estate user is also researched.

Targeted research questions

This chapter contributes to the findings that will be used to answers the following sub-question:

1. What is added value?
2. What is a smart building and smart technology?
3. What are the objectives and constraints of the real estate investor?

Furthermore, the findings of the literature review will be used to create the parts of the value map seen in Figure 44. Mostly topic 2 and 3 will be used to find the connections between stakeholders and their objectives and the added values.

Figure 44. Part of the smart value map, stakeholder and added values. Own ill.

Technology – Topic 1

This section dives deeper into the convergence of the fourth industrial revolution and the real estate sector. First, the trends and cycles will be described, then property technology will be described and finally the concept of the smart building will be further discussed.

Technological trends and adoption cycles.

Industrial revolutions and the adoption thereof often described as being cyclical with similar patterns across innovative developments. According to Moore (1991) (technological) innovations see four different phases until widespread adoption is achieved.

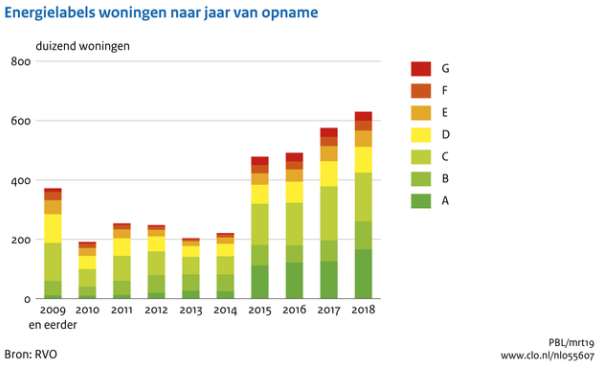
I. The first phase is led by the **Innovators** and represent at most 2,5% of the market. These are the companies that pursue new technologies and innovations in order to gain early advantage. In the smart technology market, OVG Real estate can be seen as the innovator as The Edge is seen as the first smart building in the world.

II. The second phase is the **Early Adopters** and represents at most 13,5% of the market. This group pursues new technologies in order to gain competitive advantage.

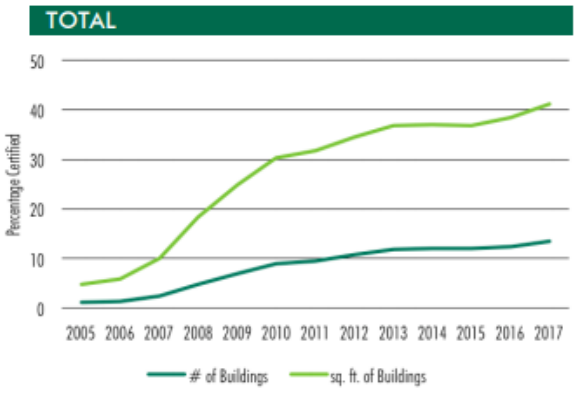
III. Then comes the **Early Majority,** representing 34% of the market. This is the group that waits for the new innovations to be proven in before acting quickly and adopting it.

IV. The last two group is the **Late majority**. This group represents the rest of the market (50%) and are the companies that wait until new innovations are well established with enough support and proof.

A good example of an adoption cycle can be seen through sustainability. Graph 1. show the amount and type of energy label in Dutch houses. In 2010, the amount of C labels was low. In 2018, this amount almost tripled, showing a growing adoption of sustainability. With the introduction of a new law in the office sector that requires all offices of 100 m² and larger to have a C label by 2023, the late majority will soon be forced to adopt sustainability, whereas 10 years ago, people were still unconvinced by sustainability. In the United States of America, the amount of certified sustainable buildings went from 5% in 2005 to more than 40% in 2017 (CBRE, 2018). This seems like the early majority phase is fully on its way for sustainable buildings. Graph 2 represents the growth in green building certificates in the 30 largest markets in the USA.

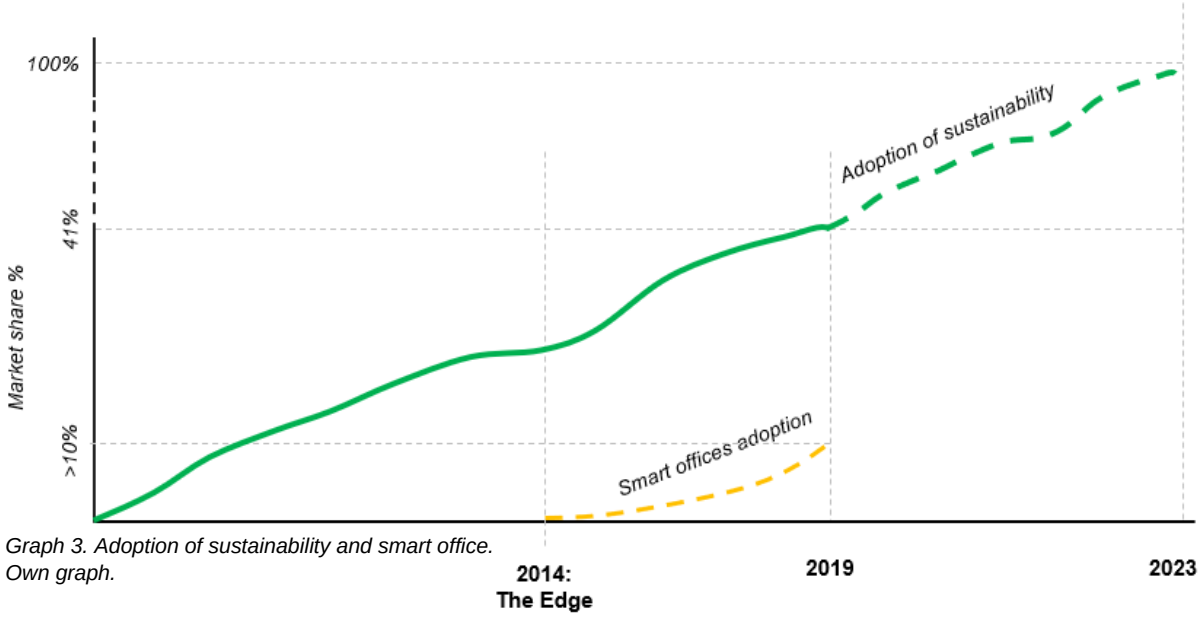


Graph 1. Energy label's in Dutch housing. Source: RVO (2018)



Graph 2. Percentage of green certified buildings USA markets. Source: CBRE (2018)

Graph 3 shows the difference in adoption between sustainable buildings and smart buildings (offices). The green line represents the adoption of green office. This line is based on the amount of certified green offices in the USA (CBRE, 2018), which is supposedly 41% and the adoption of energy labels in The Netherlands. When comparing this percentage to the phase mentioned by Moore, the adoption of green offices is nearly in the 'late majority' phase and based on the new law in the Netherlands the office sector will reach full adoption of C-label sustainability in 2023.



Graph 3. Adoption of sustainability and smart office. Own graph.

Smart offices, however, are still in the 'early adopters' phase (Interviewee 1C, 2019) which means that the market share of smart buildings is below 10%. The smart office trend started around 2014 with the delivery of The Edge. The green certification trend for offices started around 2005.

Property technology

PropTech in general is technological innovation that is above all directed and relevant to real estate and is part of the fourth industrial revolution. However, property technology (PropTech) is not something that is new or uniquely found in the fourth industrial revolution. Andrew Baum (2017) identifies two waves of property technology; PropTech 1.0 and PropTech 2.0. Baum states that the first PropTech wave occurred between 1980 and 2000 and was focussed on data and computing power. In the mid-1980s computing was already 40 years old and up to the start of the first PropTech wave has had no impact on the real estate sector. The introduction of the personal computer (PC) was what set the wave in motion as it changed the way of working and therefore the way offices were used and designed. The dotcom bubble was the end of the first PropTech wave. In the years after, the rise of online residential markets, such as Funda in the Netherlands, formed the bridge between PropTech 1.0 and PropTech 2.0.

Andrew Baum (2017) introduces a Venn diagram (figure 45) to show the categories that fall under the PropTech 2.0 wave.

Given the Venn diagram of Baum (2017) it is shows that smart buildings are a part of 'smart real estate' with the only difference being that smart real estate also refers to smart cities.

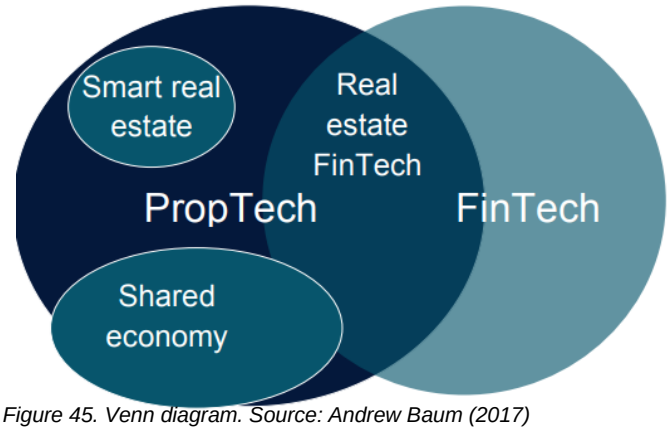


Figure 45. Venn diagram. Source: Andrew Baum (2017)

By now, in 2018, the second wave of PropTech is in full motion. Hundreds of start-ups and new applications or forms of technology join the movement. Throughout multiple report there are common themes that these different applications belong to. The next section will compare and combine all the common these found throughout literature in order to create some structure in the world of property technology.

PropTech categories

In this section a contribution will be made to answering the sub-question: "What are smart building technologies?

While a lack of documentation on the actual smart technologies that are used in building prevent the full answering of this question, literature review can at least provide the **categories** of smart building technology. As said, the actual applications will be inventoried through the case studies.

Appendix IV shows an overview of the PropTech themes or categories found throughout the reviewed literature. Many of these themes are very similar and are can therefore combined into 9 different categories. Due to the lack of literature on the topic of property technology many of the themes have very different names since there is no baseline or standard categorisation yet. But some themes, such as Information, or often called Big Data, are found in almost all sources. Within this research the focus is mostly on Smart Real Estate. PropTech that do not impact real estate assets, such as brokering platforms or payment methods, will be left out of the overview.

The 9 categories in figure 46. will be discussed in detail in the following section.

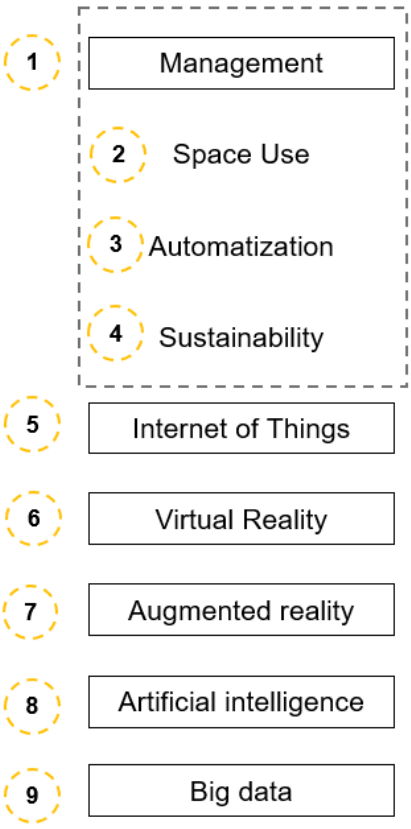


Figure 46. Proptech categorisation (Own. Ill)

1. **Management**
   Technology combined with real estate management is often referred to as smart real estate management (SREM) to distinguish it from the traditional real estate management. The complexity of the technology used in smart buildings requires smart management (Ullah et al., 2018). The core of SREM is innovative technology, sustainability and user-centredness and also includes asset and resource management (Ullah et al., 2018). SREM manages the smart real estate processes such as data collection and the processing of that data to information. The aim of SREM is to promote the overall quality of the real estate services (Ullah et al., 2018)

As with standard management, this category can be sub divided in:

- Property management; The applications in this category target the day-to-day processes in regard to the operation of smart real estate, including leasing and tenant communication (Baum, A., 2017). According to Chemitiganti (2017) property management can benefit from smart technology by the optimisation of resources, reducing energy waste, preventing maintenance and saving money.

- Facility management; The applications in this category are especially focussed on the efficiency and sustainably of the smart real estate. This is for example the quantification of building data and tools that make buildings more efficient (Baum, A., 2017

- Other management classes that are not specifically targeted at smart buildings such as: construction management and home services management (Baum, A., 2017)

2. Space Use

Space enhanced by technology, or the use of space improved by technology is another commonly found theme in literature. This includes indoor mapping to generate data (information) on the occupancy of space. This offers insights into, for example, the hidden vacancy in an office. This category can be seen as part of **property management.**

3. Automatization

As with artificial intelligence, automation is about minimalizing human intervention (Rossini, P. 2000). Robotics take automatization a step further and aim at tackling simple, large scale tasks such as surface cleaning, security services, façade painting and inspection (Deloitte, 2018). This category can be seen as a sub-category of **property management.**

4. Sustainability

The importance of sustainability makes it a key category that is targeted by property technologies. According to Deloitte (2018) sustainability can be achieved through property technology by performing sustainability assessments such as an assessment on the energy efficiency of buildings. Sustainability also targets social, environmental and financial aspects of buildings and cities (Wise, N. 2016). This category is a sub-category of **facility management** as it aims also at increasing efficiency and reducing energy use.

5. Internet of Things

The internet of Things (IoT) refers to a network of internet-based physical devices that can communicate with one another (Ullah et al., 2018). In real estate the IoT network is used to control temperature, humidity, lighting levels and air quality, allowing for unprecedented levels of control over the environment. For many real estate stakeholders this is a distinct advantage (Zhilong et al., 2015; Dijkstra, M. 2017; Li, C.Z. 2016). The main applications of the internet of things network is the possibility to react to user behaviour, proactive maintenance and repair, interconnectivity between smartphones and installations and enhanced environmental control (Zhilong et al., 2015; Donovan. et al 2018)

6 + 7. VR / AR

Virtual reality (VR) is technology that is involved in the creation of virtual worlds without interaction with the physical world. Augmented Reality (AR) enhances the physical world creating a mix between digital and real life (Boga et al. 2018). Virtual reality could be used to provide users with a 3D walk-through of real estate property without having to be on location (Taking et al., 2017)

8. Artificial Intelligence

Artificial intelligence refers to the execution of functions done by the human brain using computer programming and minimal human intervention (Rossini, P. 2000). In sorts it is the recreation of the human brain through a computer. Artificial intelligence systems can aid, or even replace, humans all the while reducing human errors. Artificial intelligence can for example perform maintenance, cleaning or repairs in places that might be hard to reach for humans (Warburton, D. 2016)

9. Big data
Big data refers to large amounts of data that cannot be effectively processed by traditional software (Winson-Geideman et al., 2017). Big data is also defined as a collective term for larger, interrelated datasets and the extraction of useful information from these large datasets (Winson-Geideman et al., 2016). Big data can be used to create overviews of business performance to more efficiently achieve overall organisational objectives. It can help to overcome inefficiencies and enable real estate owners to make better decisions Du et al. 2014; Zhou et al. 2015)

These 9 categories give an overview of the types and categories of technology that are found in smart buildings. As was said before, due to the lack of information the actual applications will be categorised through the cases studies and then related to these categories.

Smart buildings

Baum (2017) describes smart buildings as the result of combining space and technology. The definition of Shulman (2014) goes a bit deeper and states that smart buildings are properties that use sensors to collect data that can be used to manage the building more efficiently. According to Shulman (2014) the key features of a smart building are sustainability, user-centredness and the implementation of disruptive and innovative technologies to achieve holistic benefits that are otherwise not achievable.

The next section dives deeper into the sensors, the data collection and the efficiency that lead to the holistic benefits that are not achievable without the implementation of innovative technologies.

To understand the "smartness" of a smart building the *technology* that is combined with the space must be understood first. According to Zsebik (n.d.) the four technological key aspects of a smart building are:

1. A communications network
2. Sensors
3. Intelligent controls
4. Smart features.

Since smart buildings are still in the early development stage it is not surprising that most smart buildings are very similar. The similarity offers the chance to create a 'conceptual overview' of what currently defines a smart building. Figure 47. shows a schematic overview of a smart building, partially based on the 4 key aspects of Zsebik and the definition of Shulman.

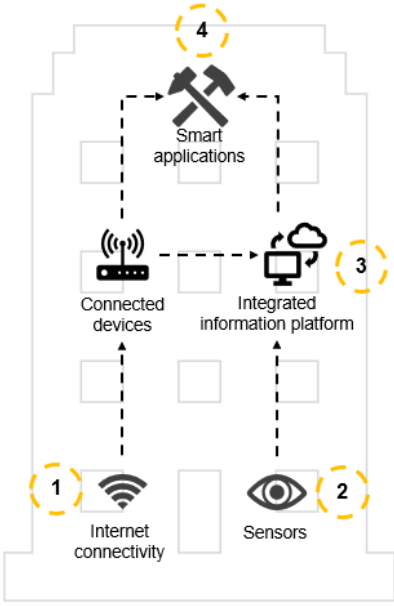


Figure 47. Smart building concept, icons by PowerPoint)

Collect and send data (Shulman, 2014);

5. **Communications network** (Zsebik)
   The communications network consists of internet connectivity (connectivity) and connected devices that can send and receive data. This creates a network of devices that are able to interact with one and other.

6. **Sensors** (Zsebik)
   Sensor technology is used to detect and respond to input from the physical environment. This provides constant data on the environment such as light intensity, temperature, air quality, sound pressure and motion (Arditi, 2015)

Enable the improvement of efficiency (Shulman, 2014);

7. **Intelligent controls** (Zsebik)
   These controls are required to manage the whole system. On the 'front-end the intelligent controls

are interfaces and dashboard that can be used to interpret information. On the 'back-end' the intelligent controls are complex software that gathers, processes and transforms data into information.

8. **Smart applications** (Zsebik)
   These are the features that have impact on the building processes. These applications use the information provided by the intelligence controls. The use of smart applications, resulting from the ability to process, analyse and learn from all the data is what makes a building smart (Nouveau, 2017).

Furthermore, a distinction must be made between the types of data used by the systems to create the information that powers the applications

Internal data

Internal data is the data that is produced by the sensors and it unique to the building. This is for example the indoor temperature, the indoor air quality or the indoor lighting intensity.
Internal data can be further divided in historical data, live data and predictive data.

Historical data is based on previously collected data. The 'older' the system or building the larger this amount of data becomes. By analysing historical data, it is then possible to identify recurring patterns in the data. These patterns can be used to define various behaviours of the building and its users and steer the building to react to these behaviours, increasing the efficiency (Linder, 2017)

Live data is the data that represent what happens at the moment it is accessed. The sensor tracks various factors that can be accessed in real-time (Kejriwal, 2016). An example of real-time data is when a user logs into the smart application to find an empty workspace, the application then provides live data on what desks are free.

Predictive data uses real-time and historical data to predict certain situations. By identifying the historical patterns behaviour that is likely to happen in the future can be predicted before it happens (Linder, 2017).

External data

External data is data that is not specific to the building. This is for example weather forecast, outdoor air quality and outdoor light intensity. Like internal data this can be divided in historical and live data. Where historical data can provide insights for expected values and live data gives actual values.

From data to smart application

The intelligent controls mentioned by Zsebik (n.d.) are an important part of the smart building since they enable the smart applications.

Deloitte (2015) introduces 5 phases that take the input (sensors and connectivity) and enable the output (smart applications). The five phases are seen and described in Table 6. below:

Create	The sensors monitor the building processes and create data.
Communicate	The connectivity allows devices to send and receive data amongst one another.
Aggregate	All the data collected by the sensors, the devices and other data producing sources are collected and combined.
Analyze	The collected data is then analysed in order to create information that can be acted upon.
Act	The information produced in the analyse phase is then used to exert actual impact on the building processes.

Table 6. Processes in a smart office. Based on Deloitte (2015)

The smart building in theory

This section gives an overview and summarizes the concept of smart offices in a theoretical setting.

Integrated technology

A smart office is an office where technology and space are integrated. Sensor technology and connectivity increase the efficiency of the office and provides unique user experience, comfort and control over the environment. The data that the building produces is used to recognize patterns of use in the building to which the building processes can be adapted further increasing building efficiency. Lastly, a connectivity network allows building systems and installations to communicate, send and receive data with one another provide new possibilities in terms of interoperability. Figure 48a shows the smart building concept again in terms of integrated technology

Impact of smart on value

Theoretically this leads to the results found in figure 48b. Figure 48b illustrates the benefits of smart buildings, based on the definition above. The figure is closely based on the flowchart created by Boyd (2006). Boyd's flowchart illustrated how sustainable buildings provided benefits to the value of the asset. In line with the definition a smart building sacrifices capital costs, increasing them, to improve working environment and reduce building costs. Following the theoretical line this leads to more demand for space and a higher operating income. Finally, it results in one negative impact due to increase capital costs and three positive impacts showing the theoretical benefits of smart buildings mentioned throughout the previous sections.

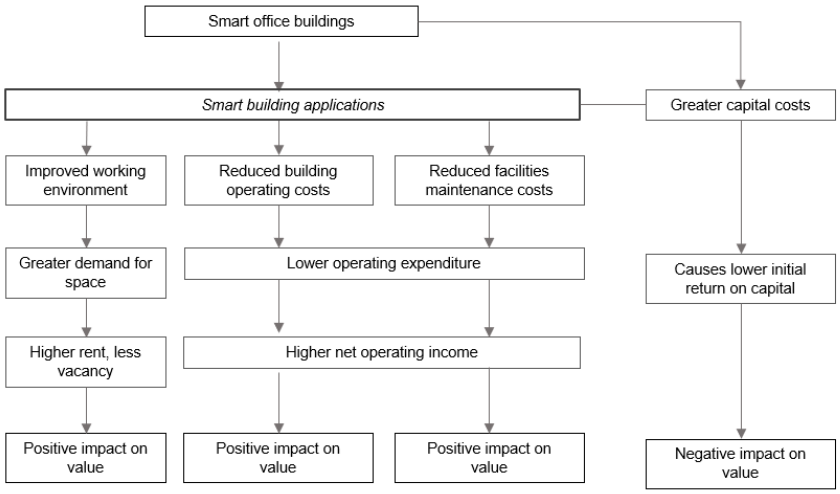


Figure 48b. Smart office building concept. Own illustration based on Boyd (20006)

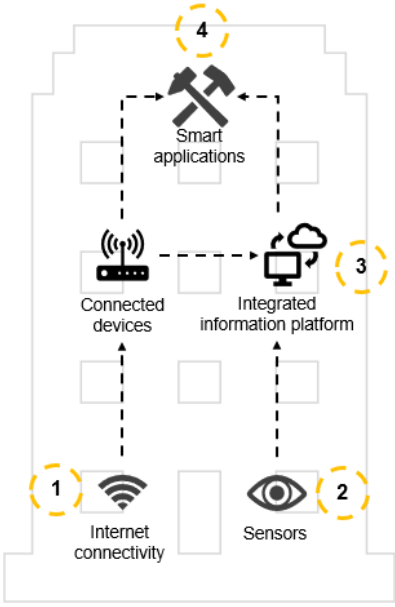


Figure 48a. Smart building concept, icons by PowerPoint)

Added value – Topic 2

In corporate real estate management there are various ways in which value can be added to real estate. Something has value when it contributes to the core business or aims of a stakeholder. Added value is not always, but very often, especially for investors, expressed in and traced back to economic terms such as cash flow or market value. In line with De Vries (2007) this section will merge different ways of 'adding value' and link them to the CREM strategies named in the 'research aim' section.

This way, this part of the theoretical framework answers the following question: *What is added value?*

Different literature sources on value adding process in real estate have been reviewed and compared to each other. For each source a list of the different parameters has been made. Then, the different lists have been compared to see if there is overlap between the parameters. Finally, the overlapping points have been combined to create an overarching list of the most commonly found parameters. The figures in appendix V show the results of the literature study with the 11 recognized parameters on the left side and the sources that have been reviewed.

The following section described the added values in no particular order. The connection these value parameters have with smart technology will be described later in this report, for now the focus will be put on the values themselves and the theory behind it.

Health

Health in an office building impacts the amount of sick leave, number of accidents and the satisfaction of employees (Van der Voordt, 2016). According to Charles et al. indoor air quality and thermal comfort are most important factors when it comes to user well-being. Henri et al. also indicated that indoor lighting is also important to for user well-being. This is further substantiated by Ticleanu et al. (2015) who state that good lighting can positively impact mood and circadian rhythm. Figure 49 shows the three important factor that impact the health and well-being of office users.

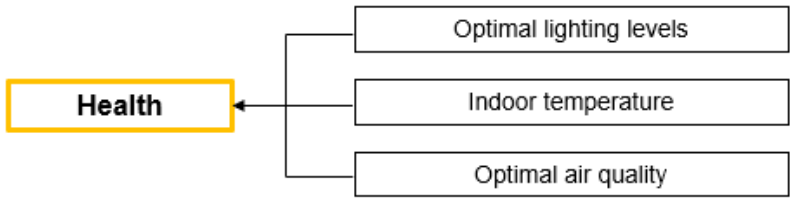


Figure 49. The added value health and how to influence it. Own ill.

Satisfaction

Figure 50 below shows how the added value can be influenced. As stated by Van der Voordt, (2016) satisfaction is impacted the quality of the indoor environment. The indoor air quality parameters such as thermal, light and air quality strongly affect the comfort of users (Esfandiari, Masoud & Zaid, Suzaini & Ismail, Muhammad, 2017). Other studies show that having control over work environment has a postive inlfuence on satisfaction, health and effectiveness (Huang et al., 2004; Leather, Beale, & Sullivan, 2003 ; Lee & Brand, 2005; Kwon & Remøy, 2018)Tenants that are satisfied are more likely to work better and

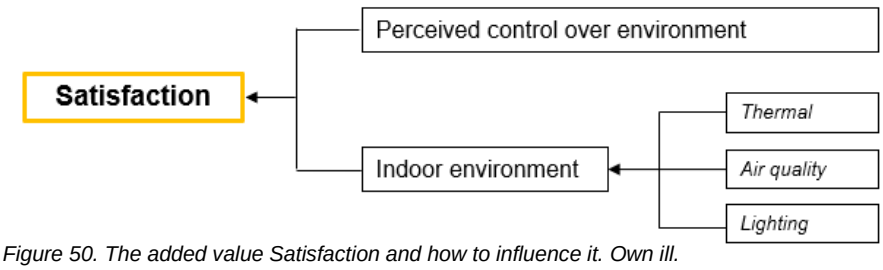


Figure 50. The added value Satisfaction and how to influence it. Own ill.

harder, meaning that a satisfied employee is a productive employee (Saari & Judge, 2004). Furthermore, GRESB (2017) states that there is a strong relationship between the satisfaction of tenants and the likelihood of lease renewal (tenant retention). One of the interviewees claimed that tenants of smart homes are willing to pay more rent due to the (additional) comfort that the smart technology in their homes offer them (Interviewee, 1D, 2019).

Productivity

According to a Danish study the improvement of physical dimensions of work environment (internal climate) firm can increase the productivity of the employees (Buhai, Cottini, & Nielseny, 2008). Like satisfaction, the ability to control the environment boosts effectiveness (productivity) (Huang et al., 2004; Leather, Beale, & Sullivan, 2003; Lee & Brand, 2005). This is represented in figure 51.

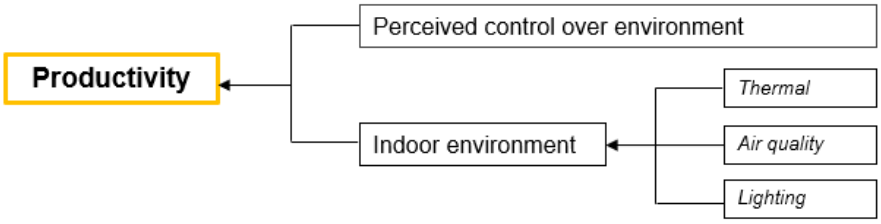


Figure 51. The added value Productivity and how to influence it. Own ill.

Adaptability

Jensen et al. (2012) state that adaptation is an added value while multiple other researchers refer to it as flexibility (De Jonge, 1996; Den Heijer, 2011; Van Meel et al, 2010). Adaptability it is about the ability to solve problems without hindering primary processes, being able to adapt to change (Den Heijer, 2011). Van der Voordt (2016) states that using Flex 2.0 or Flex 2.0 Light the adaptability of a building can be scored effectively. The Flex 3.0 method lists 44 flexibility performance indicators that are used to assess the adaptability of a building. Amongst these indicators are for example measure and control techniques and customisability and controllability of facilities (Geraedts, R. 2016), as seen in Figure 52.

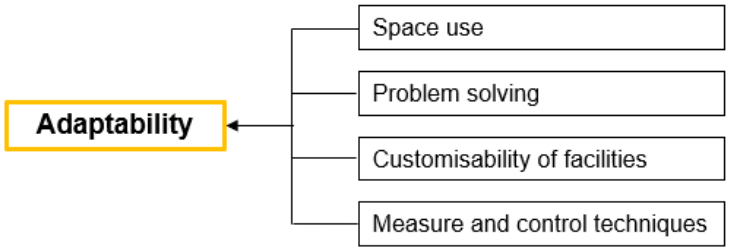


Figure 52. The added value Adaptability and how to influence it. Own ill.

Sustainability

With the rise of green buildings sustainability becomes more and more an important value. Van Meel et al. (2010) and Den Heijer (2011) state that reducing environmental impact and reducing the footprint respectively are ways to add value. Bradley (2002) adds energy consumption to the list of drivers that fall under sustainability. Jensen et al (2012) also mention lower carbon dioxide emissions, lower energy consumption and lower water consumptions as ways to support environmental sustainability. All these factors are also seen in Figure 53 below.

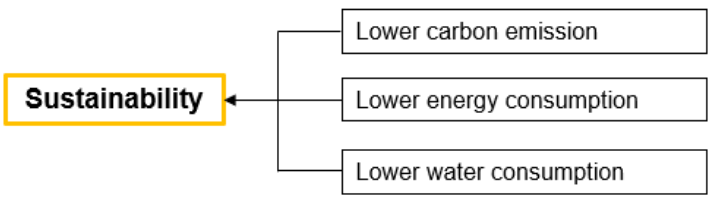


Figure 53. The added value Sustainability and how to influence it. Own ill.

Culture

Culture, or corporate culture, are the ways of working within an organisation. It is focussed on the internal users of the building but also on matching the use of the building with the organisational or corporate culture (Den Heijer, 2011). Den Heijer (2011) also states that culture, or supporting culture, is about stimulating interaction. This is in line with Van Meet at al. (2010) who state encouraging interaction as a way to add value (Figure 53.)

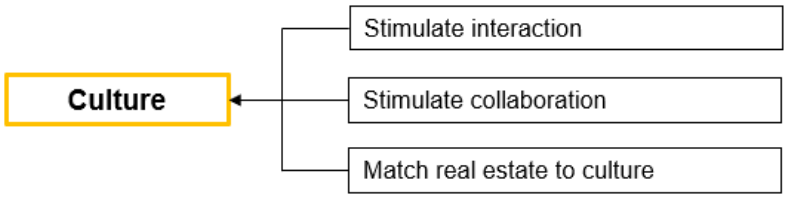


Figure 53. The added value Culture and how to influence it. Own ill.

Branding

All most all the research papers, expect for the one by Jensen (2010), mention branding, or something very related, as a way to add value. Den Heijer (2011) mentions supporting image as an added value and states that it is the image to users and external parties such as potential employees, customers and clients. Ultimately branding leads to competitive advantage as stated by Den Heijer (2011) and Khanna et al. (2013). According to van der Voordt (2016) high quality surroundings impact branding. Jensen et al. (2013) state the Green processes improve image. In line with this Den Heijer (2011) links branding to innovating, creativity, sustainability or having an exclusive character as an organisation, as seen in figure 54.

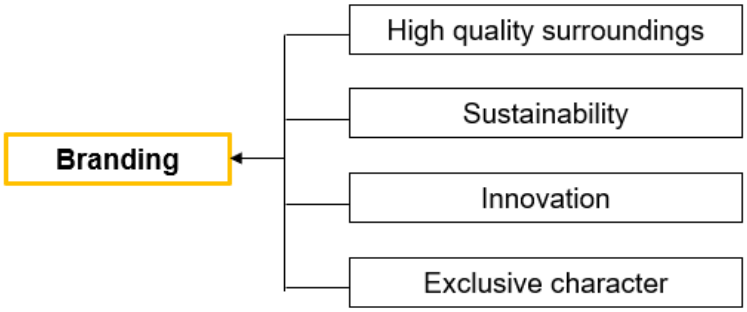


Figure 54. The added value Branding and how to influence it. Own ill.

Risk

Manganelli (2015) describes three risk classifications that real estate investors face.

1. **Business Risk;**
   The risks that come with attracting and retaining tenants and the competition of other investments. This is influenced by changing user preferences and changes in business operations. Not being able to find tenants means that the real estate asset will be vacant and un-exploitable.
2. **Financial risk;**
   Financial risk is the growth potential of the investment, or the risk that it will not grow. But also, the lack of available funding and the danger of insolvency. Not being able to finance a certain investment, or not being able to pay back the financing is a big risk that comes with an investment that is not as feasible as expected.
3. **External risks**;
   External risk can be changes in regulations, constraints imposed by other stakeholders or any environmental risks. An example can be a tenant withholding rent due to financial problems.

Parallel to that, Greer (1997) identifies four categories of risk;

- Operational risk; caused by management problems
- Credit risk; caused by the inability of other stakeholders to meet their obligations
- Liquidity risk; caused by the difficulty to sell an asset.
- Market risk; caused by uncertainty resulting from changes in market conditions.

Figure 55. shows an overview of the ways to decrease risk for an investor

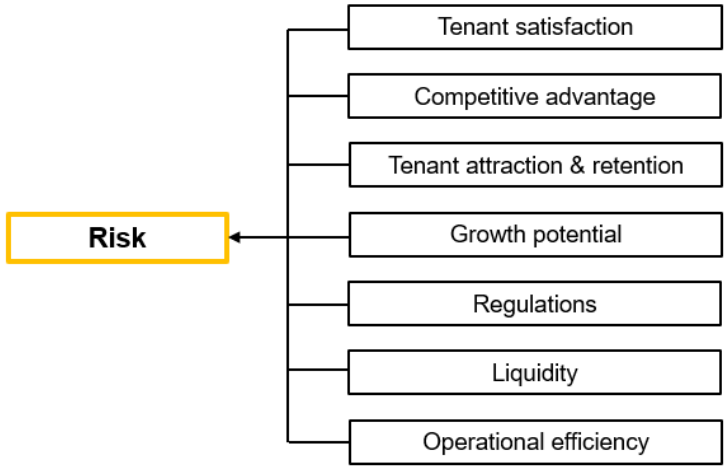


Figure 55. The added value Risk and how to influence it. Own ill.

Cost reduction

Costs, or operating expenses (OPEX), are the recurring costs related to property. Cost reduction can be achieved by cutting overall costs and personal costs but can also be achieved through higher production efficiency or lower percentage of absenteeism. The most used intervention to reduce costs is the reduction of floor area (Den Heijer, 2011). Figure 56 shows an overview of the cost reduction added value.

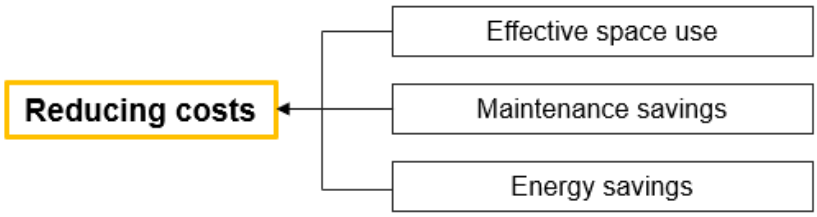


Figure 56. The added value Costs and how to influence it. Own ill.

Asset value

Increasing the value of an asset can be done through branding, making a building more marketable to others, more suitable to (paying) users or by choosing valuable locations (Den Heijer, 2011). Other sources

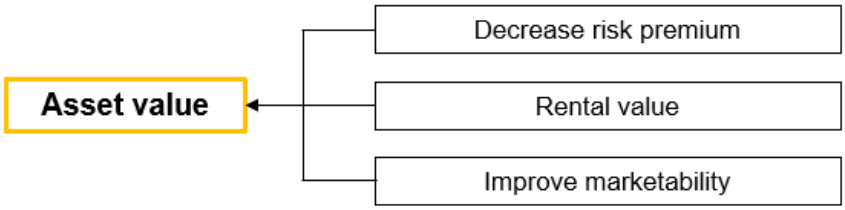


Figure 57. The added value Asset Value and how to influence it. Own ill.

also indicate that the asset value is based on rent value (Remøy, 2010). This is in line with a common valuation method where the asset value is determined by the division of the net operating income with the required yield.

CAPEX

Capital expenditure are the upfront costs associated with the investment object. In the case of a smart building the CAPEX also includes the additional costs required to integrate the smart technology, as seen in figure 58. As will be described in a later section, the capex is mostly seen as a constraint.

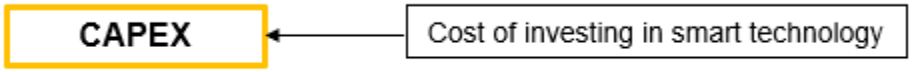


Figure 58. How CAPEX is influenced in this research. Own ill.

Income

Figure 59 shows the added value income. Income in the form of rental income is one of the most important objectives of the investor. For the cash-flow investor this is even the main objective. Achieving higher rental income through lease contracts is the main way to positively influence income. Another way is to provide additional (opt-in) services in exchange for additional rent. Furthermore, tenant retention and attraction is key to having any income at all.

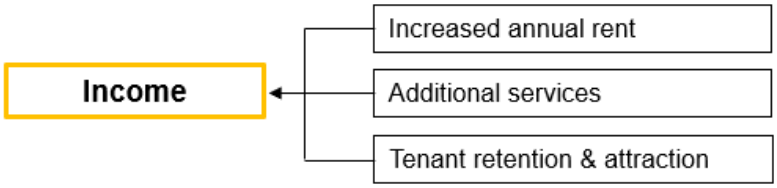


Figure 59. The added value income and how to increase it. Own ill.

Important to note is the 'special' interaction between income, costs and market value. As was stated by Remøy (2010), the market value is also depended on the rent level. Figure 60 below the capitalisation method to calculate market value. By subtracting operating costs (2) from rent income (1) the net operating income (3) can be calculated. Then by dividing the net operation income (3) by the capitalisation rate (4) the market value is obtained. This means that increasing income and decreasing costs directly impact the asset value. Furthermore, the capitalisation rate (4) also includes the risk premium which is based on **risk.** Therefore, decreasing risk will increase the market value.

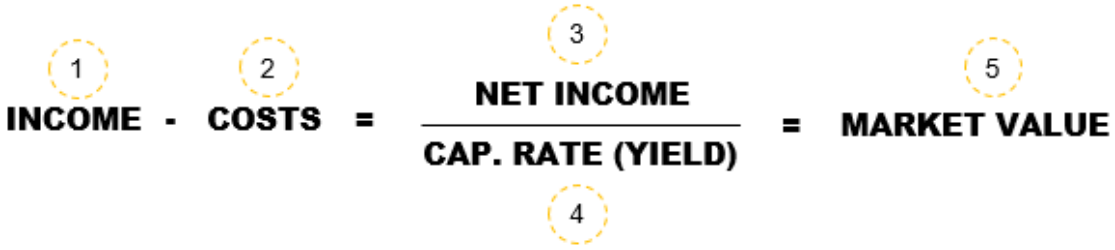


Figure 60. Determinate of market value through the capitalisation method. Own ill.

The results of this section answer the question: *What is added value?* And seen in Figure 61, the answer to the sub-question provides the 'added value' part of the value map. The next section described the stakeholder objectives and will connect those to the added values.

Figure 61. The added value part of the Smart Value Map. Own ill.

Stakeholders – Topic 3

Since value depends on the objective of stakeholders it is important to cover all bases and also do research on the objectives of other relevant stakeholders in the real estate office sector. Based on this section the 'Stakeholder' and 'Objective' part of the value map will be created (Figure 62).

Figure 62. The stakeholder objective part of the Smart Value Map. Own ill.

Real estate is a multi-stakeholder sector where stakeholders have different goals, needs and wishes. Due to the problem resulting from a mismatch in supply and demand the stakeholders will be divided accordingly, with the investor representing the supply side and the user or tenant representing the demand side. This way the objectives of the stakeholders of the two sides can be aligned, further creating a match.

Real estate investor

Relevant research question: *What are the objectives and constraints of the real estate investor?*

Manganelli (2015) defines the investors as the person, or institution, that engages in real estate with the goal of making profit. Active investors make decisions themselves and do everything that has a direct effect on the operation results. Passive investors do not take decision but delegate them to other stakeholders.

Van Gool (2007) distinguishes two types of investors; the investor who sees real estate as a primary product and not as a way to achieve high yield, for example governmental bodies such as the RVB (Rijksvastgoedbedrijf). The other type of investors is the commercial investor who uses real estate to achieve the highest possible yield, either with a long- or short-term vision. Keeris (2008) divides the commercial investor, as defined by Van Gool (2007) again in four different kind of investors that are yield driven:

1. The institutional investor
2. The professional private investor
3. The private investor
4. The speculative investor.

Keeris argues that the difference between the four investors the time scope is, with the institutional investor investing with the longest and the speculative investors investing with the shortest time vision out of the four.

Geltner et al. (2001) indicate that investors fundamentally have two, mutually exclusive, objectives main in commercial real estate. The first being the growth (value) objective and the second the income (current cash-flow) objective. The main difference, again, being time horizon. The growth objective is paired with a long time horizon with no immediate need to use the invested capital. This objective is often seen amongst institutional and private investors (see types of commercial investors as defined by Keeris).

The income objective is paired with a more short-term and pressing need to generate cash from the investment. Both objectives, however, are driven by yield. By combining the literature (Van Gool, 2007; Keeris, 2008; Manganelli, 2015; Geltner et al 2001) two types of investor profiles can be defined:

- **Value-increase investor (long term)**

- **Cash-flow investor (short term)**

Constraints
Other than time and yield Geltner (2006) states other criteria that concerns and affects most investors in the real estate market. Nase (2018) describes similar criteria. These criteria can be seen as constraints, as they are often used to 'judge' the feasibility of an investment.

Risk (Geltner, 2006; Nase, 2018)
The possibility that the investment performance varies over time in the future.

Liquidity (Geltner, 2006; Nase, 2018)
The rate at which the asset is absorbed by the market at the corresponding asset value. Nase (2018) describes this as ease of transfer and cost of transfer.

Complexity (Geltner, 2006)
The amount of expertise and effort needed to manage the investment assets.

Size (Geltner, 2006)
The amount of capital needed to execute the investment. This is also referred to as Capital expenditure (CAPEX)

Capital constraint (Geltner, 2006)
The absolute upper limit of available capital to invest.

The overview of the investor profiles can be seen in Figure 63.

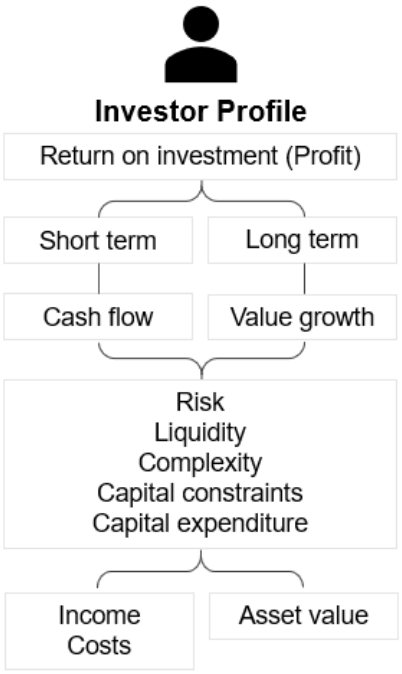


Figure 63 stakeholder drivers, objectives and constraints. Own ill.

Real estate users

Real estate users play a very important role when it comes to real estate investments. Investors generate income through lease contracts with real estate users. This income based on how well the real estate fits the objectives and preferences of the users. If something is valuable for the real estate user, it indirectly holds value for the investor. It is therefore important to create an overview of user objectives and preferences. The real estate user can be divided in two:

1. User – The organisation

If a company, for example Deloitte, rents office space it is to provide possibilities for her employees to execute the core business. The focus of the firm is the optimal productivity of the employees, since that is what drives the production and therefore the revenue. When looking at the list of added value processes most of them are important for the corporate entity. Branding for example can help with attracting clients, whilst improving the health of the employees will raise their satisfaction, productivity and reduce down time and costs associated with sickness and medical leave. This is further supported Lorenz (2008) who took a normative approach on the perception of owners and end users stating they value buildings that are cheaper to run, increase well-being and improve image.

2. User - The employee

Organisations need employees to carry out the core businesses. The performance of the employees is directly linked to the success of the organisation and therefore very important.

In the recent year's 'soft' factors such as status, appearance and ambience have become as important as the 'harder' factors such as location, accessibility and workplace environment (Remøy, 2010). In turn, workplace environment is also more and more important, leading to employees not just being satisfied with a compatible salary (Florida, 2004; Rodenburg, 2005).

Leaman (2000) states that users like situations where they can change things on occasions with predictable states, the ability to quickly and efficiently respond to changing conditions and the possibility to intervene quickly and effectively. While they dislike the exact opposite of the three.

It can be concluded that employees' preferences, apart from salary and location, are increasingly focussed on high quality workplace environment and different soft factors. Since the normative approach of Lorenz (2008) also included the employees the importance of buildings for users is also the contribution to well-being and image.

The dynamic between investor and real estate user is important for this research. Figure 63a shows the relation between the Investor, the employee and the tenant. As can be seen the employee executes the core business of the company it is employed at. The company uses office space offered by the investor, so the employees can execute the core business. In return the company, the tenant, pays rent which generates income for the investor. All three stakeholders are dependent on one another, either directly or indirectly and their interests are therefore intertwined.

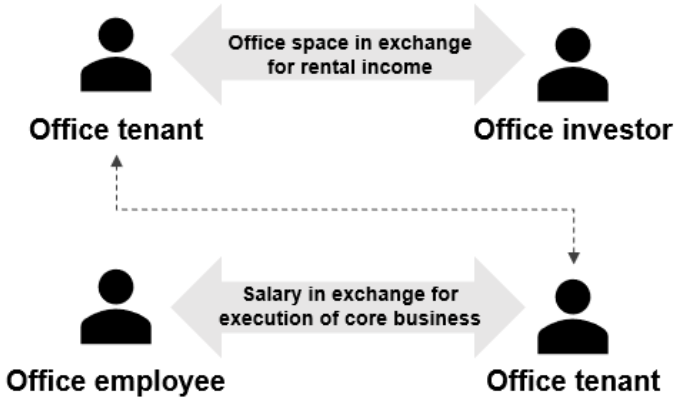


Figure 63a dynamic between employee, tenant and investor. Own ill.

The previous section described the types of investors and users that are relevant to the research. For each stakeholder the objectives have been stated. Figure 64. shows on overview of the relevant information for the research, per stakeholder.

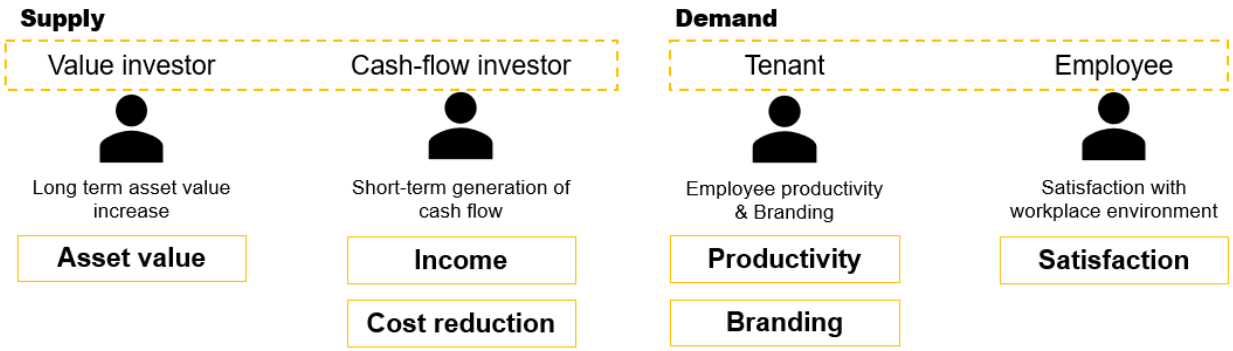


Figure 64 Overview of investors and users and their value objectives. Own ill.

Since the aim is to improve the match between supply and demand it is important to keep in mind what is important for both sides. If the objectives of both the users and the investors can be aligned through the implementation of smart applications, it is important to create clear connections between the objectives and the smart applications. The next section will take the first step in creating this connection. The values inventoried and substantiated in the 'added value' section will be connected in accordance to the division between supply and demand made in figure 64. This will enable the connection between the stakeholders and the smart applications that is necessary for the value map. As such the first 'link' between two of the elements in the value map will be made.

Added value through property technology

This section is, in sorts, the conclusion of the literature review. It combines two of the topics researched and creates the first part of the value map. As such, the stakeholders that have been linked to their objectives will now be linked to the various added values. This creates the part of the value map indicated in orange in figure 65. One sub-map will be made for the investors (supply) and one for the users (demand)

Figure 65. The stakeholder, objectives and added values part of the value map. Own ill.

There are multiple value interrelationships, meaning that certain values impact each other and therefore lead indirectly to stakeholder objectives.

An example can be seen in figure 65a below, where Sustainability contributes to Branding. Sustainability itself is also seen as an added value, so by increasing or contributing to sustainability the branding added value is impacted simultaneously. It is also seen in figure 65b where (tenant) Satisfaction leads to a reduction in the risk associated to the investment.

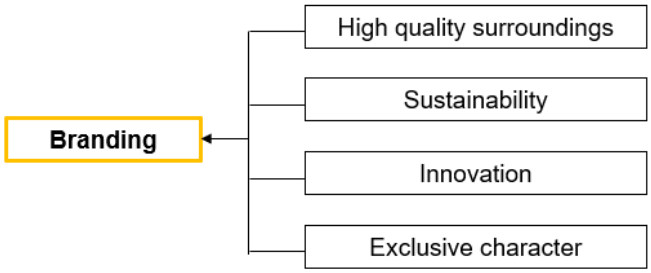


Figure 65a. the interrelationship between sustainability and branding. Own ill.

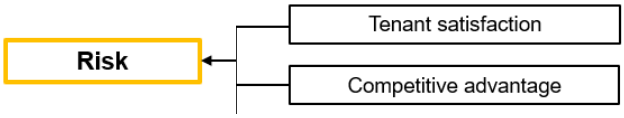


Figure 65b. the interrelationship between satisfaction and risk. Own ill.

To reduce clutter in the value, map the indirect values are shown in table 7. In line with the previous example: sustainability directly influences cost reduction, branding and risk.

This value:	Leads to this value:	This way:
Sustainability	Branding	Having green processes (Jensen et al. 2013)
Sustainability	Risk reduction	By increasing marketability and liquidity
Branding	Risk reduction	By increasing tenant attraction and liquidity
Innovation	Branding	Providing innovative concept and technology
Health	Branding	By providing higher quality surroundings
Health	Satisfaction	By providing higher quality surroundings
Health	Productivity	By improving the indoor environment
Productivity	Branding	As a result of high-quality surroundings
Productivity	Satisfaction	As it is a core objective of tenants
Satisfaction	Branding	Result of satisfaction with workspace
Satisfaction	Risk	Through tenant retention and attraction
Satisfaction	Productivity	Through satisfaction with indoor environment
Culture	Branding	Providing an exclusive character
Adaptability	Branding	Innovative technology that allows control over systems
Adaptability	Satisfaction	Providing ways to have control over environment
Adaptability	Innovation	Innovative concept of controlling systems

Figure 7. The interrelationships between the added values. How one value can impact another Own ill.

Figure 66 shows the direct connections or links that can be made between investors objectives and the added values.

The objectives, and thus the 'end goals' is found on the left side. By impacting the values on the right side of the map, and following the lines accordingly, the stakeholder objectives can be influences positively or negatively.

As example: reducing energy consumption in an office building leads to increased sustainability (Bradley, 2002). But simultaneously, lower energy consumption also leads to lower energy costs. These impacts, and reduces operation costs (Den Heijer, 2011).

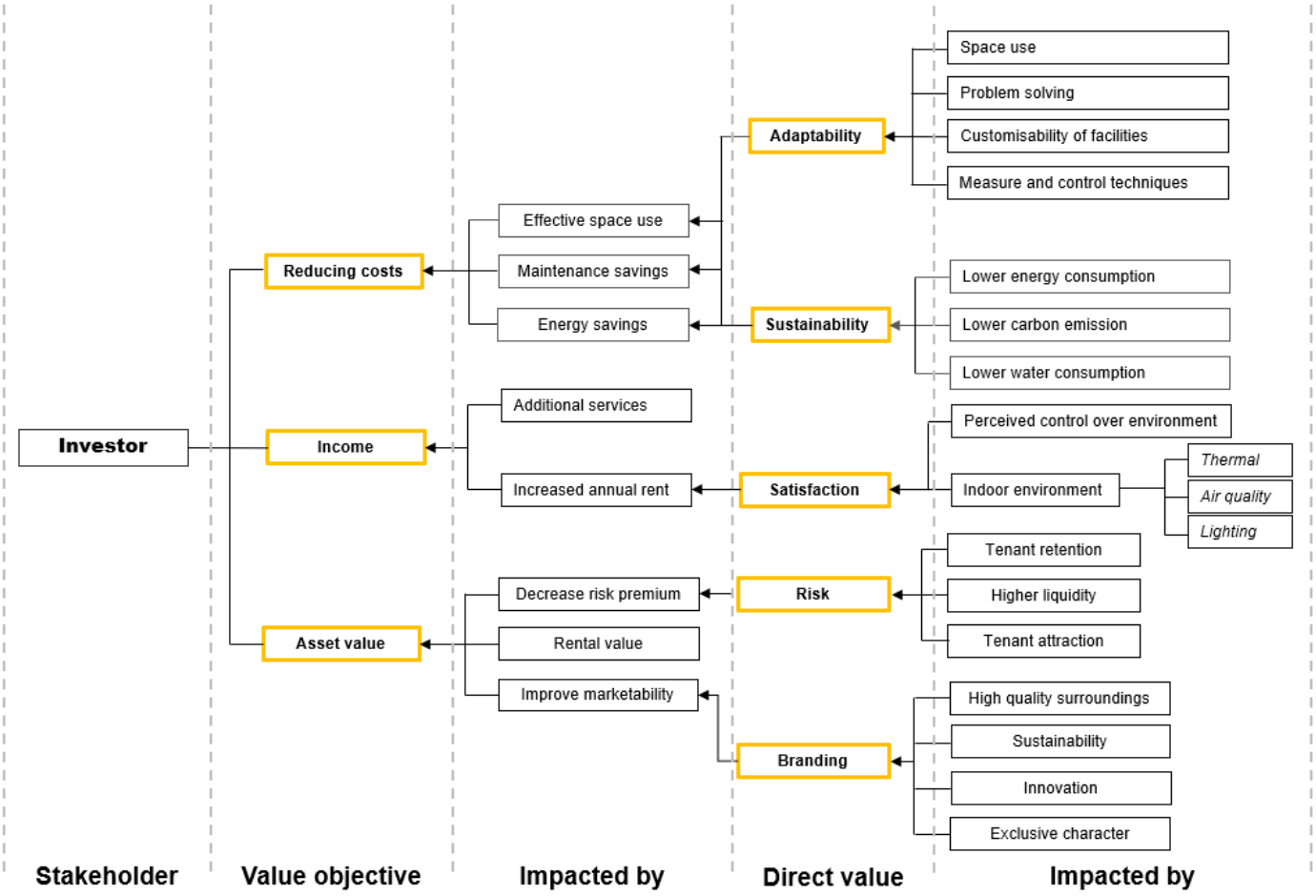


Figure 66. The direct connection between investor objectives and added values. Own ill.

Looking back at the objectives of the cash-flow investor, reducing costs was one of the main objectives. Therefore, measures that increasing energy savings hold certain value for the cash-flow investor while also increasing sustainability. On the other page the map is made for the user objectives. The complete map is a combination of figure 6 and table 7, since values in table 7 can also lead to the investor objectives.

Figure 67 shows the connection between the user objectives and the direct values. Similar to the value map of the investors the user objectives are on the left and the values that impact them on the right. Also, table 7 is needed for the complete map.

To illustrate further: Optimizing indoor quality in an office building improves the 'Health' added value seen in Figure 67. Better air quality improves the overall indoor environment. An overall indoor environment leads to user satisfaction, which is one of the objectives of the user.

To improve user productivity, the other objective, 'Health' or 'Adaptability' can be improved. The perceived control over environment leads to productivity and since adaptability includes the rate at which control can be had over the environment, one leads to the other and ends up contributing to the user objectives.

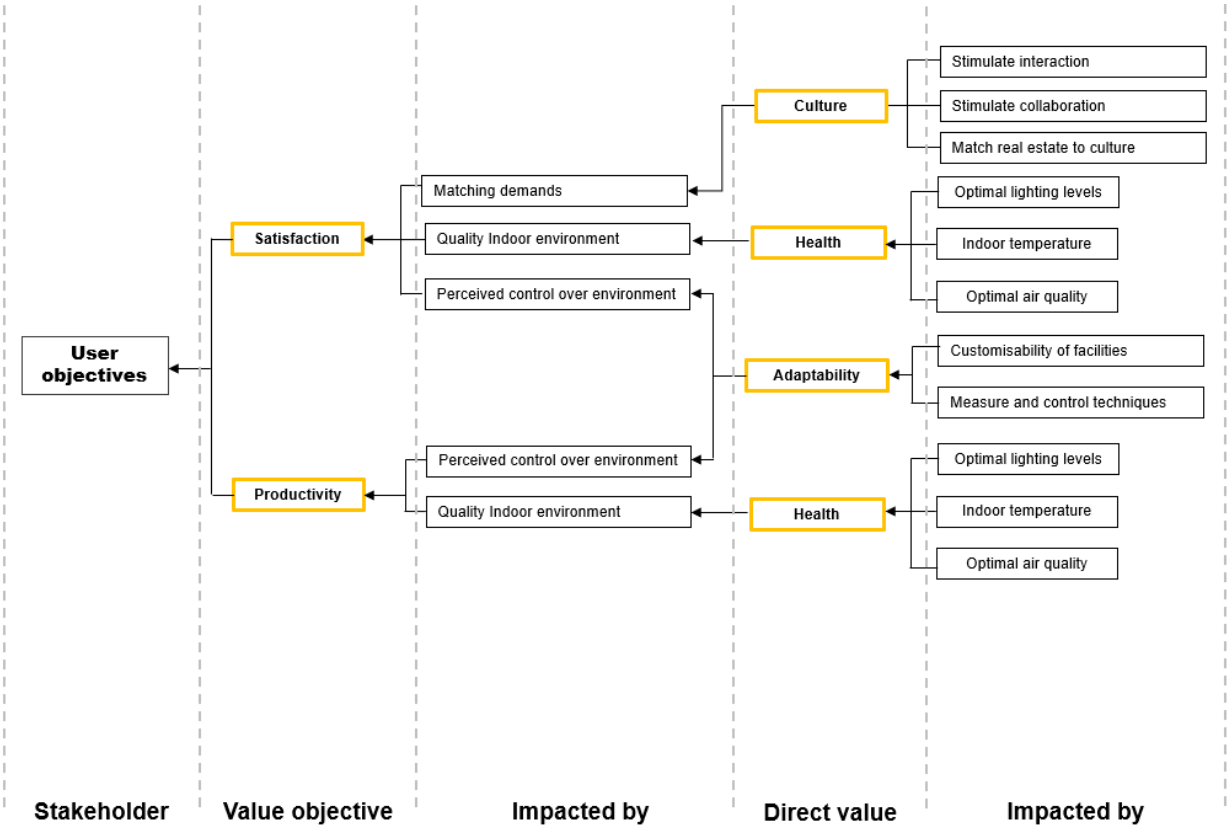


Figure 67. User objectives connected to the added values. Own ill.

Now that the first part of the value map is made, the second part needs to be made, and the two parts need to be combined. As was said in the methodology chapter, the second part of the map is based on the findings of the case studies.

The next section introduces the three cases on which the value map is based. Each case will be described in detail together with their contribution of the value map.

Literature review conclusions

To conclude the literature review some of the research sub-questions will be partially answered and listed again in table 8. This creates an overview of what information has been collected through the literature review and how that information contributes to the overall research.

What is added value?	What is a smart office and smart technology?	What are the objectives and constraints of the real estate investor?
Added value is the rate at which a certain aspect or factor contributes to the improvement of a stakeholder's core objectives. This means that 'value' depends on the stakeholder and its goals. In the context of the research the objectives of the investor have been defined. A certain action or implementation is of added value for an investor if it has a positive impact on its core objectives; income, costs or asset value. The impact can be either direct or indirect.	A smart office uses sensors and internet connectivity to collect data on the performance of the office. This data is then processed and transformed into information that can be used to influence the building processes. The way the information is acted upon can improve the efficiency of the office. The biggest difference between a 'normal' office and a smart office is the amount of data that is available and used to impact performance.	Real estate investors are, at the core, drive by profit. This means that their objectives revolve around a certain return on investment. One type of investors achieves this return on investment by focussing on short-term cash-flow while the other type of investors achieves this by long-term asset value development. The constraints of the investor are mostly related to different types of risk and the amount of capital available to incite change.

Table 8. Literature review conclusions. Own table.

As seen in table 8 the literature review can give an answer to three of the sub-questions. Both the sub-question on added value and the objectives and constrains of the investor have been answered quite completely. However, the question on smart technology still lacks information on the applications that use the information to impact the building processes. This question will be answered more thoroughly through the case studies. Furthermore, the answers to the sub questions on added value and the investor will be used to structure the end product.

The added values found through the literature review, as seen in 'added value – topic 2' will be used as input in the Expert panel to obtain a certain importance score per added value. That way, through a panel of multiple participants, a certain consensus can be found on which added values are important when it comes to offices.

3.2 Case study results

Table 9 shows the three cases that have been selected.

The case	The criteria
The Edge	1. Main function is office buiding 2. Branded as the first smart building constructed 3. Is located in Amsterdam on the Zuidas 4. Is co-developed by OVG Real estate and Deloitte
The Edge Olympic	1. Main function is office building 2. EDGE technologies calls it the new generation of smart buildings. 3. Is located in Amsterdam 4. Developed by EDGE Technologies and OVG Real Estate
The Outlook	1. Is an office building 2. Business Insider (2018) calls it a smart office. 3. Is located on Schiphol near Amsterdam 4. Is developed by Schiphol Real Estate

Table 9. Selected cases based on give criteria. Own table.

The cases are constructed based on the four topics found in section 2.3 on page 29. First a general description of the office is given and a then a contribution overview of the interviewees is shown. Then, the case findings are described, and the case is summarized to give a case specific answer to the sub-questions. The case summaries then used as input for the cross-case analysis. The findings of the cross-case analysis will give a holistic overview of the technology that drives the smartness of the building, the smart applications that are enable by the smart technology and the influence of the smart applications on the added values. Figure 68 shows the part of the value map that the cross-case analysis provides input for.

Figure 68. In orange: the part of the value map provided by the cross-case analysis findings

Case structure

- **Building description**
- **Data collection**.
- **Case findings:**

A. Input will describe the developer or investment drivers that led to the development of a smart office and what technologies enable the 'smartness' of the office.

B. Processes will describe the internal processes that are enabled by the smart technologies.

C. Outputs are the actual applications or tools that affect the building processes and increase the efficiency of the office.

D. Outcomes describe if and how the smart applications impact the added values mentioned in the 'added value' section of this research

The Edge

Building description:

The first case is The Edge (Image 1). Located in Amsterdam and developed by OVG Real Estate in 2015, The Edge received worldwide media attention after completion. Back in 2014 The Edge was hailed as the most sustainable building in the world reaching a 98,4% BREAAM score (BREAAM, 2019). More in line with this research, The Edge was the first smart office building. Together with Deloitte OVG Real Estate developed the office building and fitted it with approximately 6.500 Philips luminaires with integrated sensors. In total the office building holds 30.000 sensors (OVG, 2019). The office is now multi-tenant smart office with Deloitte still being the anchor tenant.

Image 1. The Edge. Source:

Key facts:

Location:	Gustav Mahlerlaan 2970
Size:	40.500 m² office space
Delivery date:	2014
Development type:	New built
Main function:	Office buildin

Stakeholders:

An overview of all the involved stakeholders are found in Figure 69. The Edge was co-developed by OVG Real Estate and Deloitte. Subsequently the office building was sold to DEKA Investments who leased the office back to Deloitte, OVG and other companies. After a while, OVG moved to another office; The Edge Olympic, another smart office and the third case of this research. DEKA Investments appointed CBRE and CBRE CWS as asset, property and facility managers. The office is currently used by Deloitte Holdings, AKD and a few other tenants. The digital backbone of the building was developed together with Philips, Mapiq, and Schneider Electric. All providing a separate 'part' of the smart building.

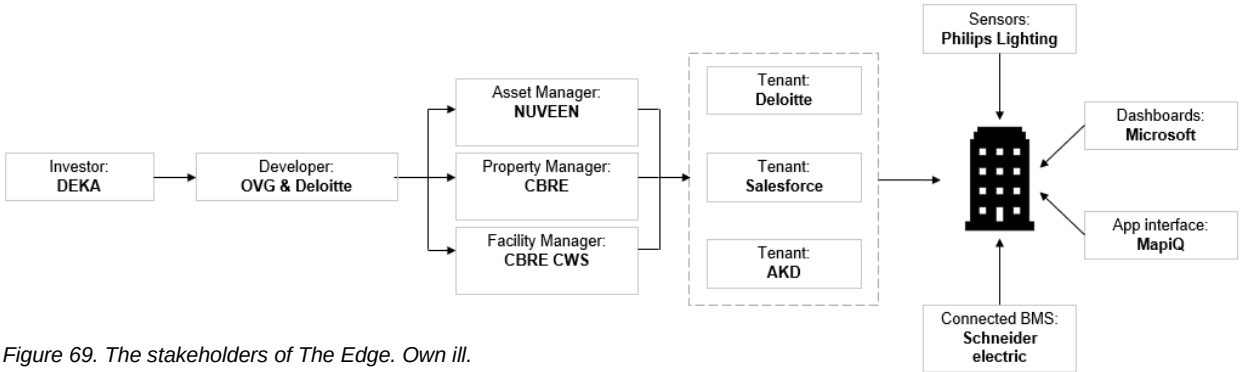


Figure 69. The stakeholders of The Edge. Own ill.

Case data collection

For The Edge case two interviews have been conducted to cover the four case topics.

The first interview (Interviewee 1A) was done with the facility manager of The Edge. The asset management of the Edge is done by CBRE who was enlisted by the owner of The Edge. As the facility manager of The Edge the interviewee had the final responsibility in terms of facility management for four years. All the tasks that are related to the daily use of the office building, such as lighting, cleaning, climate, security and day to day budgeting were managed by the interviewee. The satisfaction of both the user and the client was very important. The main goal of the interviewee was to make sure everything works correctly for daily use.

The second interview (Interviewee 2A) was done with an employee of Deloitte, the main tenant and user of The Edge, who has worked full-time in The Edge since its delivery in 2015. This interviewee is on the end-user side of the building and mostly involved with the user oriented smart applications found throughout the building. Furthermore interviewee 2A also worked a while in the old office of Deloitte.

The contribution of the two interviews will be described in the next section, divided over the four topics.

As an Employee at CBRE the interviewee has been involved since before the delivery of The Edge.

Types of smart applications found in The Edge

Both the interviewees provided insights into the different smart applications found throughout the Edge. While most of the information is well documented and available online the interviewees confirmed most of the information and added new information to it. Interviewee 1A mostly discussed and explained what types of management smart applications are found in The Edge and their purpose and impacts. Interviewee 2A, as an employee and full time user of the office, provided insights into the way the applications are used by the employees.

The way the smart technology works in The Edge

Both interviewee 1A and 2A are closely involved with the daily use of the smart applications and can therefore provide insights into how the smart applications work and how they are used. Interviewee 1A explains that the data is collected by thousands of sensors throughout the building. All this data is collected in the Data lake and then used by multiple tools that analyse and process the data. In turn, the information can be used by the smart applications to improve the building processes. Interviewee 2A explains in detail how the applications are used by the users and what the pro's and cons are. The value is seen in the applications but due to the lack of ease of use most of the apps are not used often.

The reasons and motivations for the implementation of smart technology.

Interviewee 1A states that the development of The Edge was mainly initiated due to Deloitte requiring a new office for their changing ways of working. As more of their employees used the office as a place for interaction, they believed that a smart office would be best to support the changes. Furthermore the office was developed by OVG who believed that smart offices would improve the sustainability of offices whilst providing branding benefits.

The results of the implementation of smart technology.

As the facility manager of the Edge interview 1 is closely with any operational performances of The Edge. Interviewee 1A states that the energy efficiency of the Edge is very high but can't attribute that to just the implementation of smart technology. Due to the high occupancy of The Edge the adaptive systems are less useful since most rooms are constantly in use. However, the increased branding as a result of the development of The Edge was also clearly seen in the amount of daily visitors, meetings planned per week and number of job applications. Many visitors came to see the 'smartest building in the world'.

Case findings

As was mentioned at the beginning of this chapter, the case findings are structured according to input, process, output and process. Figure 70 shows an overview of this structure as recognized within The Edge. In the next section each part will be described and linked to the next part.

First the inputs will be described, this part is represented by the top part of Figure 70. The inputs consist of the sensors, the internet connectivity, the external data and the data collected through devices. Furthermore, the drivers that led to the development of The Edge are also considered as input and therefore described.

Then the process part will be described. This part is illustrated by the 'Process' part of the infographic and represents the processes that use the input to enable the outputs.

Thirdly the outputs will be described, in the infographic the outputs are represented by the bottom part. The outputs are the smart applications such as 'adaptive climate', 'controllable lighting' and 'find workspace'. All the applications found in the 'output' part of figure 70 will be described.

Finally, not shown in figure 70, the outcomes will be described. The outcomes are connections that can be made between the 'output' and the impact of the output on the added values as previously defined in the 'added value' section.

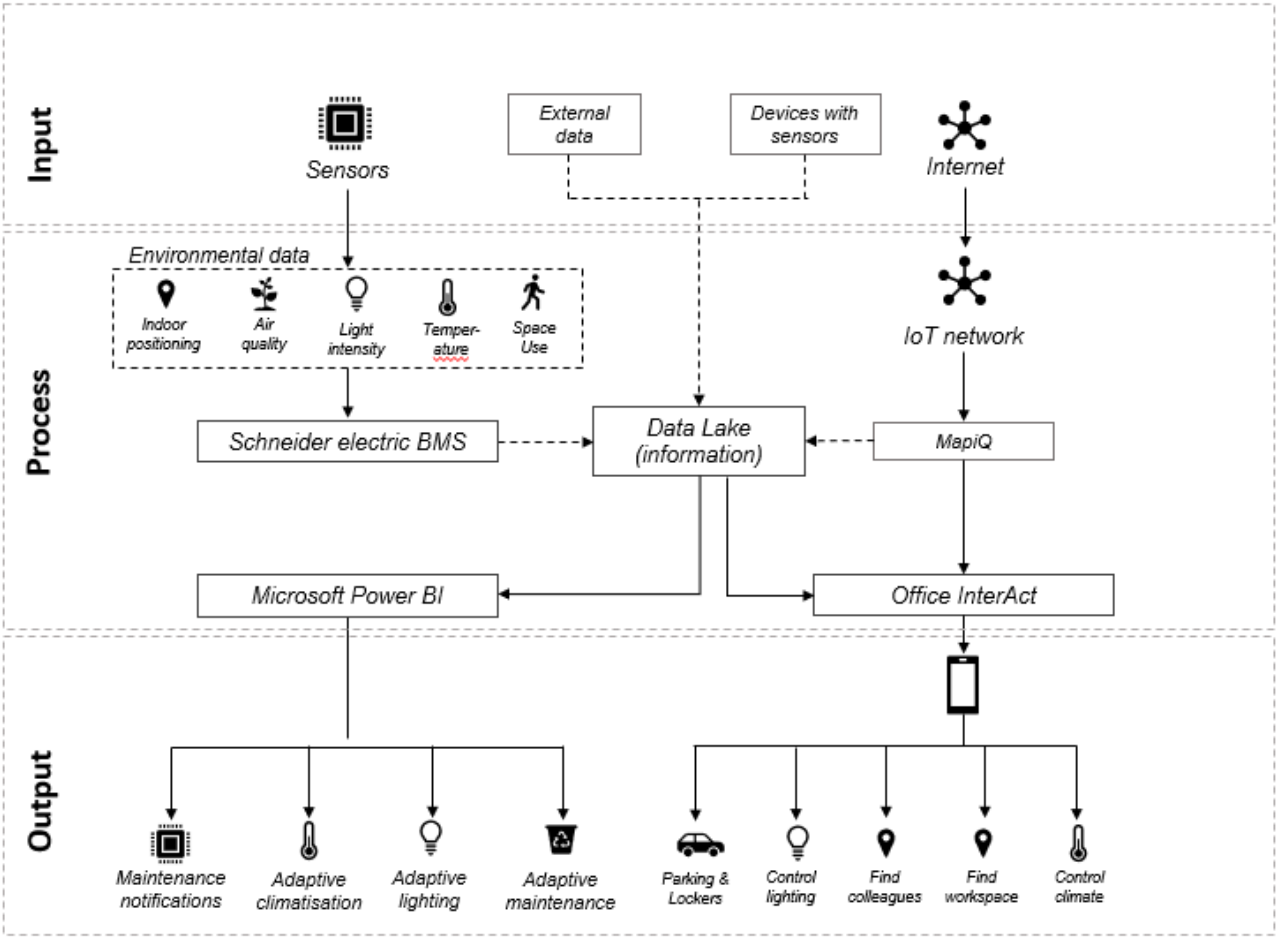


Figure 70. The Edge infographic. Icons source: PowerPoint. Own ill.

A. Input

The input layer of figure 70 below and consist of three elements; the stakeholder drivers, technology and the external data and data produced by devices throughout the building. The next section describes these three inputs.

Technology

In line with the description in the section 'smart buildings', the building is enabled by the implementation of sensors and internet connectivity. The sensors in The Edge are provided by Philips and are integrated in the luminaires. The Philips luminaires are powered by ethernet which provides them both with energy and connectivity. The sensor integrated luminaires powered by ethernet found throughout the Edge are specifically developed by Philips for The Edge. The sensors all have their own IP address and are also connected to the heating, the cooling and the ventilation systems (BREAAM, 2014). The connected installations are part of the Schneider electric Building Management Systems (BMS). Additionally, many devices such as the printers and coffee machines are also equipped with sensors providing an additional input of data (Interviewee 1A, 2019). Lastly, external data is also used as input.

Drivers

Due to the changing ways of working of the consultants at Deloitte, the firm wanted an office that would fit this new way of working better. Throughout the years before the development of The Edge Deloitte's portfolio was moving beyond just Audit and Tax and offered more and more advisory services. This combined with the fact that more and more consults started to, or could, work remotely resulted in a new real estate strategy. The rising impact of IT and big data resulted in Deloitte wanting to make a statement with their new office building (Jalia, A. Bakker, R. & Ramage, M., 2014). The Chief Information Officer of Deloitte, Erik Ubels, played a huge role in the implementation of internet of things technology in the building. Together with OVG Real Estate, Deloitte started to flesh out the vision of a high-tech office building.

From the perspective of OVG, the conviction was that smart buildings would make a difference in environmental sustainability (Jalia, A. Bakker, R. & Ramage, M., 2014). The CEO of OVG, inspired by Al Gore's rhetoric of climate change, was very driven to developed highly sustainable buildings. The conviction that smart buildings are very sustainable, combined Deloitte's need for a smart building resulted in the collaboration of OVG and Deloitte and subsequently the development of The Edge. This collaboration shows that the initiative of one stakeholder can break the circle of blame seen on page 18.

Table 11. below shows an overview of the inputs of The Edge.

Input overview	
Sensor technology	The sensors placed throughout the building continuously gather data on the building processes, the environment and the use of the building.
Internet connectivity	The internet activity enables the sensors and devices to send and receive information. This enables systems and devices to interact with each other.
External data	External data and device data are also continuously collected, similar the data collected by the building sensors.
Initial drivers	Deloitte wanted a smart office to support their new work culture. OVG wanted to create an innovative sustainable building.

Table 11. Inputs of the Edge. Own table.

B. Process

The input of sensor technology and internet connectivity allow the sensors throughout the building to send data to a data lake. This data lake is a large (growing) amount of data stored on a server owned by Deloitte (Interviewee 1A, 2019). The data lake is constantly being fed with information of users, the building but also with external factors such as traffic and weather data. This data lake can be used to 'find' data that one seeks to analyse. The data in The Edge is not analysed in real-time but is stored to be used whenever required (Jalia, A. Bakker, R. & Ramage, M., 2014). As such the data first goes into the data lake, and *then* is used through the Microsoft Power BI software or MapiQ to enable the actual smart applications.

This required data from the data lake is collected, analysed and transformed into comprehensible information. All this data is gathered and visualised in the Microsoft Power BI software. Facility management can then use this software, which displays the information in real-time through various dashboard, to enable the smart implementations seen at the bottom of the infographic. Simultaneously, through the specially developed software application InterAct Office in combination with the MapiQ software, users of The Edge can use a phone application to have access to the applications that will be explained in the Output section.

The processes that connect the input with the outcome can be divided in 5 stages coined as the 'Information value loop' by Deloitte (2015). Table 11a shows how these processes are recognized in The Edge.

Process	**Process**
Create	The use of sensors to generate information about a physical event or state. In The Edge this is represented by the Philips sensors.
Communicate	This phase represents the sending & receiving of data between systems and devices. In The Edge this is enable by internet connectivity.
Aggregate	This phase is the gathering of the information created throughout time and sources. In The Edge this phase is represented by the 'Data Lake' where all the information is gathered.
Analyze	In the Edge this phase is the analysis of the information of the Data Lake to enable the Microsoft Power BI and the Office InterAct. This phase analyses the information and produces descriptions or predictions to act upon.
Act	This phase impacts the actual building processes by enabling the smart applications. This phase is aimed at maintaining, regulating or changing the building processes.

Table 11a. Processes of the Edge. Own table.

C. Output

Figure 70 also shows the smart applications as a part of the ‘Output’ layer. This section describes these smart applications and the impact they have on the building processes.

In line with figure 73, The Edge uses the following smart applications:

1. **Maintenances notifications when devices need repair or maintenance;**
   Amongst other devices, printers and coffee machines are equipped with sensors. Whenever ink or coffee or milk is running low, maintenance receives a notification. This way the devices are “never” down but are replenished before it is an inconveniency to the users.

2. **Adaptive climate;**
   Whenever the sensors in a room measure that there is no activity, the heating or cooling is energy saving mode and the ventilation is set on stand-by. This avoids unnecessary energy consumption since the room is not in use and does not need to be fully climatized. The second the sensors measure activity in the room, the climate systems turn on again.

3. **Adaptive lighting;**
   Like the adaptive climate, the lights turn off automatically whenever there is no motion being measured by the sensors.

4. **Adaptive maintenance;**
   On paper, adaptive maintenance means that rooms or areas are only cleaned when they have been used. If the room has not been used the whole day, it is skipped during the maintenance routine. In actuality, this is different, as will be explained in the ‘results’ chapter.

User applications

1. **Workplace finder**
   Through occupancy sensors above the desks throughout the Edge, employees can quickly see where a spot is available to use.

2. **Colleague localisation**
   Employees working in The Edge can, through the mobile application, find co-workers throughout the building. However, this required users to be logged in into the application.

3. **Control over light intensity**
   Through the mobile app employees can also adapt the light intensity in their direct environment. By simply pointing the camera at the to be changed light, the user can change the lighting intensity.

4. **Control over temperature**
   Through the connected installations and the mobile applications employees in The Edge can alter the temperature in their direct environment. The app enables temperature change of -3^{o} to +3^{o} Celsius.

5. **Parking spot finder**
   Users can find an empty parking spot before arriving at the parking garage. The app will guide them to the place where an empty parking spot is located, avoiding any time wasted searching for an empty space.

6. **Locker services**
   Users can use lockers to store their belongings through the app. This is necessary since there are no assigned desks meaning that nothing can be left on a desk overnight.

Table 12 below gives an overview of the smart applications and their impact. The impacts of the smart applications are what substantiates the connections with the added values that will be made in the 'Outcome' section.

Output	Output impact
Adaptive climate systems	The actual use of the building is monitored, and the installations are regulated accordingly, improving the efficiency of the climate systems.
Air quality regulation	Air quality is monitored and whenever a certain threshold is crossed the installations regulate
Adaptive maintenance	The actual use of space and devices is monitored. Maintenance routines are adapted based actual use. This improves the efficiency of maintenance.
Adaptive lighting	The actual use of space is monitored, and lighting systems are regulated accordingly. This improves energy efficacy.
Maintenance notifications	The devices being able to send notifications before they require maintenance enables maintenance to occur before necessary, improving building performance
Controllable lighting	The connectivity enables users to connect with the lights and adapt them according to their preferences. Improving their control over the environment.
Controllable climate	The connectivity enables users to connect with the climate systems and adapt them according to their preferences. Improving their control over the environment.
Find colleagues	The connectivity between devices enable employees to find each other throughout the building, supporting interactive culture
Find workspace	The data on space used enables employees to find empty workspaces. Increasing ease and user experience.
Book rooms and lockers by phone	Connectivity between systems enable employees to book rooms and lockers through their phone, increasing ease of use and user experience.

Table 12. The smart applications found in The Edge and their impact on building processes. Own table.

D. Outcome

In this section the 'outcomes' will be discussed. In the essence this will be done by connecting the applications mentioned in the 'output' section with the impact it has on the value drivers found in the literature review. Subsequently these drivers will be connected to the investors to create a connection between the input of technology and the contribution of benefit it offers to the investor. This connection will be referred to as the Value Chain. However, first the results and lessons learned will be described.

Results and lessons learned

The impact of The Edge as an icon was severely underestimated. The initial business case expected a slight rise in meetings and visitors after moving to The Edge. The business case was based on around 35.000 meetings a year and 600 visitors a week. In the first operational year of The Edge there were approximately 100.000 meetings and about 500 visitors a day (Interviewee 1A, 2019). Subsequently the amount of job applications at Deloitte increased as well.

Due to the reduced number of workplaces per employee the operational results were different than initially expected. On Friday's, many consultants came to the office instead of working remotely. This resulted in a 20% overuse. During the week the office often was at almost full capacity. This means that the adaptive maintenance had to be used in a different way. Instead of *less* maintenance the information gathered by the sensors was used for *more* maintenance wherever necessary. Due to the high occupancy there was no space unused to skip during maintenance routines.

The sensors in the devices resulted in smoother operations. After a while the information produced by the sensors provided time periods in which the devices were used the least. Maintenance (re-filling etc.) of those devices is scheduled based on these time periods to avoid downtime during peak hours.

The adaptive climate systems did contribute to cost reduction, but due to the high occupancy of the office the reduction is limited (Interviewee 1A, 2019). According to Interviewee 1A however, with proper management the data provided by sensors can save up to 30% in energy costs, depending on occupancy, compared to a situation where there are no adaptive climate systems.

On the user side of the building the applications are still lacking. After a while many employees sit in the same space on a daily basis resulting in unofficial personal desks. This means that colleague localisation is less effective, as most employees can be found in the same spot. On top of this the colleague localisation requires the user to be logged in, which many employees forgo (Interviewee 2A, 2019).

Additionally, controlling the climate is done through another application than finding colleagues or a workplace, as one is done through MapiQ and the other through the Schneider electric BMS (see figure 70) The use of multiple apps decreases the user friendliness (Interviewee 2A, 2019)

The effects of controlling the lights and climate is less effective in the open spaces of The Edge, but valuable in the smaller units found throughout The Edge (Interviewee 2A, 2019)

Output	Impact of the output on the building processes	Outcome
Adaptive climate systems	Less energy is used due to the climate systems only performing at capacity when necessary. Less energy used overall means higher sustainability and lower operational costs. Installations that automatically adapt increase adaptability directly.	- **Sustainability** - **Cost reduction** - **Adaptability**
Air quality regulation	Air quality is automatically regulated according to quality standards. Optimally regulated carbon dioxide concentration ensure productivity stays high. Optimally regulated air quality contributes to health and raises satisfaction with work environment.	- **Health** - **Productivity** - **Satisfaction**
Adaptive maintenance	Maintenance routines are only performed when necessary. This means that depending on the actual use, less maintenance might be performed. This saves maintenance (operational) costs.	- **Cost reduction** - **Adaptability**
Adaptive lighting	Lights only turn on whenever a room is being used. This saves energy since lights are not consuming unnecessarily, thus increasing sustainability and reducing energy costs. Adaptable systems increase adaptability of the building.	- **Sustainability** - **Cost reduction** - **Adaptability**
Maintenance notifications	Devices send out notifications to management before intervention is needed, reducing overall downtime. Less down-time reduces complaints (Interviewee 1A, 2019).	- **Satisfaction**
Controllable lighting	Users can control the lighting intensity through the smart phone, increasing the controllability they have over their environment. Perceived control over environment raises user satisfaction and productivity. Controllable systems increase adaptability.	- **Adaptability** - **Satisfaction** - **Productivity**
Controllable climate	Users can control the temperature through their smart phone, increasing the controllability they have over their environment. Perceived control over environment raises user satisfaction and productivity. Controllable systems increase adaptability.	- **Adaptability** - **Satisfaction** - **Productivity**
Find colleagues	Users can find co-workers, stimulating collaboration and interactive between users and reducing time spend searching for co-workers. Increase collaboration affects culture creation.	- **Culture** - **Satisfaction**
Find workspace	Users can find an empty workspace, reducing time spend searching for a place to work	- **Satisfaction**
Book rooms and lockers by phone	Users are able to book rooms and lockers offering them more services and efficiency.	- **Satisfaction**
Overall concept of smart office	Increases the branding of the office due to the use of cutting edge and innovative technologies and due to the perceived higher quality of office space.	- **Branding**
Co-development of smart office	Less risk and income guarantee for OVG due to the co-development of the smart office with Deloitte.	- **Risk**

Table 13. The outputs and the outcomes of The Edge. Own table.

E. Case summary

This section concludes the case and therefore summarizes the case according to the four topics that were used to structure the case and answer the sub-questions. The case summary is found in table 14. The overview is divided in the types of smart applications, how these applications are enabled, the reasons for developing a smart office and the results of the development of The Edge.

Types of smart applications	How they work	Reasons and motivations	Results
In total 10 different smart applications have been identified in The Edge. These applications use the information gathered by the sensors to impact and improve the building processes. The smart applications are either used to improve user experience or increase operational efficiency.	The applications are enabled by the sensors throughout the building and the internet connectivity. The sensor collect building data that is then analysed in order to see where improvements can be made. These improvements are done through the smart applications.	The main reasons that led to the development of The Edge was the fact that Deloitte demanded a smart office to enable and enhance their new strategy. This new strategy needed a building that enhanced interaction between users.	The main results of the implementation of smart technology is the increased energy efficiency of the building and the branding benefits. Furthermore, the smart applications reduce costs, improve user satisfaction, health and productivity and increase the overall adaptability of the office.

Table 14. Case summary of The Edge. Own table.

Input for cross-case analysis

Figure 74 gives an overview of the information that will be used for the cross-case analysis. The development of The Edge as a smart office resulted in the implementation of the applications found under 'smart applications'. These smart applications resulted in the added values found under 'outcome'.

As can ben seen in figure 74 the eleven smart applications that have been observed in The Outlook and were listed in table 12 have had a positive impact on the added values shown on the right side of figure 74. These impacts have been listed previously in table 13.

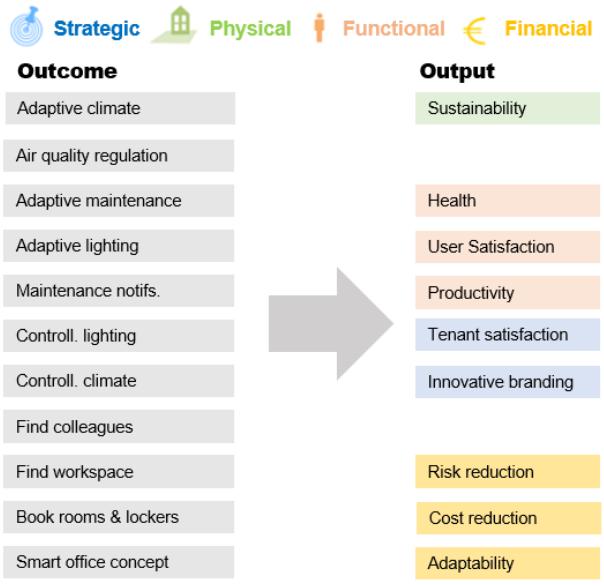


Figure 74. Input for the cross case analysis of The Edge. Own ill. (2019)

Figure 74 shows that, in line with the four perspectives of CREM, the financial and functional perspectives are impacted the most by the implementation of smart technology, while the physical perspective is impacted the least of the four perspectives. However as was seen in the value interrelationships section something that contributes to one value (or output) often also contributes to another.

The outlook

Building description:

The third case is The Outlook. Located in Schiphol Airport. The building was tailor-made 11 years ago for Microsoft (Interviewee 1B, 2019). Last year, the lease contract of Microsoft ended and Schiphol Real estate, the owner of the office building and the land it stands on, was informed by Microsoft that they needed a smart office to fit their new way of working. According to Microsoft, the office needed to become a place of interaction where users are enabled by the building. In exchange for a lease extension Schiphol Real Estate re-developed the office into a smart office. The office is now multi-tenant smart office with Spaces being the second largest tenant.

Image 2. The Outlook. Source:

Key facts:

Location:	Evert van de Beekstraat, Amsterdam
Size:	36.000 m^2
Delivery date:	2018
Development type:	Redevelopment
Main function:	Office building

Stakeholders:

The Outlook is owned and developed by Schiphol Real Estate. Schiphol Real Estate also owns the ground and the surrounding buildings. Currently, the main tenant is Microsoft, other tenants are Spaces, Cargill and various smaller tenants. The integrated sensors are provided by bGrid. The backend that collects all the sensor data is developed and provided by CGI. On this backend Microsoft develops all the API's used to process the data into information. The phone application interface is provided by MapiQ. Figure 75 below shows an overview of the main stakeholders involved with the development and use of The Outlook.

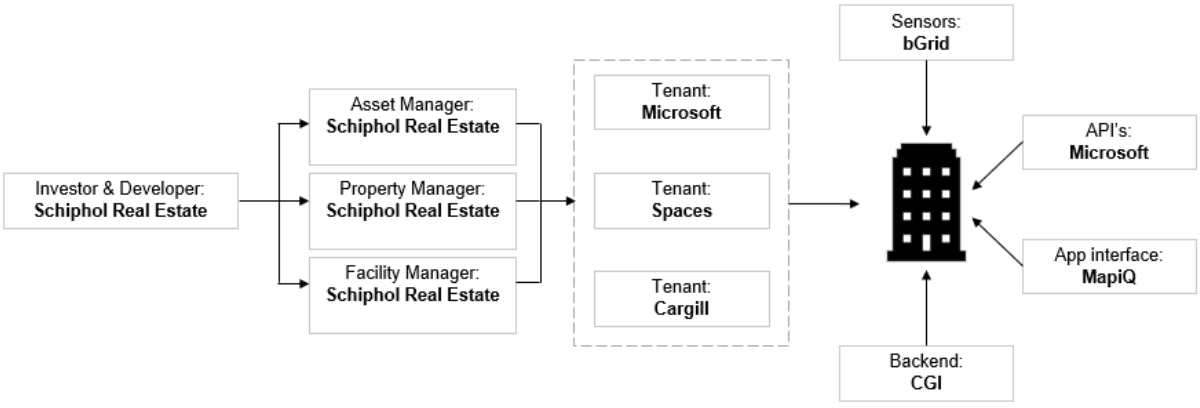


Figure 75. The Outlook stakeholders. Own ill. (2019)

Case data collection – The Outlook

For The Outlook case two interviews have been conducted to cover the four case topics.

The first interview (Interviewee 1B) was done with the project developer of The Outlook. Employed by Schiphol Real Estate this interviewee is knowledgeable on both he investment and the management side of The Outlook, covering both perspectives with one interview.

The second interview (Interviewee 2B) was done with an employee of Microsoft who has worked full-time in The Outlook since its delivery in 2018. This interviewee is on the end-user side of the building and mostly involved with the user oriented smart applications found throughout the building.

The contribution of the two interviews will be described in the next section, divided over the four topics.

Types of smart applications found in The Outlook
Both the interviewees provides information on the smart applications found throughout The Outlook. As was defined in the 'smart building' section of Chapter 3, the smart applications are the features that use the data collected by the building to improve and exert actual impact on the building processes. Interviewee 1B provided insights into the actual use of the user oriented smart applications. Interviewee 1 provided insights into the smart applications focussed on building management. A more detailed list of the smart applications found in The Outlook will be provided in later in this section. Interviewee 2B provided insights into the way the smart applications are used by the employees working in the office. While not all the applications are fully used the usefulness and value is seen by the interviewee.

The way the smart technology works in The Outlook
Interviewee 1B was closely involved in the development of The Outlook and therefore provided detailed in formation in the processes that enable the smart applications. In line with figure 47 in the 'smart building' section of Chapter 3, the interviewee described how The Outlook gathers building data through sensors and devices connected to the internet network. The interviewee explains that the data is then gathered in the backend of the building where it is then processed by software applications and transformed into legible information to be used as input for the smart applications. The explanation of interviewee 1B of the smart technology found in The Outlook corresponds closely with the findings of the literature review on smart buildings (figure 47).

The reasons and motivations for the implementation of smart technology.
Due to interviewee 1B being closely involved with the development of The Outlook on the side of the investing and developing company, Schiphol Real Estate, the reasons and motivations behind the development of specifically a smart office could be discussed in depth. According to the interviewee the lease contract between Schiphol Real Estate and their anchor tenant Microsoft was almost expiring. Microsoft, a tech giant, wanted an office that supported their new workplace ideology. Their workplace vision is one where the office enables and supports interaction amongst users. To also keep up with new developments and be the innovator people expect Microsoft to be, a smart office was needed. Schiphol Real Estate agreed to developed and invest in a the retrofitting of The Outlook into a smart office in return for an extension of the lease contract. Furthermore, Schiphol Real Estate sees potential in the development of smart office in terms of sustainability and cost reduction.

The results of the implementation of smart technology.
At the time of the interview the building was in use for just 6 months, meaning that most of the data on the results or impacts of the smart technology was not yet fully collected or analysed. However, the expectations were discussed with Interviewee 2B and specifically how they expect that the smart applications will or are influencing and improving the building processes.

Case findings

Similar to the case findings of The Edge, Figure 77 shows an infographic overview of the input, process and outcome structure recognized in The Outlook. In the next section each part will be described and linked to the next part.

First the inputs will be described, this part is represented by the top part of figure 77. The inputs consist of the sensors, the internet connectivity. Furthermore, the drivers that led to the development of The Outlook are also described

Then the process part will be described. This part is illustrated by the 'Process' part of the infographic and represents the processes that use the input to enable the outputs.

Thirdly the outputs will be described, in the infographic the outputs are represented by the bottom part. The outputs are the smart applications such as 'adaptive climate', 'controllable lighting' and 'find workspace'. All the applications found in the 'output' part of the infographic will be described.

Finally, as with The Edge case, the outcomes will be described and the impact of the smart applications on the added values will be described.

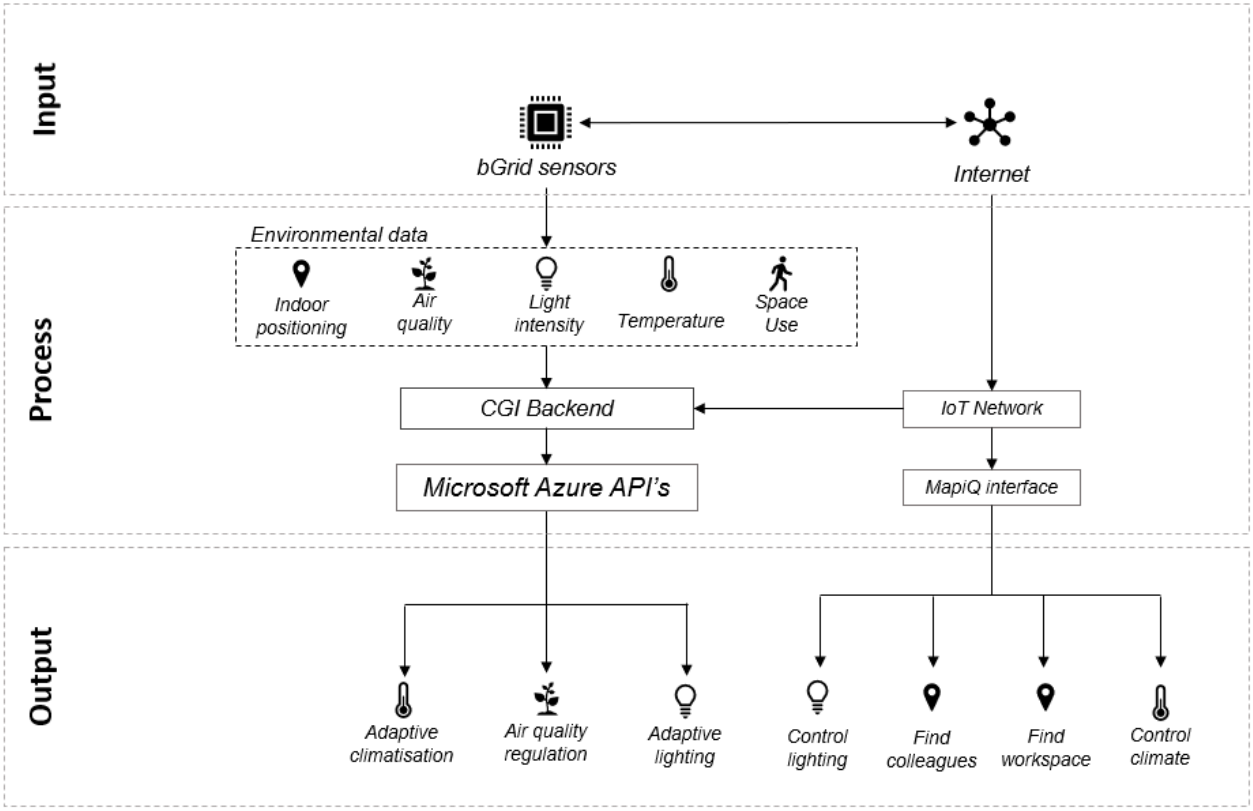


Figure 77. The Outlook Infographic. Icons by PowerPoint. Own ill. (2019)

A. Input

The input layer of figure 77 is described in this section and consist Sensors and internet connectivity. This, again, is in line with the theoretical concept of the smart building found in the 'smart building section'.

Technology
As seen in figure 77. The Outlook is enabled by sensor technology and internet connectivity. The sensors are provided by bGrid and constantly measure the environment and send the data to be processed in the backend of the system. The internet enables the sensors to send and receive data.

Drivers
According to Interviewee 1A the most important drivers that led to the development of The Outlook, was tenant satisfaction. During the contract renegotiations at the end of the lease term Microsoft, the anchor tenant, stated that they wanted a smart office in order to execute their new corporate strategy where the office becomes a place for (personal) interaction. In order to satisfy Microsoft as a tenant and ensure future income, Schiphol Real Estate agreed to develop a smart building. This agreement resulted in an extension of the lease contract.

Another driver that contributed to Schiphol accepting to develop a smart building was the belief that smart offices would also contribute to the sustainability goals of Schiphol Real Estate (Interviewee 1A, 2019). Also important for Schiphol Real Estate is health or offering a healthy work environment. Schiphol Real Estate wants to offer high quality office space in order to maintain the reputation that their office space is qualitative.

The last driver mentioned by Interviewee 1 is adaptability, the ability, through sensors, to adapt the building to the actual use. The theory is that by using occupancy sensors Schiphol Real Estate gains insights into the amount of space used by their tenants. Whenever a tenant uses more space than necessary, Schiphol can offer to decrease the amount of space they use and let the remain space to other tenants. Additionally, the theoretical costs savings that are expected by Schiphol due to adapting the installations to actual use played a significant role in the agreement (Interviewee 1A, 2019)

All the inputs are gathered in table 15 below.

Input overview	
Sensor technology	The sensors placed throughout the building continuously gather data on the building processes, the environment and the use of the building.
Internet connectivity	The internet activity enables the sensors and devices to send and receive information. This enables systems and devices to interact with each other.
Initial drivers	Microsoft needed a smart office to create a culture where interaction is at the centre. Schiphol Real estate agreed in order to retain Microsoft as a tenant and because of the perceived benefits of a smart office.

Table 15. Input overview of The Outlook. Own table.

B. Process

The constant measuring of the environment in the building results in data that has to be processed, this occurs in the process layer of figure 77 and will be described below.

The data produced by the sensors in The Outlook is data on indoor positioning of the users, current air quality, intensity of the lighting, temperature in the building and actual use of space. This data is 'rough' and without proper processing not actually useful (Interviewee 1B, 2019). The data is sent to the backend provided by CGI. This backend collects the data and enables Microsoft to develop API's that use the data and transforms it into usable information. These API's are developed through Microsoft Azure, a cloud computing service for building and deploying applications (Interviewee 1B, 2019). Different from The Edge, the Outlook does not use a data lake to store the data.

Simultaneously the Internet of Things network powered by the internet enables sensors and devices to interact between each other. This enables the MapiQ phone application to interact with devices and installations throughout the building.

After receiving certain data, the Microsoft API's monitor and analyse the data and transform it into information needed for the OUTPUT layer of the infographic. This layer is where the actual impact occurs.

Table 16 again shows the 5 key phases of the process layer. The content of these 5 phases are however a bit different compared to The Edge.

Process	Process
Create	The Outlook uses bGrid sensors to collect and create data on the building processes.
Communicate	Similar to The Edge the internet connectivity allows devices to communicate with on another and allows for data to be sent and received.
Aggregate	The Outlook gathers the data collected by the sensor in the backend developed by CGI. This is different compared to The Edge where the data is collected in a Data Lake. The data for this phase is also collected through connected devices in the Internet of Things Network. These devices provide additional data on space use and are used for localisation.
Analyze	The analysis of the information gathered in the backend is done through Microsoft Azure Cloud software. Multiple API's can be developed on the backend which allow for the analysis and use of information. Microsoft uses the Azure Cloud to develop their own API's to test new applications.
Act	The API's developed on the backend enable the 7 smart applications found in the 'output' layer of the infographic. These applications act on the analysed information and impact the processes within The Outlook.

Table 15. process overview of The Outlook. Own table.

C. Output

The output layer of figure 77 will be described in this section. This layer consists of the smart applications that are used in The Outlook to improve the building processes and make the building smart. This section introduces and describes the applications.

Adaptive climate
Whenever a room is not in use the climate systems are be powered down to save energy. The sensors in the room detect whenever the room is in use again and the installations react by powering up again. Furthermore, based on historical data, adaptations can be made to the amount of heating or cooling in parts of the building that are historically unused during certain periods.

Adaptive lighting
Very similar to the climate the lighting can be adapted to actual used thanks to the building data collected by the sensors. Whenever a sensor measures activity in a certain space, the lights turn on accordingly. Whenever no motion is registered, the lights turn off.

Air quality regulation
Due to the sensors constantly measuring the air quality information is gathered on the concentration of carbon dioxide in the air. By connecting the ventilation installation with this information, the systems can automatically increase ventilation, and thereby decreasing carbon dioxide concentration, whenever a certain threshold is reached.

Control lighting
Through a special phone application, powered by connectivity and the Internet of Things, users can control the lighting intensity in their direct environment. The intensity range is limited to avoid unnecessary deviation and energy consumption.

Control climate
Through the same application as the lighting control feature, users in The Outlook are capable of adaption the temperature based on their own preferences. Similarly, the extent to which the temperature can be changed is limited to a couple degrees

Find colleagues
User of the Outlook can find other users within the building. The requirement for this feature is that users must be logged in into the application.

Find workspace
Like the “find colleagues” the Internet of things application of The Outlook lets the users find empty workspaces. Since The Outlook is designed around the flex working concept most employees do not have a set desk. Through the occupancy sensors employees arriving can quickly find an empty place to work that fits their requirements.

The impact of the applications found in The Outlook are described in table 17 below. As done in The Edge case the impact will be linked to the added values to create the connection needed for the Smart Value map. The left side of table 17 shows the applications and the right side the impact on the building processes.

Output	Output impact
Adaptive climate systems	The actual use of the building is monitored by sensors and the installations are regulated accordingly, improving the efficiency of the climate systems.
Air quality regulation	Air quality is monitored and whenever a certain threshold is crossed the installations regulate
Adaptive lighting	The actual use of space is monitored, and lighting systems are regulated accordingly. This improves energy efficacy.
Controllable lighting	The connectivity enables users to connect with the lights and adapt them according to their preferences. Improving their control over the environment.
Controllable climate	The connectivity enables users to connect with the climate systems and adapt them according to their preferences. Improving their control over the environment.
Find colleagues	The connectivity between devices enable employees to find each other throughout the building, supporting interactive culture
Find workspace	The data on space used enables employees to find empty workspaces. Increasing ease and user experience.

Table 17. process overview of The Outlook. Own table.

D. Outcome

Because The Outlook was only delivered and used recently the amount of actual results is limited from the operational side. The outcomes seen in table 18 below are still mostly expectations as the actual results will be gathered over several years (Interviewee 1B, 2019).

One difference that was discussed is the fact that The Outlook does use adaptive maintenance. According to Interviewee 1B (2019) this is because user behaviour in terms of 'dirtying' space is not measurable by sensors and therefore the need for maintenance cannot accurately be predicted yet.

Based on the interview with Interviewee 2B, the user experience is somewhat represented. Similar to The Edge the control over the climate and lightings is seen as a useful tool, even though it is less noticeable in the open spaces (Interviewee 2B, 2019). The localisation of co-workers does stimulate interaction and is useful when employees switch workplaces throughout the day (Interviewee 2B, 2019).

Output	Outcome	Outcome
Adaptive climate systems	Less energy is used due to the climate systems only performing at capacity when necessary.	- **Sustainability** - **Cost reduction** - **Adaptability**
Air quality regulation	Air quality is automatically regulated according to (high) air quality standards, this always keeps the air quality optimal .	- **Health** - **Satisfaction** - **Productivity**
Adaptive lighting	Lights only turn on whenever a room is being used. This saves energy since lights are not consuming unnecessarily.	- **Sustainability** - **Cost reduction** - **Adaptability**
Controllable lighting	Users are able to control the lighting intensity through the smart phone, increasing the controllability they have over their environment.	- **Adaptability** - **Satisfaction** - **Productivity**
Controllable climate	Users are able to control the temperature through their smart phone, increasing the controllability they have over their environment.	- **Adaptability** - **Satisfaction** - **Productivity**
Find colleagues	Users are able to find co-workers, stimulating collaboration and interactive between users and reducing time spend searching for co-workers.	- **Culture** - **Satisfaction**
Find workspace	Users are able to find an empty workspace, reducing time spend searching for a place to work	- **Satisfaction**
Overall concept of smart office	Increases the branding of the office due to the use of cutting edge and innovative technologies and the perception that it is high quality office space.	- **Branding** - **Innovation**
Co-development of smart office	Less risk and income guarantee for Schiphol Real Estate due to the fact that the building was developed for Microsoft.	- **Risk** - **Income**

E. Case summary

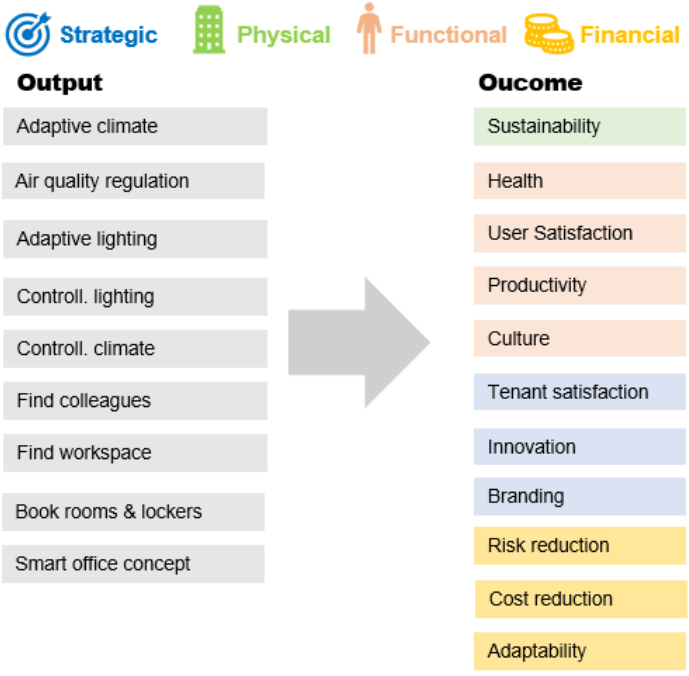
This last section concludes the case and therefore summarizes the case according to the four topics that were used to structure the case and answer the sub-questions. The case summary is found in table 19. The overview is divided in the types of smart applications, how these applications are enabled, the reasons for developing a smart office and the results of the development of The Outlook.

Types of smart applications	How they work	Reasons and motivations	Results
The Outlook currently uses 7 smart applications to improve the building processes, with several applications still in development. The tools are very similar to the tools found in The Edge with the biggest difference being the processes that enable the tools.	As described in the 'process' section the tools are enable by the gathering of data through sensors. The information is then gathered in the backend where the data is analysed and processed in order to usable by the smart applications.	The reasons that led to the development of the Outlook are very similar to the reasons that led to The Edge. Microsoft demanded a smart office to support their new work culture. In order to secure income and increase sustainability and branding Schiphol Real Estate agreed.	The smart applications improve the sustainability, health, productivity and user satisfaction. Due to the adaptivity the operational costs are reduced. The use of smart technology also improves the innovative image of Schiphol Real Estate and reduce investment risk.

Table 19. Case summary of The Outlook. Own table.

Input for cross-case analysis

The findings of the case that will be used for the cross case analysis have been gathered and are illustrated in figure 81 . The smart applications and the impacted added values are shown in the left and right side respectively. In order to improve comparability the impacted added values have been categorised according to the four CREM-strategies.



As can ben seen in figure 80b the nine smart applications that have been observed in The Outlook and were listed in table 17 have had a positive impact on the added values shown on the right side of figure 80b. These impacts have been listed previously in table 18.

Figure 80b shows that, in line with the four perspectives of CREM, the functional perspective is impacted the most by the implementation of smart technology, while the physical perspective the least.

Figure 80b. input for cross-case analysis: The Outlook. Icons by PowerPoint.

The Edge Olympic

Building description

Image 3. The Edge Olympic. Source:

Like The Edge, The Edge Olympic is developed by OVG Real Estate together with their subsidiary EDGE Technologies. The building is a redevelopment of an old building, similar to The Outlook. The building is in use since 2018 and the official opening is in 2019. Within OVG Real Estate and EDGE Technologies the Edge Olympic is seen as the Model II, with The Edge begin Model I. The biggest difference between the two office buildings is the fact that OVG Real Estate also exploits the office and uses it as their own office. From the perspective of OVG Real Estate the limitation with The Edge was the fact that they did not control all the data due to the data lake being on the Deloitte server. By taking the exploitation in their own hands, OVG has full access to the data produces by the Olympic. According to OVG the Olympic is the first building in a new generation of smart offices.

Key facts

Location:	Fred. Roeskestraat 115
Size:	Approximately 12.500 m² office space
Delivery date:	2018
Development type:	Redevelopment
Main function:	Office building
Certifications:	Energy label A, BREAAM Excellent, WELL Platinum, Cradle2Cradle

Stakeholders

The Edge was mainly developed by OVG Real Estate together with EDGE Technologies. Unlike The Edge, there was no tenant involved in the development of the building. This is due to a shift in strategy from the side of OVG which will be explained in a later section. The office has been acquired by TH Real estate, who is therefore the investor. TH Real Estate is represented by Nuveen in terms of Asset Management. OVG Real Estate is responsible for the property and facility management of the asset. The building is used by OVG Real estate, EDGE Technologies and various other tenants such as Microsoft and Ledger Leopard.

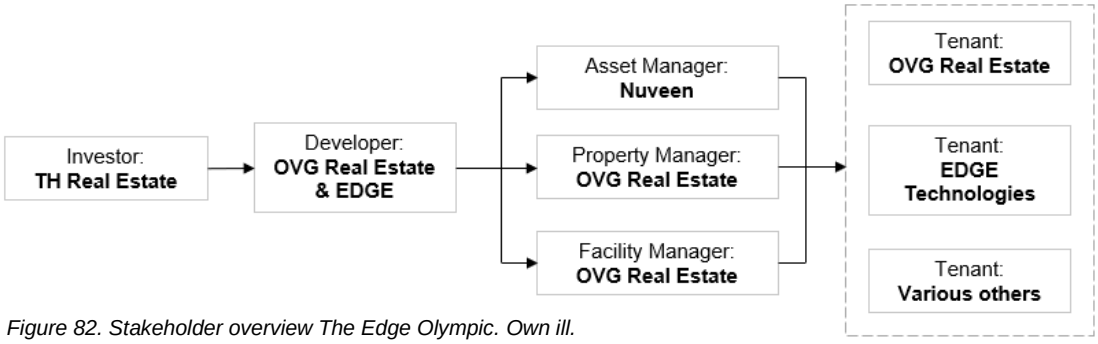


Figure 82. Stakeholder overview The Edge Olympic. Own ill.

Case data collection

For The Edge Olympic case four interviews have been conducted to cover the four case topics. Three of the interviews were held face to face and one was performed by e-mail due to the interviewee being located in another country.

The first interview (Interviewee 1C) was done with an Azure Internet of Things Engineer working at EDGE Technologies. Interviewee 1C is responsible for programming backend API's, the analysis of data and programming the dashboards. The interviewee works in the smart solutions team and is mostly active on the technological side of things when it comes to the smart buildings.

The second interview (Interviewee 2C) was done with the development director of OVG Real Estate/EDGE Technologies. Interviewee 2C is responsible for the Dutch Developments and therefore also for The Edge Olympic. He was closely involved in the development of The Edge Olympic.

The third interview (interviewee 3C) was conducted with an employee of EDGE Technologies. Interviewee 3C has been working for OVG/EDGE Technologies for almost a year and working both in The Edge and now in The Edge Olympic.

The fourth and last interview (interviewee 4C) was conducted with the Fund manager of the Cityhold Office Partnership, a venture that targets prime-located standing investments and project developments in Europe. The CHOP venture believes that a long term strategy combined with sustainability and smart technology is key to ensuring that the portfolio remains future proof. The Edge Olympic was acquired by the CHOP venture. The contribution of the four interviews will be described in the next section, divided over the four topics.

Types of smart applications found in The Outlook
Interviewee 1C provided insights into the smart applications found in the Edge Olympic. According to interviewee 1C, if The Edge is Model 1 then the Edge Olympic can be seen as Model 2 which also explain why the smart applications are very similar to the ones found in The Edge. According to interviewee 1C the main aim, on the technological side of things, was to achieve higher integration in terms of systems and installations.

Interviewee 3C provided insights into the user oriented smart applications found in the Edge Olympic. Due to also having worked in the Edge, interviewee 3C was able to compare the applications found in both offices in terms of user friendliness and usefulness.

The way the smart technology works in The Outlook
As an internet of things engineer, interviewee 1C was able to provide in depth information into the inner workings of the Edge Olympic. The aim to achieve high integration was reached by connection all the systems and installations through one single platform, instead of multiple platforms as in the case of The Edge. Similar to the findings of the literature review (figure 47.) the data is collected by sensors and connected devices and communicated between systems and installations through internet connectivity. The data is then processed and transformed into information which can be used by the smart applications to improve building processes.

The reasons and motivations for the implementation of smart technology.
Interviewee 2 was closely involved in the decisions made that resulted in the development of the Edge Olympic. As development manager interviewee 2C is closely involved in the strategic decisions of OVG Real Estate/EDGE Olympics. Interviewee 2C explains how and why OVG Real Estate decided to developed The Edge Olympic at own risk, with no pre-signed tenants or investor. Due to the success of the Edge, the prime location of the asset and the expected quality in terms of sustainability, smart and health the risk of any vacancy was perceived as very low. Furthermore a newly developed strategy pushes the development of offices that are sustainable, healthy and smart. According to interviewee 2C the Edge Olympic is the first iteration of the new generation of office buildings.

The results of the implementation of smart technology.
Again due to the recent delivery of the building the amount of data available on the results is limited. However, interviewee 2C stated that there were no problems to fully rent out the office building after delivery. The exact contribution of smart technology to this is however not substantiated yet. Furthermore, interviewee 4C, the fund manager of the venture that acquired The Edge Olympic, states that a positive resulted can be seen in term of rental value and tenant attraction when comparing the asset to similar objects that are not smart.

Case findings

Similar to the case findings of The Edge and The Outlook, Figure 83 shows an overview of the input, process and outcome structure as recognized in The Edge Olympic. In the next section each part will be described and linked to the next part.

First the inputs will be described, this part is represented by the top part of Figure 83. The inputs consist of the sensors, the internet connectivity. Furthermore, the drivers that led to the development of The Edge Olympic are also described

Then the process part will be described. This part is illustrated by the 'Process' part of figure 83 and represents the processes that use the input to enable the outputs.

Thirdly the outputs will be described, in the infographic the outputs are represented by the bottom part. The outputs are the smart applications such as 'adaptive climate', 'controllable lighting' and 'find workspace'. All the applications found in the 'output' part of the infographic will be described.

Finally the outcomes will be described and the impact of the smart applications on the added values will be described.

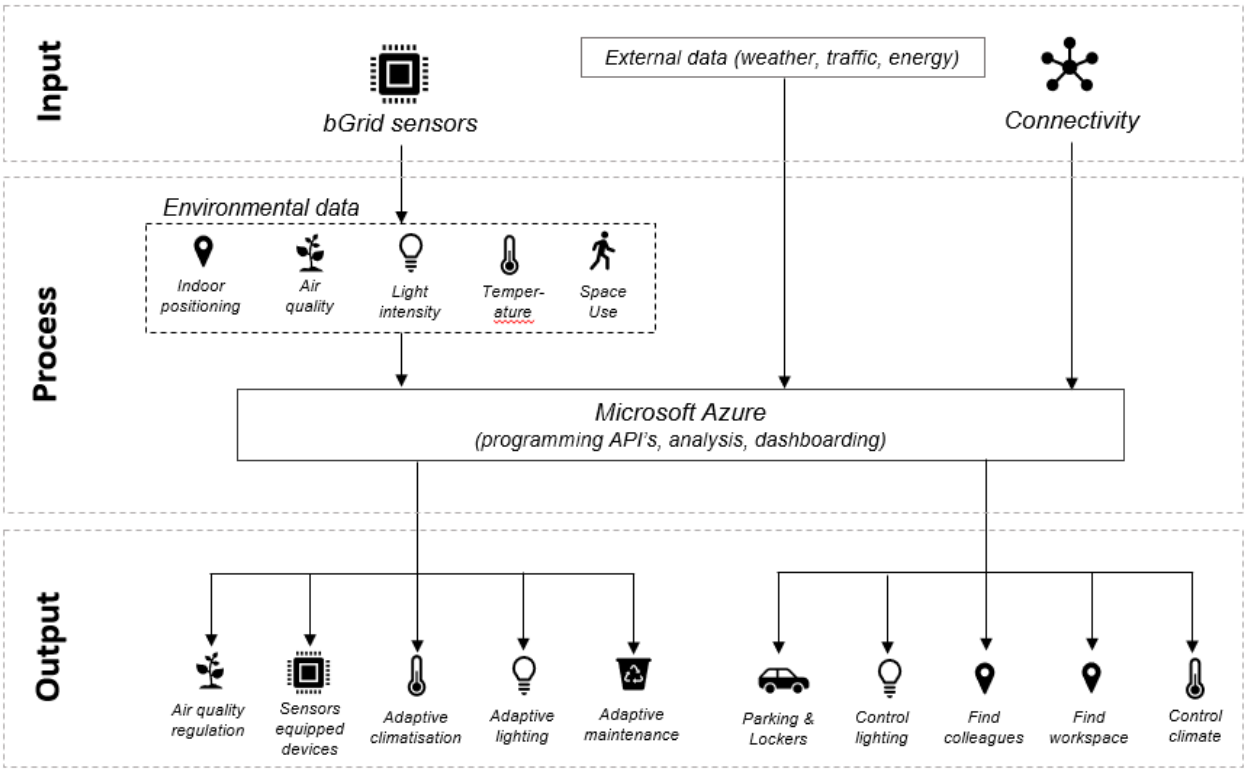


Figure 83. The Infographic of The Edge Olympic. Icons by PowerPoint. Own ill.

A. Input

The input layer seen in figure 83 consist of two elements; the stakeholder drivers and the technology. The input layer is seen below in figure 84.

Technology
Similar to the Outlook, but different to The Edge, the Edge Olympic uses bGrid sensors for the data collection. To reduce the technological obsolescence the sensors are integrated in a very modular way in the ceiling, meaning that the sensors can easily be replaced whenever better sensors are available (Interviewee 1C, 2019). Again, internet connectivity runs through the building and enables the interconnectivity of the devices and installations.

Drivers.
The trigger that led to the development of The Edge Olympic came from OVG Real Estate. Since the delivery of The Edge, technology had advanced and many lessons were learned. Powered by the drive to innovate and deliver sustainable building, the development of The Edge Olympic was to prove that OVG Real Estate could not just do it again, but also better, smarter and faster (Interviewee 1C, 2019).

The success of The Edge convinced OVG Real estate that smart buildings were the future and resulted in a change in strategy and vision within OVG, which also led to the conception of EDGE Technologies (Interviewee 2C, 2019). The goal was to create a smart building blueprint that could be used as a service. This blueprint is based on three key aspects; sustainability, health and smart.

Another key driver championing the development of smart offices is the so-called ‘war on talent’. The new generation, and therefore the new talent, is more and more demanding when it comes to the quality of their work environment. Closely related to that is the trend of job-hopping where employees change jobs faster than before (Interviewee 1C, 2019).

The Edge Olympic was acquired by the CHOP venture that targets prime offices where sustainability and smart technology represented (Interviewee 4C, 2019). The primary rationale of the acquisition is the **user experience.** By providing the tenants and their employee with a more vibrant working environment the tenant satisfaction increases. The rationale is that a satisfied tenant leads to a longer-term relationship and therefore tenant retention. Furthermore, Interviewee 4C states that there is an obsolescence risk for the properties that are not successfully embracing smart technology, sustainability and user well-being. Investing in smart offices decreases this risk and captures best the long-term value that real estate offers.

Table 20 below, shows an overview of the 4 inputs that either enable the smart office or led to the development of the smart building.

Input overview	
Sensor technology	The bGrid sensors placed throughout the building continuously gather data on the building processes, the environment and the use of the building.
Internet connectivity	The internet activity enables the sensors and devices to send and receive information. This enables systems and devices to interact with each other.
External data	External data and device data is also continuously collected, similar the data collected by the building sensors.
Initial drivers	OVG & Edge technologies wanted to show that The Edge could be improved and saw multiple benefits in the development of more smart offices.

Table 20. Input overview the Edge Olympic Own table.

B. Process

This section will described the 'process' part of The Edge Olympic infographic seen in figure 83. In line with the other cases this section will describe the various smart processes found in The Edge Olympic.

The biggest difference in terms of technological implementations is the fact that everything comes together in Microsoft Azure, instead of having separate systems. This makes the interaction between systems, and therefore data sets, more efficient and with broader possibilities. As can be seen in figure 83, the data from the sensors, the external data and the connectivity all comes together in the Microsoft Azure backend. All the API's, analytical tools and dashboard are built on Microsoft Azure combining everything in a single platform and a single login. This integration of systems allows for new insights and enables machine learning between the systems. Table 21 below shows the five different processes that connects the input layer to the output layer.

Process	Process
Create	In The Edge Olympic the data is gathered by the bGrid sensors. Data is also created through connected devices and by gathering external data.
Communicate	This phase represents the sending & receiving of data between systems and devices. Similar to the other smart offices this is done through internet connectivity.
Aggregate	This phase is the gathering of the information created throughout time and sources. The Edge Olympic gathers all the data in Microsoft Azure Cloud on which all the API's are built
Analyze	This phase uses the data gathered in Microsoft Azure and analyses that data so it can be used by the API's. The API's transform the data into visualised information which can be used to act upon.
Act	This phase impacts the actual building processes by enabling the smart applications. This phase is aimed at maintaining, regulating or changing the building processes to make them more efficient.

Table 21. Process overview of the Outlook. Own table.

C. Output

The actual applications enabled by Microsoft Azure are fairly similar to the applications found in The Edge and The Outlook and will be described in this section, in line with the 'output' layer of figure 83. According to Interviewee 1C (2019) the biggest improvement between The Edge and The Edge Olympic is the back-door integration and not the actual smart applications.

1. **Maintenances notifications when devices need repair or maintenance;**
   Devices equipped with sensors automatically send notifications when (or just before) in need of maintenance.

2. **Adaptive climate;**
   As seen before, climate installations power down significantly whenever a room is not in use.

3. **Adaptive lighting;**
   Like the adaptive climate, the lights turn off automatically whenever there is no motion being measured by the sensors. The light intensity inside the building decreases when more natural light is available and the light follows the circadian lighting (Interviewee 1C, 2019).

4. **Adaptive maintenance;**
   Maintenance is adapted to actual use of the rooms. Whenever a room has not been used during a day it is not cleaned.

5. **Workplace finder**
   Through occupancy sensors above the desks throughout the Edge Olympic, employees can quickly see where a spot is available to use.

6. **Colleague localisation**
   Employees working in The Edge Olympic, through the mobile application, find co-workers throughout the building.

7. **Control over light intensity**
   Through the mobile app employees can also adapt the light intensity in their direct environment.

8. **Control over temperature**
   Through the connected installations and the mobile applications employees in The Edge Olympic can alter the temperature in their direct environment.

9. **Locker services**
   Users can use lockers to store their belongings through the app. This is necessary due to the fact that there are no assigned desks meaning that nothing can be left on a desk overnight.

10. **Room booking**
    Users can book and reserve rooms through the phone application.

Table 22 below shows an overview of the smart applications (outputs) found in The Edge Olympic. The 'output impact' column of table 21 represented the impact that the smart applications have on the building processes.

Output	Output impact
Adaptive climate systems	The actual use of the building is monitored, and the installations are regulated accordingly, improving the efficiency of the climate systems.
Air quality regulation	Air quality is monitored and whenever a certain threshold is crossed the installations regulate
Adaptive maintenance	The actual use of space and devices is monitored. Maintenance routines are adapted based actual use. This improves the efficiency of maintenance.
Adaptive lighting	The actual use of space is monitored, and lighting systems are regulated accordingly. This improves energy efficacy.
Maintenance notifications	The devices being able to send notifications before they require maintenance enables maintenance to occur before necessary, improving building performance
Controllable lighting	The connectivity enables users to connect with the lights and adapt them according to their preferences. Improving their control over the environment.

Controllable climate	The connectivity enables users to connect with the climate systems and adapt them according to their preferences. Improving their control over the environment.
Find colleagues	The connectivity between devices enable employees to find each other throughout the building, supporting interactive culture
Find workspace	The data on space used enables employees to find empty workspaces. Increasing ease and user experience.
Book rooms and lockers by phone	Connectivity between systems enable employees to book rooms and lockers through their phone, increasing ease of use and user experience.

Table 22. Output overview of the Outlook. Own table.

D. Outcome

While it is still early to have concrete numbers on the performance of the building some results are perceived. Firstly, the user experience has been improved compared to The Edge but still leaves some to be desired. While the benefits of having everything in one app is a big step up, the login itself is not as smooth as could be (Interviewee 3C, 2019). The possibility to influence the climate and the possibility to book rooms and lockers are very useful (Interviewee 3C, 2019)

In terms of air quality, the upper limit of CO_2 concentration within The Edge Olympic is set at 800 ppm max. The Well certificates sets this limit at 1000 ppm while industry standards allow 1200 ppm max. Due to the sensors the CO_2 concentration can be measured and regulated. On top of this employees can see live data related to air quality which improves the healthy perception of the building.

Due the three health, green and smart aspects of the office, combined with the location, the building was very desirable and tenants were ready to pay the price asked (Interviewee 2C, 2019). However, the exact contribution, or the exact impact the smart technology had on this is not clear as it is offered as a 'full-package'. Furthermore, due to the prime location, the tenants (increasingly) expect the asset to also be of prime quality.

Due to the quality of the building the business risk of OVG, in regard to leasing the building, decreases as the increased marketability attracts more possible tenants. In fact, this risk is now low enough for OVG to develop buildings without any tenants signed before the development.

From the investment side the CHOP venture is already seeing very positive leasing results in respect of the smart office in the portfolio (Interviewee 4C, 2019). This in terms of, for example, lease-up speed and rental levels, indicating a positive impact on the investment portfolio. Furthermore, the CHOP portfolio sees enhanced occupier experience, energy savings and optimised maintenance across the included office (Interviewee 4C, 2019). However, it is hard to say the exact contribution of the smart technology on this positive impact.

Table 23 shows an overview of the smart applications in The Edge Olympic, the impact these smart applications have and the resulting added value that is improved or impacted by the smart applications. The output column shows the smart applications, the outcome column the impact and the added value column shows which added values are influenced.

Output	Outcome	Added value
Adaptive climate systems	Less energy is used due to the climate systems only performing at capacity when necessary.	**Sustainability** **Cost reduction** **Adaptability**
Air quality regulation	Air quality is automatically regulated according to (high) air quality standards, this keeps the air quality optimal at all times.	**Health** **Productivity** **Satisfaction**
Adaptive maintenance	Maintenance routines are only performed when necessary. This means that depending on the actual use, less maintenance might be performed.	**Cost reduction** **Adaptability**
Adaptive lighting	Lights only turn on whenever a room is being used. This saves energy since lights are not consuming unnecessarily.	**Sustainability** **Cost reduction** **Adaptability**
Maintenance notifications	Devices send out notifications to management before intervention is needed, reducing overall downtime.	**Satisfaction**
Controllable lighting	Users are able to control the lighting intensity through the smart phone, increasing the controllability they have over their environment.	**Adaptability** **Satisfaction** **Productivity**
Controllable climate	Users are able to control the temperature through their smart phone, increasing the controllability they have over their environment.	**Adaptability** **Satisfaction** **Productivity**
Find colleagues	Users are able to find co-workers, stimulating collaboration and interactive between users and reducing time spend searching for co-workers.	**Culture** **Satisfaction**
Find workspace	Users are able to find an empty workspace, reducing time spend searching for a place to work	**Satisfaction**
Book rooms and lockers by phone	Users are able to book rooms and lockers offering them more services and efficiency.	**Satisfaction**
Overall concept of smart office	Increases the branding of the office due to the use of cutting edge and innovative technologies and due to the perceived higher quality of office space. Also increased tenant attraction and rental levels	**Branding** **Income** **Risk**

Table 23. Output and outcome overview of the Outlook. Own table.

E. Case conclusions

This section concludes the case and therefore summarizes the case according to the four topics that were used to structure the case and answer the sub-questions. The case summary is found in table 24. The overview is divided in the types of smart applications, how these applications are enabled, the reasons for developing a smart office and the results of the development of The Edge Olympic.

Types of smart applications	How they work	Reasons and motivations	Results
In terms of smart applications, the Edge Olympic does not differ from The Edge. The users have the same influence over the environment and the building operations are also adapted in accordance to the actual use of the office.	The Edge Olympic is said to have high levels of integration (Interviewee 1C, 2019). All the data is collected in a single platform which allows for more possibilities as time goes by. The sensors collect the data and the connectivity enables the interaction between systems and installations. The collected data is analysed and acted upon through the smart applications.	The Edge Olympic was not developed together with a certain tenant. Due to the success of The Edge, and the new possibilities in terms of technology, OVG was convinced that their end-product would be very marketable and redeveloped the Edge Olympic was a smart office.	The Edge Olympic is a very sustainable and healthy building with higher user satisfaction. From an investor's perspective higher rental levels and faster tenant attraction are perceived, increasing income and reducing investment risks.

Table 24. Summary overview of the Outlook. Own table.

Input for cross-case analysis

The findings of the case that will be used for the cross case analysis have been gathered and are illustrated in figure 87. The smart applications and the impacted added values are shown in the left and right side respectively. In order to improve comparability, the impacted added values have been categorised according to the four CREM-strategies.

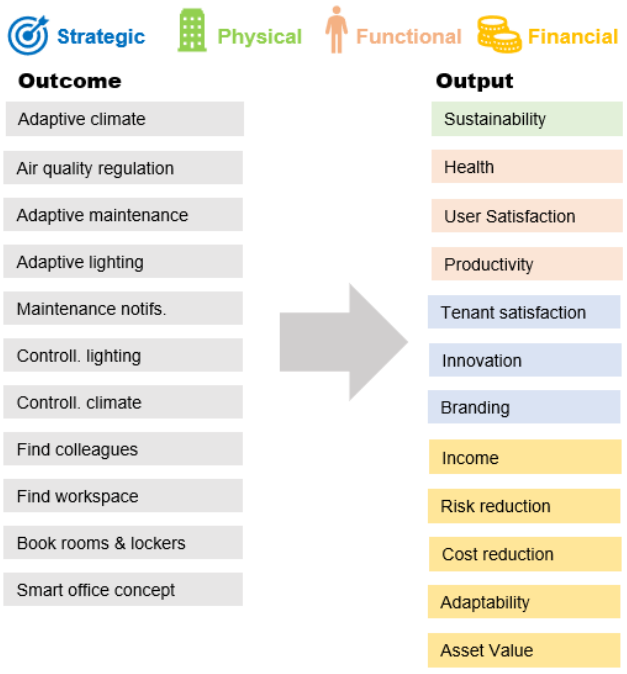


Figure 87 shows the nine smart applications found in the Outlook that have a positive impact on the added value (outcome).

Figure 87 shows that, in line with the four perspectives of CREM, the financial perspective is impacted the most by the implementation of smart technology, while the physical perspective the least.

Figure 87. Cross-case contribution of The Edge Olympic. Icons by PowerPoint. Own ill.

3.3 Cross case analysis

In this section the cross-case analysis is performed and discussed. In line with the discussed methodology, figure 88. shows the concept of the comparative analysis. The aim of this section is to create a single overview of the lessons learned through the cases and answer the following sub-questions:

1. *What is the effect of implementing smart technologies in office buildings?*

While the three cases are similar, creating one overview of all the applications and outcomes will draw better conclusions. As mentioned in the 'Methodology' chapter the three cases will be compare in regard to the different smart applications that are implemented and the outcomes or effects of the smart applications. By combining similarities, the 'Why' and 'What' questions can be answered through a combined overview and the sub-question (1) can be answered. Figure 88. Provides an overview as a reminder of the cross case analysis design.

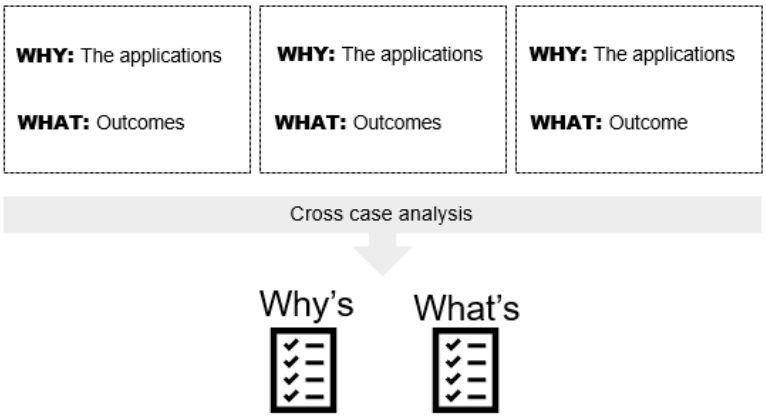


Figure 88. Cross case analysis design. Icons by PowerPoint. Own ill.

Furthermore, a certain 'weight' will be given to applications or added values that are mentioned multiple times

If a certain smart application is used in all the three cases it will be given a score of '3'. If a certain application is only used in one of the three cases, it will be given a score of '1'. This will create an overview of the most used applications and will be compared to the results of the Expert-panel to see if the most used application matches the most useful application.

The same scoring system will be used for the added values. If sustainability has been an added value in the two of the three cases it will receive a score of '2'. Again, these added values will be compared to the results of the Expert-panel to see if the most important added value matches the most impacted added value. Furthermore, any other conclusions that have been observed through the case findings will be discussed in this chapter.

Compare and combine – Added values

Figure 89 shows an overiew of the the three case summaries. All the identified added values, categorised according to the CREM perspectives, are combined into one overview.

The column on the right side of figure 89 shows the combination of the influenced added values seen throught the three cases. In grey, the amount of times is shown that the specific added value was perceived to be influenced through the smart applications. For example, the all three cases the sustainability was improved due to the smart applications that adapted the insallations to the actual use. In just one case, The Edge Olympic, was the income mentioned as an improved added value.

This weighting only illustrates the amount of times it was associated with the smart building and not the actual importance. Due to the lack of quantifiable results no conclusion can be drawn on the quantiable impact on the added value. This will further be discussed in the limitations section.

The three cases are very similar in terms of impacted added values. The only differences can be seen in ‘Culture’, ‘Asset value’ and ‘Income’. In the case of The Edge Olympic, the added value ‘Culture’ was not mentioned either as a driver or as a result. In the Edge and The Outlook, culture or supporting culture, was a key driver for the development of the smart office.

Another difference is seen between The Edge Olympic and the two other cases. Interviewee 4C (2019) specifically mentioned that a positive impact is seen in terms of income value and asset value when it comes to the smart assets. This direct positive impact was not mentioned in the other two cases. For the rest, due to the applications being very similar, the impacted added values are also similar.

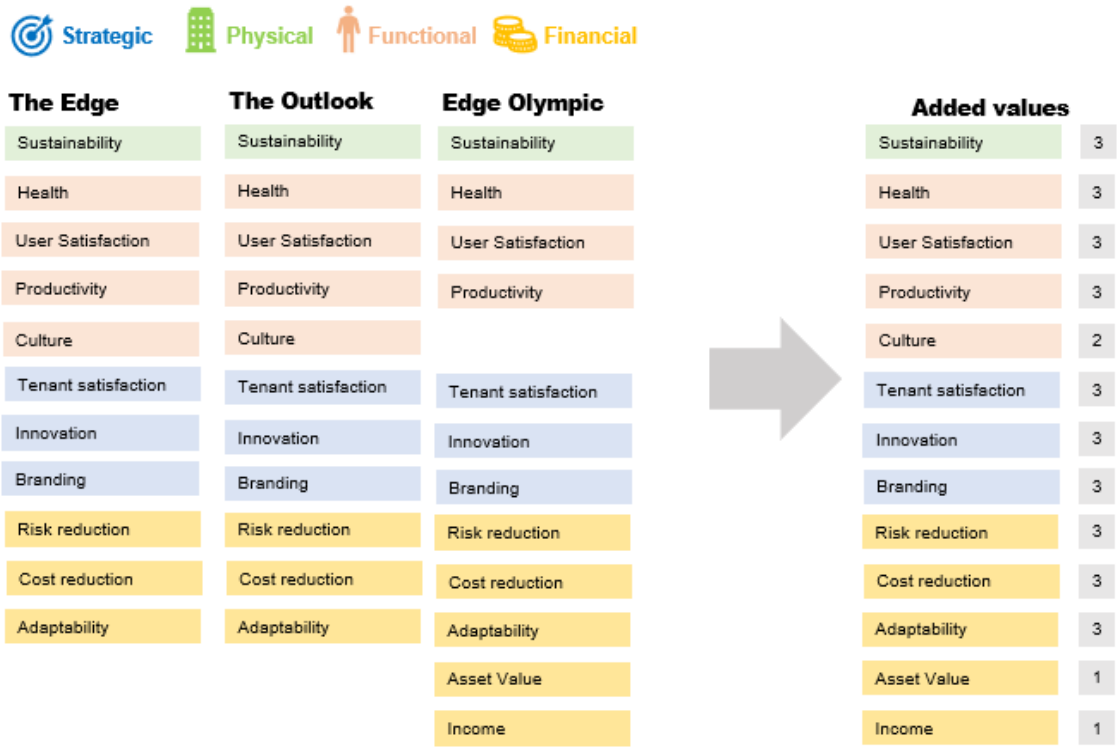


Figure 89. Cross case analysis results - added values. Icons by PowerPoint. Own ill.

Compare and combine – Smart applications

The second part of the cross case analysis compared and combines the smart applications that are found in the cases. Similar to the cross-case analysis on the added values, figure 90 shows an overview of the smart applictions per case. The three overviews are then combined into one single overview, with the amount of times an applications have been used indicated as a number value (right side of figure 90.)

As can ben seen in figure 90, the similarity across the cases in terms of smart applications is very high. The only difference being that The Outlook has fewer smart applications compared to the other two cases. As can be seen The Outlook has no applications that impact maintenance routines. As Interviewee 1B (2019) explained during the interview, the need for maintenance can net yet accurately be measured through sensors and therefore is not something that can be improved through a smart application. The room and locker booking application was not mentioned during the interview with Interviewee 1B (2019) and is therefore assumed to not be implemented. All the other applications seen in figure 90, however, are similar across the three cases.

Based on figure 90. a partial answer can be given to the sub-question: *What is smart technology in relation to office buildings?*

Smart technology in an office building refers to technology that enables the use of one the applications found in figure 90.

The Edge	The Outlook	The Edge Olympic
Adaptive climate	Adaptive climate	Adaptive climate
Air quality regulation	Air quality regulation	Air quality regulation
Adaptive maintenance		Adaptive maintenance
Adaptive lighting	Adaptive lighting	Adaptive lighting
Maintenance notifs.		Maintenance notifs.
Controll. lighting	Controll. lighting	Controll. lighting
Controll. climate	Controll. climate	Controll. climate
Find colleagues	Find colleagues	Find colleagues
Find workspace	Find workspace	Find workspace
Book rooms & lockers		Book rooms & lockers
Smart office concept	Smart office concept	Smart office concept

The smart applications	
Adaptive climate	3
Air quality regulation	3
Adaptive maintenance	2
Adaptive lighting	3
Maintenance notifs.	2
Controll. lighting	3
Controll. climate	3
Find colleagues	3
Find workspace	3
Book rooms & lockers	2
Smart office concept	3

Figure 90. Cross case analysis results – smart applications. Own ill.

From smart to value

Based on the findings of the cross-case analysis thus far a more complete answer can be given to the question: *What is the effect of implementing smart technology in office buildings?*

As was mentioned at the beginning of section 3.2 ‘case study results’, answering this question will provide the part of the smart value map shown in figure 91.

Figure 91. In orange: the part of the value map provided by the cross-case analysis findings

The answer to the sub-question: *What is the effect of implementing smart technology in office buildings?* is illustrated in figure 92. Figure 92 combines the case findings and the cross-case analysis findings to create an overview of the input, process, output and outcomes found throughout the cases. This holisitc overview combines all the elements of the three cases and shows which added values are impacted by the implementation of the smart technology.

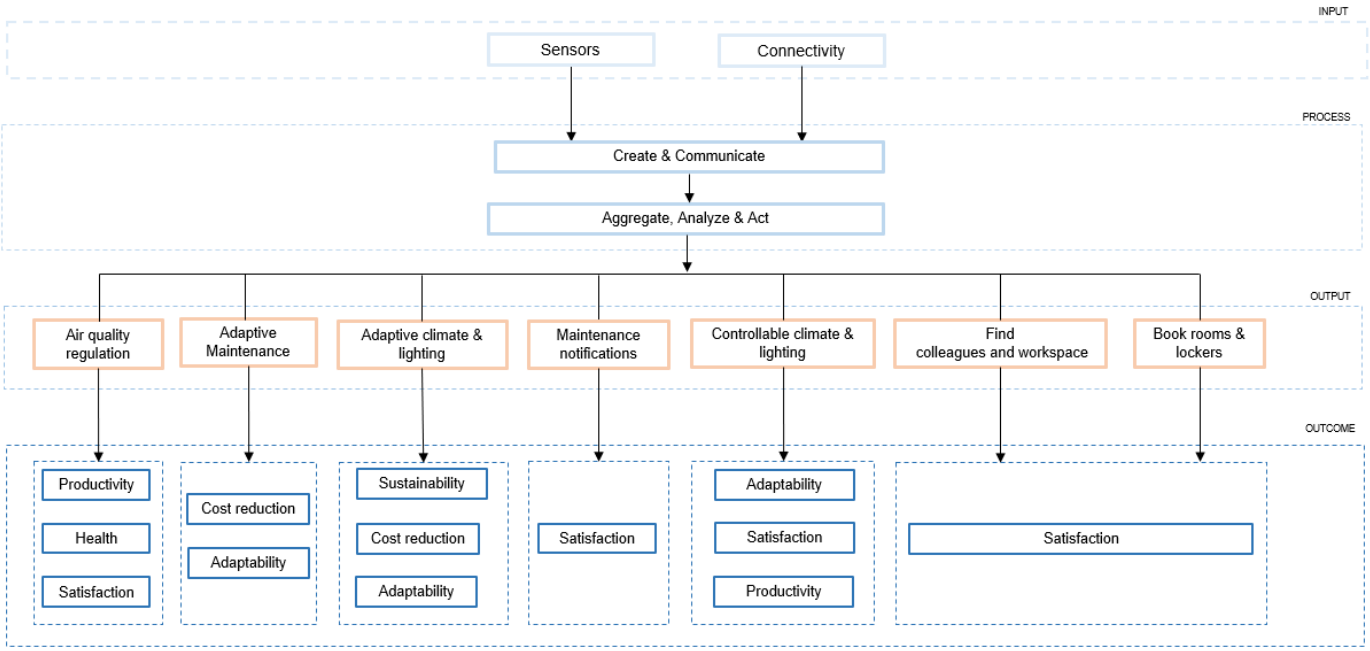


Figure 92. The holistic overview of how smart technology in office building can impact several added values. Own ill. (2019)

Figure 92 shows that the implementation of sensors allow for the creation of data. This is further enhanced by the introduction of internet connectivity between systems, installations and devices. The connectivity allows for even more data collection but also for the interaction between devices.

The collected data is aggregate and then analysed. The analysis of the data gives insights into the building performance and processes. By visualising the data and transforming it into information certain acts are enabled. These acts revolve around improving building processes and performance, making the office more efficiently.

These ‘acts’ are the smart applications, or the output in figure 92. The cross-case analysis shows a lot of overlap across the cases when it comes to the smart applications. Therefore, also the outcomes are very similar. The outcomes are seen at the bottom of figure 92 and consist of the values that are impacted using the smart applications. As in seen in tables 13, 18 and 23 certain applications impact multiple values. The adaptive climate and lighting systems improve sustainability, decrease operational costs and provide more adaptability.

With this figure the cross-case analysis is completed. The four case study topics have been extensively researched and the sub-questions answerable through the case studies have been answered.

The next chapter will give an answer to main question by answered the sub-questions first. Finally, the end-product, the Smart Value Map, will be introduced and described.

3.4 Expert panel results

In total two rounds have been performed for the Expert panel, the results are described in this section. The findings of the Expert-panel will be also compared with the findings of other research methods to identify any alignment.

As was written in section 2.5 ‘Expert panel’, the Expert panel aims at gathering certain consensus on the importance of the added values, the usefulness of the smart applications and any perceived connection between the smart applications and the added values. The findings are gathered in the next three sections. The first round of the Expert panel will be described first and then the second round.

Expert panel round 1

Number of participants: 12
Number of answers: 12

In line with the methodology the twelve participants were asked to score the added values and the smart applications based on their importance or usefulness. Of the twelve participants round 1 gathered a total of twelve answers. The results of round 1 are found in figure 93 and 94.

Added value	Score	Geometric mean
Satisfaction	79	7,1
Sustainability	72	6,4
Health	65	5,9
Productivity	62	5,3
Adaptability	56	4,6
Branding	55	4,5
Risk	55	4
Culture	40	3,4

Figure 93. Expert-results: importance of values. Own ill.

Smart application	Score	Geometric mean
Lighting adapt.	92	8,4
Climate adapt.	89	8,1
Controll. climate	71	6
Maintenance adapt.	68	5,8
Controll. lighting	63	5,4
Maintenance notifs.	63	5,3
Room & Locker booking	55	4,2
Workplace finder	57	4
Colleague local.	48	4

Figure 94. Expert-results: usefulness of applications. Own ill.

Importance of added values

Figure 93 shows the score each added value received through the Expert-panel. The participants were asked to score each added value based on their importance, this is represented by the 'score' column in figure 93. Then, the geometric mean of each value is calculated. The values are then ranked based on the geometric mean. A higher geometric mean indicates that the value is perceived as more important.

Figure 93 shows clearly that Satisfaction is the most important value according to the Expert-panel. The geometric average shows that Satisfaction is at a 7,1. This indicates that there is not complete consensus. Complete consensus would mean a geometric mean of 8. The least important value is Culture. Sustainability is also ranked very high, taking the spot for the second most important added value.

Usefulness of smart applications

Figure 94 shows the results of the Expert-panel in regard to the usefulness of the smart applications as perceived by the participants. At the top, close after one another, and very ahead of the third place are the lighting and climate adapting smart applications, hinting at the importance of either cost reduction, sustainability and adaptability.

When looking at the results of the added value in figure 93, sustainability indeed scores very high, while adaptability is ranked in the bottom half. This means that the lighting and climate adaptability applications are probably more associated with sustainability than with adaptability.

The least useful smart application is perceived to be the colleague localisation feature. The smart application that enables the user to find a workspace or book rooms and lockers is also ranked at the bottom.

Perceived relations between added values and smart applications

Figure 96 shows the relation between added values and smart applications as perceived by the respondents. The numbers in the cells represent the amount of times a certain connection is seen. For example, the Adaptive Climate smart application has been associated with sustainability by 10 respondents. While the respondents associated the adaptive climate applications 0 times with Culture. This process is shown for all the smart applications.

	Adaptive climate	Lighting adapt	Colleague local.	Workplace finder.	Room & locker booking	Controll. climate	Controll. lighting.	Maintenance notif	Maintenance adapt.
Sustainability	10	10	7	0	1	1	6	6	5
Productivity	7	10	1	4	7	5	9	8	3
Satisfaction	8	7	2	7	8	9	8	8	4
Risk	1	0	4	1	0	0	1	1	4
Health	8	6	1	0	1	0	6	6	2
Culture	0	0	1	5	3	2	0	0	0
Branding	2	3	3	4	4	4	2	2	3
Adaptability	5	4	5	0	3	1	5	3	2

Figure 96. Perceived relations between added values and smart applications. Own ill.

Looking back at figure 93, 'Sustainability' is one of the most important values as perceived by the respondents. And therefore, it is no surprise that the most useful applications are also perceived to be the Adaptive climate and adaptive lighting applications.

Expert panel round 2

Number of participants: 12
Number of answers: 6

In line with the methodology, the twelve participants were confronted with their answers from the first round as compared to the answers of the group. Out of the twelve participants, six answers were gathered with only one participant changing his initial scoring of the added values based on the group results. Since no

changed have been made in terms of the usefulness of smart applications, only the added values will be described.

Ranking round 1	(Geomean)	**Ranking round 2**	(Geomean)
Satisfaction	**7,1**	Satisfaction	**7,3**
Sustainability	**7,0**	Sustainability	**6,9**
Health	**5,7**	Productivity	**6,7**
Productivity	**4,8**	Health	**5,9**
Adaptability	**4,8**	Adaptability	**4,0**
Branding	**4,7**	Branding	**3,9**
Risk	**4,2**	Culture	**3,8**
Culture	**2,8**	Risk	**2,8**

Figure 96a. Comparison between the ranking of round 1 and round 2 using an average scoring.

As can be seen the position of Satisfaction and sustainability remain unchanged at the top. Although satisfaction increases in terms of geometric mean and sustainability decreases a bit it is not enough to change the top two. However, the top three spot does change. As is seen in figure 96a productivity moves up and replaces health as third most important added value. Another change we see is the fact that risk and culture, while still at the bottom, exchange places as least important added value.

Comparison to other findings

With the results of the Expert-panel representing the 'consensus' on either the added values, the smart applications and the relations between the two, the various methods used can be compared amongst on another to find any similarities or differences. Furthermore, the importance given to the added values found in figure 93 on the previous page can be used a certain weighting factor.

The first overlap that can be noticed is the fact that the most important added value, according to the Expert-panel respondents, is 'Satisfaction'. Satisfaction of user or tenant was also mentioned as very important driver for the development of the smart offices in the cases. The efforts to keep the tenants or employees satisfied or to increase their satisfaction were a key driver for the development of The Outlook, The Edge and The Edge Olympic. In The Outlook case, Schiphol agreed to develop a smart office to keep Microsoft satisfied. In The Edge case, the office was developed to increase collaboration and interaction between employees and better satisfy their needs. According to the investor of The Edge Olympic, the main reason of the acquisition was the provide optimal user experience (Interviewee 4C, 2019).

A strong connection can therefore be made between a common value that drives the development of smart office and the perceived importance of that value, in this case Satisfaction.

Sustainability, the second most important value, was also mentioned as a key driver behind the development of the three smart offices, further pointing at alignment between the drivers and the perceived importance of the added values. It is not surprising that the most important values are also the main drivers behind developments. But the fact that these coinciding values and drivers led to the decision to develop a **smart** office, does strengthen the claim that a smart office increases both added values.

Interestingly, 'Culture', which was found to increase satisfaction, is the least important added value. Although both Microsoft and Deloitte requested a smart office in order to increase or create a certain culture, that particular value itself is not perceived as very important for the investor or developer. Since the investor and/or developer are not the end-user of the office, the culture only matters if it matters to the tenant.

A big difference between theory and the results of the expert-panel is the fact that 'Risk' is seen as one of the least important added values. Theory shows that one of the biggest barriers of adapting smart technology is the fact that it is perceived as risk. Yet, risk itself is not seen as a very important factor.

Chapter 4. Conclusions

With the completion of the cross-case analysis, all the methods have been concluded and the final conclusions can be made. Both the Delphi panel results as well as the case study results point towards a high importance in keeping the tenants satisfied or increasing the satisfaction of the tenants. While the theory indicate that the investor objectives are more quantified, either optimizing cash flow or increasing asset value, the other methods indicate that the satisfaction of the tenant might be more important. As was seen in the case of The Outlook for example, the main reason that Schiphol Real Estate decided to invest in smart technology was in order to retain Microsoft as a tenant or in order words to keep Microsoft satisfied. Before the main research question is answered the importance of satisfaction will be expanded.

The importance of satisfaction

Both the findings of the case studies and of the expert panel shows the importance of satisfaction. Satisfaction is shown to have a positive influence on tenant retention, tenant attraction and lease terms, as per interviewee 4C of the Edge Olympic case. This means that keeping tenants satisfied will ensure constant rental income for the investor. Tenant turnover costs time and increases the risk of vacancy. By keeping the tenants satisfied the investor has income certainty for longer periods of time.

Employee satisfaction is specifically of value for the tenant. Keeping employees satisfied decreases employee turnover and positively influences employee attraction. Furthermore, employee satisfaction also has a positive influence on the productivity of the employees. Similar to how investors keep tenants satisfied, the tenants must keep employees satisfied to achieve their core objectives.

Due to difference in findings between the theory and the Expert panel and Case studies two smart value maps will be constructed in order to answer the main research question.

1. A smart value map that connects smart technology to Satisfaction
2. A smart value map that connects smart technology to income, costs and asset value

Together these two maps represent the findings of this research in terms of investor objectives.

4.1 Main research question

To answer the main research question the smart technology found in office buildings must be connected to the real estate investor. This is done by connecting all the different parts of the research according to the value map seen in figure 102.

Figure 102. The structure of the Smart Value map. Own ill. (2019)

Table 26 below shows how the different parts of the smart value map have been substantiated. Each part of the smart map is based on a part of the research.

Value map part:	Based on research part:
Stakeholder	Section 3.1 – Topic 3
Objectives	Section 3.1 – Topic 3, Delphi panel results, case studies
Added values	Section 3.1 – Topic 2
Smart applications	Section 3.3 – cross case analysis
Smart technology	Section 3.1 – Topic 1 & Section 3.3 – cross case analysis

Table 26. Different parts of the Smart Value Map and where in the report they are substantiated. Own table.

The smart value map made to answer the main research questions will firstly focus on showing how smart office can be used to increase (tenant) satisfaction. Afterwards other connections will be made between the more quantitative objectives of real estate investors and smart technology.

Figure 103 gives the following answer to the main question: *How can smart technology in office buildings provide added value to real estate investors?*

> *"Smart technology can improve the satisfaction of the employee by providing interactive control over the environment and a higher quality indoor environment. Tenant satisfaction, retention and attraction increase as a result to increase the investor's guarantee for long term income."*

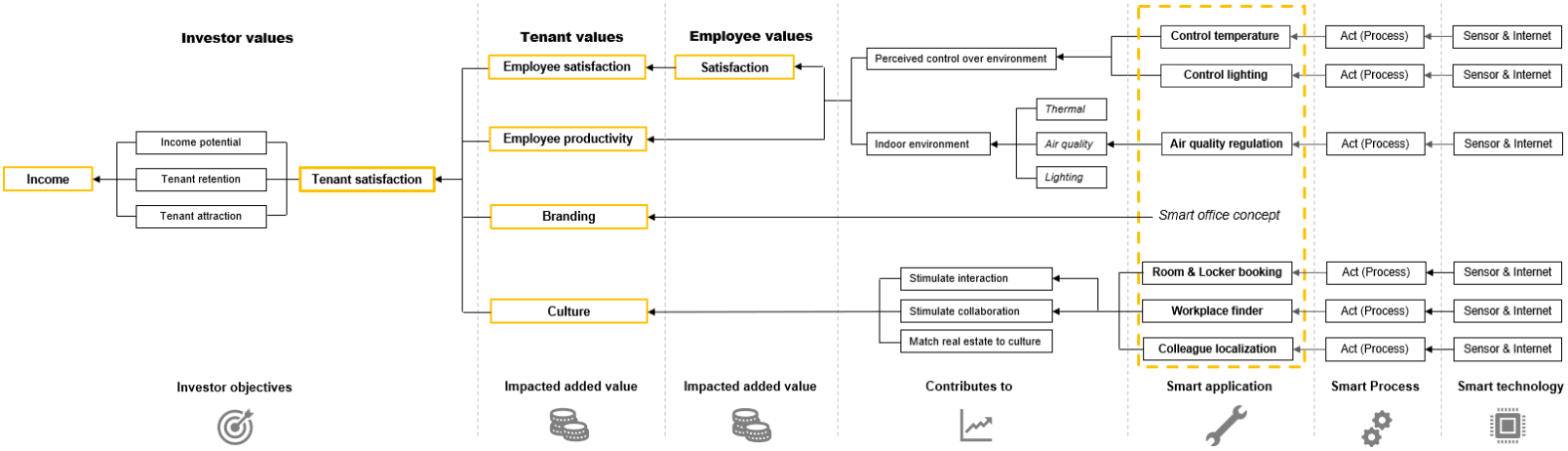


Figure 103. Connecting smart technology to satisfaction. Own ill. (2019)

Step by step

To understand the structure of the smart value map shown in 103 and substantiated the connection made between smart technology and tenant satisfaction the smart value map will be divided in different steps. Each step will be explained and connected to the next to end up with the smart value map seen in figure 103. The first step zooms in on the user values, as defined in 'section 3.1 – topic 3'. The second step connects the smart applications

Starting with the goal of contributing to increasing the tenant satisfaction, the first step is connecting the added values that impact tenant satisfaction to the objective to increase tenant satisfaction.

In figure 103 a distinction has been made between four different added value that contribute to the satisfaction of the tenant. As was seen through the literature review, 'Productivity', 'Employee satisfaction', 'Culture' and 'Branding' are added values that contribute to tenant satisfaction and are therefore connected to it.

The second step add the employee and it's preferences to the value map. As was seen in step one, employee satisfaction contributes to tenant satisfaction and is therefore valuable if increased. For each of the added values mentioned, the way to contribute to them have also been added to the smart value map. This is in line with the findings of the literature review as found in 'section 3.1 – topic 2'.

The third step is connecting the through the cases studies to the smart value map. Providing the employees with tools that controls temperature and lighting enable control over the environment and therefore contributing to satisfaction as per the literature review. Furthermore, the automatic air quality regulation, in terms of carbon dioxide concentration for example, contributes to an optimal indoor environment which also increases satisfaction. The room & locker booking, workplace finder and colleague

localisation tools all contribute to the stimulation of interaction and collaboration which in turn impacts Culture. All the smart applications together increase branding through the concept of the smart office.

The fourth step connects the smart applications to the smart technology that powers them. Based on the findings of the cases and the literature review this step adds the smart processes and the sensors and internet connectivity to the Smart Value Map.

The final step connects the investor objectives to the Smart value map and completes it. As can be seen satisfaction of tenants leads to, amongst others, tenant retention. Tenant retention in turn guarantees income for the investor which is a core objective.

In line with figure 103, the conclusion can be made that certain smart applications can contribute to increasing the satisfaction of its users, be it the employee or the tenant. As per the results of the Delphi panel the user satisfaction is perceived as very important. Thus, an investor can use an additional investment in smart technology to increase the satisfaction of users with the asset. Figure 103 can be used to show that the smart technology is not just a risk but a benefit.

In line with theory

Figure 103 only contains three of the smart applications that were found throughout the cases, and are only connected to one single added value. However, the Smart value map can be expanded to include more than just 'satisfaction'. In fact, all the smart applications found through the cases can contribute to an added value. This can be seen in figure 104, which can also be found in Appendix VI. As can be seen in the figure, all the smart applications and the smart processes that enable them have been connected to the direct values, as defined in figure 66 on page 52.

The connections between smart applications and the direct values are based on the findings of the cases and therefore on tables 13, 18 and 23. However, only the applications whose effects or impacts can be substantiated by the theoretical framework have been included in the Smart Value map in figure 104. Figure 103 and 104 together show

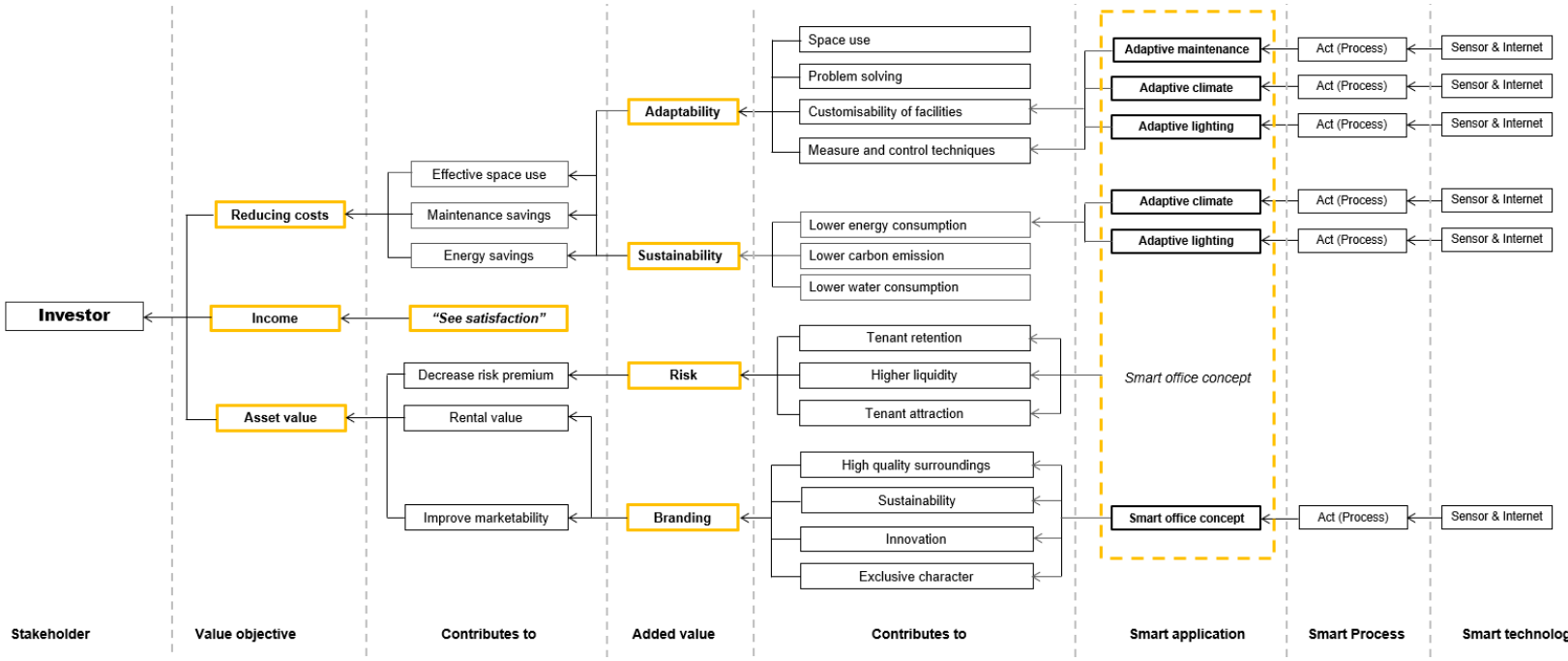


Figure 104. The Smart Value map that connects smart technology to the investor. Own ill. (2019)

4.2. Sub-questions

Sub question 1: What is smart technology in relation to office buildings?

In this research the smart building technologies are defined as the combination of the following technologies:

Sensors
Smart buildings, and therefore smart offices, use sensor technology to detect and respond to input from the physical environment. This provides constant data on the environment such as light intensity, temperature, air quality, sound pressure and motion (Arditi, 2015). The data, and the amount of data, is used as input to enable certain smart applications that ultimately provide value.

Internet connectivity
Within smart buildings internet connectivity enables devices to send and receive data amongst one another. This enables systems and installation to communicate and interact. Internet connectivity is needed to enable most of the smart processes in smart buildings such as sending the data collected by the sensors to the integrated platforms. The internet connectivity also enables the office users to directly interact with the building installations.

Integrated platforms
The integrated platforms in smart buildings are software applications were all the collected data is aggregated. Within these software applications the raw data is analysed and transformed into legible information. This information gives insights and possibilities into processes that can be improved.

Smart applications
The smart applications are the tools that use the information created by the integrated platforms to adapt or improve building processes, making the office building more efficient. The smart applications include all the tools that are specifically made possible through the sensors, internet connectivity and integrated platforms. Through the case studies the following smart applications have been identified:

- Climate systems that adapt automatically depending on whether space is being used.
- Lighting systems that adapt automatically depending on whether space is being used.
- The automatic regulation of ventilation based on carbon dioxide concentration in the air.
- Maintenance notifications sent by devices before they need maintenance.
- Lighting installations that can be controlled by users through a smart phone application.
- Climate installations that can be controlled by users through a smart phone application.
- A colleague localisation function that enables users to find co-workers throughout the offices.
- An empty workspace function that enables users to find empty workspace throughout the office.
- A function that enables users to book rooms and lockers through their smart phones

Sub-question 2: What are the objectives and constraints of the real estate investor?

This research has identified two types of stakeholders that are relevant for this research one of which is the investors, the other being the real estate user.

The investor

The investor objective and constraints are seen in figure 98. The main driver of real estate investors is profit. Investors either achieve profit by optimising and improving the cash-flow of their investment assets or by realizing long-term asset value increase.

Investors are mostly by risks, such as not being able to rent out their assets or not being able to sell their asset. But also, by capital constraints that limit the investment possibilities due to limited available monetary funds.

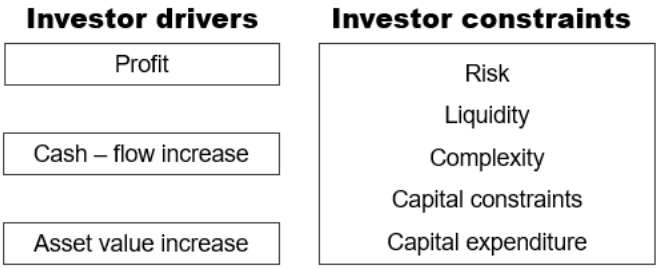


Figure 98. Investor drivers and constraints. Own ill.

Compared to the cases

The drive for profit is also seen in the development drivers that led to the development of the smart offices analysed for the case studies. Schiphol Real Estate mainly agreed to developed and invest in The Outlook in order to keep Microsoft as their tenant. By extending the lease with Microsoft, Schiphol Real Estate was assured of long-term cash flow. The development of the Edge Olympic was done due to the certainty OVG has in the financial performance of the smart offices. While one of the main reasons was also to try out new innovative developments the financial benefits associated with smart offices resulted in OVG developing The Edge Olympic without any tenant signed before the development process.

The investor constraints are less explicitly apparent throughout the cases. Interviewee 1B (2019) does mention that the upfront cost of the implementation of smart technology can be a constraint. Interviewee 1C (2019) states that the upfront costs are at most a few tens of euros per square meter, which is not considerable compared to the total redevelopment costs of The Edge Olympic. In terms of risk, the fact that only one of the three cases were developed without a pre-signed tenant shows that the investors are still not jumping at the chance to develop a smart building at their own risk. In terms of complexity Interviewee 1B (2019) mentions that using smart systems and installations do add some complexity to the operation of an office but that it is not a considerable constraint.

The user

In this research the other relevant stakeholder is the real estate user. The income of the investors is based on the rental value and the rent is paid by the tenants. In turn the employees that work for the tenant are responsible for the financial success of the tenant. In short, the investor relies on the tenant, who relies on the employee. Keeping employees satisfied is key for the tenant, and keeping tenants satisfied is key for the investor.

It is therefore no surprise that in all the cases the added value 'Satisfaction' played a key role. Both Microsoft and Deloitte demanded a smart office in order to increase the satisfaction of their employees and improve their ways of working and work culture. The investor of The Edge Olympic stated explicitly that user experience is an important value that they improve through smart offices. Furthermore Interviewee 4C (2019) stated that tenant satisfaction leads to tenant attraction and retention, which is very important for an investor. In line with this Interviewee 1B (2019) said that being known as a good place to hold office is very important for Schiphol.

In the CREM perspectives the stakeholder objectives mentioned above are represented by the Financial perspective and the Functional perspective. Figure 99 shows again the overview of the added values based on the cross-case analysis. In line with the objectives of the relevant stakeholders the most represented perspectives are the Financial and Functional perspectives. Further indicating that smart offices are above all tailored to fit the preferences of the relevant stakeholders.

Added values	
Sustainability	3
Health	3
User Satisfaction	3
Productivity	3
Culture	2
Tenant satisfaction	3
Innovation	3
Branding	3
Risk reduction	3
Cost reduction	3
Adaptability	3
Asset Value	1
Income	1

Figure 99. Cross-case analysis findings. Own ill.

By bringing back the circle of blame seen in figure 100. another conclusion can be made concerning stakeholders. As seen in the cases, two of the three cases are initiated by the user demanding a smart office. This indicates that the users do want smart buildings, but that there are none available, which is why they needed an investor to develop one for them. In the third case it is the investor, who is aware of the benefits and sure of the demand, that takes the initiative and therefore breaks the circle of blame.

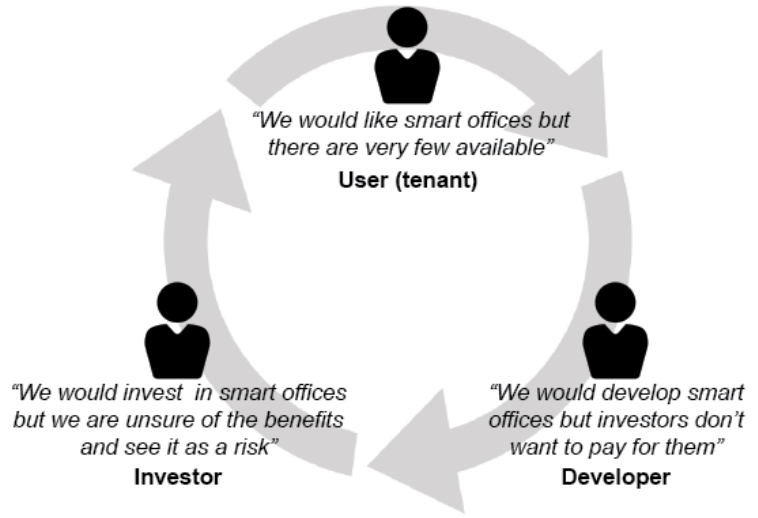


Figure 100. Circle of blame. Adapted from Cadman (2000).

Sub-question 3: What is added value?

Something is of value when it aligns with objectives. Added value therefore means that it contributes to achieving the objectives. Through literature a list of added values has been compiled. Table 25 shows an overview of the 12 added values that have been found through literature.

Additionally, the table also shows if the added value is a core objective or contributes directly or indirectly to the core objectives of the investor and in what way.

	Added Value	**Contribution**	**Explanation**
1	Health	Indirectly	Health contributes to the satisfaction of tenants as a higher indoor environmental quality is achieved.
2	Satisfaction	Directly	Satisfaction can lead to higher income potential through higher rental value. If tenants are optimally satisfied it can result in higher rental income.
3	Sustainability	Directly	Improving sustainability means better energy efficiency, this means that energy costs are lower and therefore overall operational costs also.
4	Productivity	Indirectly	Contributing to better productivity increases satisfaction and branding.
5	Adaptability	Directly	Adaptability of installations can save energy and maintenance costs.
6	Culture	Indirectly	Improving the culture of an organisation through real estate can increase satisfaction.
7	Branding	Directly	Branding can increase marketability and rental value.
8	Cost (reduction)	Core objective	Cost, or reducing costs, is a core objective as it is a part of cash flow.
9	**CAPEX**	*This added value is the only value that is negatively impacted by the implementation of smart technology, as it is increased due to higher investment costs.*	
10	Asset value	Core objective	Asset value is based on income and a core objective of the investor.
11	Risk	Directly	In valuations, risk premium is used to determine asset value, which is a core objective.
12	Income	Core objective	Income is an integral part of cash flow and therefore a core objective.

Table 25. Overview of all the added values. Own table.

Sub-question 4: What is the effect of implementing smart technologies in office buildings?

The smart applications improve many of the building processes making it more efficient, increasing sustainability, health, productivity while enhancing culture, tenant satisfaction, branding and innovation. Smart applications also indicate that they can be used to reduce costs, risk and increase income and asset value.

The answer of this sub-question is best illustrated by figure 101. Figure 101 shows not only the smart technologies; sensors and connectivity, but also the processes and smart applications that lead to the actual effects of the implementation of smart technology.

The implementation of the smart technologies, as defined in the answer of sub-question 1, lead to an improvement of the outcomes as seen figure 101.

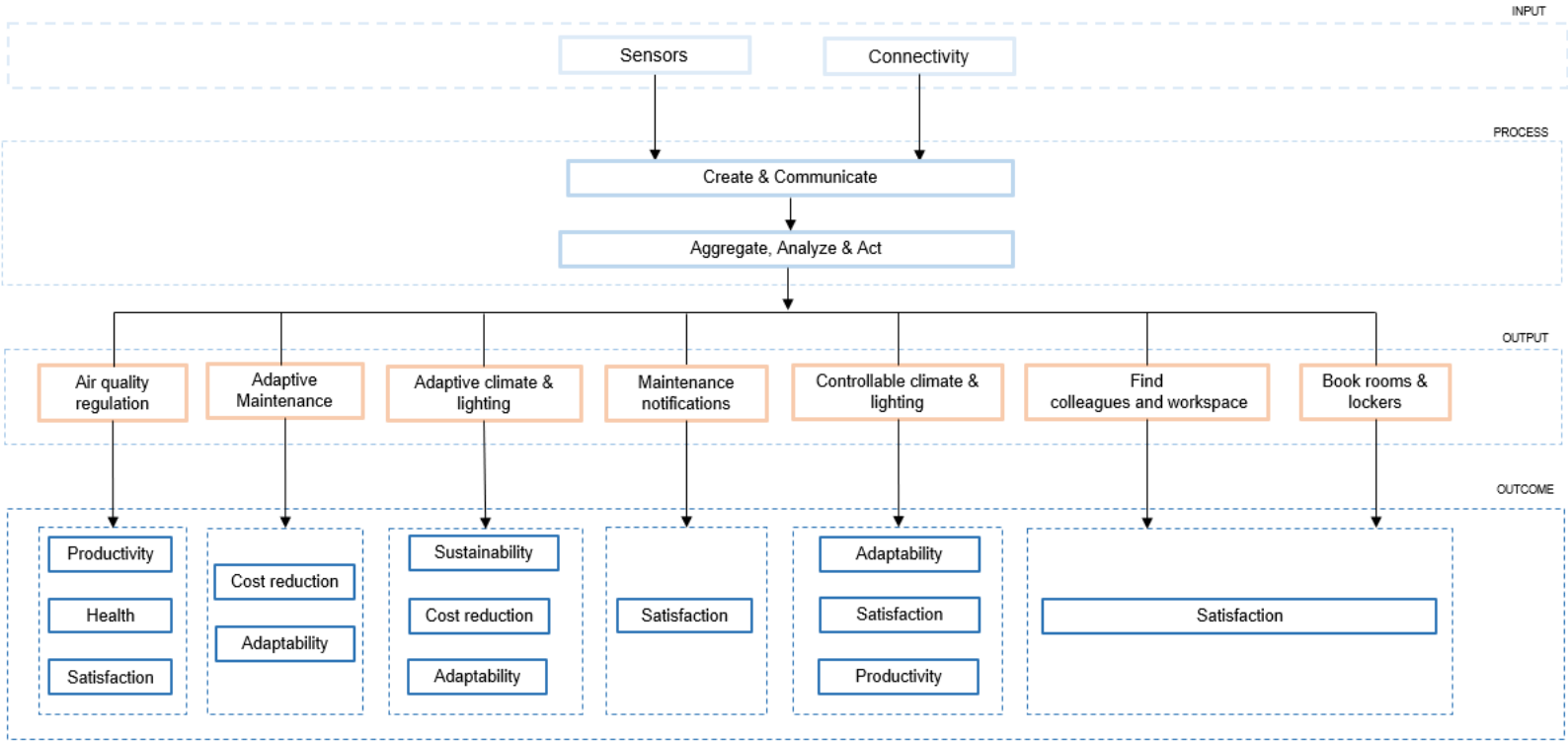


Figure 101. The overview of how smart technology in office building can impact several added values. Own ill. (2019)

Other conclusions

Expected and realised values

In all three cases, satisfaction and user experience was a big factor. The smart offices have many user-oriented tools that aim at improving the employee journey. However, the interviews with the users pointed at some flaws in the user-friendliness of the applications that are supposed to improve their comfort. For example, in one case, the workplace finder and colleague localisation are hardly ever used due to a user-unfriendly application interface and the fact that employees often sit in the same spot. So, while the smart offices try to target and improve the satisfaction of the employee, the applications that are in charge to do this are still lacking (Interviewee 3C, 2019; Interviewee 2B, 2019; Interviewee 2A, 2019). According to one interviewee (Interviewee 3C, 2019), the fact that the building is healthy (due to air quality regulation) is the biggest benefit of the smart office and not the applications that should increase the user experience.

Direct versus indirect values

The smart value map in figure 104 shows that most of the smart applications do no directly increase or have impact on the core objective of the investor. Most of the smart applications influence or increase a certain added value, which in turns contribute to the core objectives of investors. This ‘detour’ makes the value of smart technology less visible a it is not immediate or takes time to develop. Furthermore, a significant part of the applications is specifically aimed at the users of the real estate and therefore does not directly provide value for the investor. The constraint with user-oriented applications is that there is a split-incentive. The investor pays and the user profits. This makes the investor less likely to invest in those applications, unless the user (tenant) agrees to pay more to have these specific applications. An agreement like this was also mentioned by Interviewee 2C (2019). A certain lease agreement where the user oriented smart applications are opt-in might solve the split-incentive.

Reducing the gap

One of the purposes of this research was to provide information on the benefits of smart offices, to convince investors that technology is not a risk, but an opportunity. The adverse relation that investors have with new innovations slow down the adoption rates in real estate.

The smart value map in figure 104 shows that investing in smart technology can be beneficial in many ways and is not just a risk. As research is added on smart offices and smart technology the benefits will be more and more apparent. However, the capital-intensive object characteristics of real estate will remain a constraint for some investors until the value of smart technology is underpinned by quantified values.

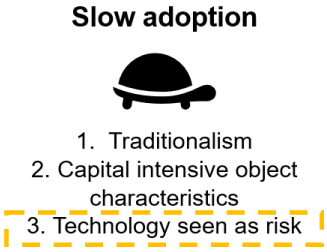


Figure 25. constraints targeted by this research. Own ill. (2019)

This map, however, can convince some investors that are on the fence and are not sure if smart technology will benefit them. So, even if the findings of this research might not convince the traditional investors due to a lack of quantified proof, it might provide the push needed for some investors to consider the implementation of smart technology during a development.

Chapter 5. Discussion

5.1 Discussions on research findings

The smart value map shows how investor objectives can be positively influenced by the implementation of smart technology. The findings are aligned with the expectations that smart buildings improve efficiency, user experience and overall performance. Some of the findings however, are not completely aligned. For example, the Expert panel showed that most of the tools that are user oriented are amongst the least useful smart applications, even though those smart applications are to increase satisfaction which, according to the Expert panel findings, is one of the most important added values.

There are some very clear connections between investor objectives and smart technology. One of the clearest connections is the fact that, by using sensors, some of the installations can adapt automatically to actual use of the building. This saves costs as the installations are not constantly powered on. While the impact is not quantified (yet) and the usefulness of these applications depend on the occupancy of the office, the potential benefits are quite clear.

The findings point at benefits of smart offices and show that costs can be reduced and satisfaction can be increased. In the end, the smart value map constructed through this research remains very qualitative. While the smart value map does show connections and therefore provides some rationale that smart technology leads to value a more quantified version of the map is needed to really convince the traditional investors. The smart value map does not show costs or quantified benefits, so the investors are still faced with the problem that there is not much information available on the actual return on investment that smart technology can provide. However, as will be stated in the recommendations, a qualitative value map is a good start for the creation of a quantitative value map.

5.2 Discussion on research design

Literature review

Due to the topic of smart offices being relatively new, the amount of academic literature on smart buildings is still very limited. The research relies heavily upon a couple of sources when it comes to smart technology. For example, the research performed by Ullah et al. (2018) proved to be invaluable. This, however, does increase the risk of biased information. In comparison, the literature on added value and the stakeholder objectives is more extensive, making those findings more reliable and valid.

Due to the lack of information all the smart applications have been research through the three cases. These applications only show the possibilities at the time of writing. This means that in ten years, the applications might be completely different rendering the Smart Value map useless. The theory on the added values seems to be more solid and resistant to changes so that part of the Smart value map is more ‘future proof’.

Interviews

The interviews proved to be a very effective and invaluable method to gather information. The enthusiasm and involvement of the interviewees resulted in one interview almost being able to cover an entire case. This was useful as the other interviews of the same case would confirm most of the information.

In the not all perspectives were represented equally for each case. Many interviewees, however, would be able to fulfil multiple roles. The Edge Olympic case was the best documented case where one employee, one development manager, one engineer and one investor were interviewed. This does strengthen the validity of the Edge Olympic case.

Since the interviews are done with stakeholders that are involved with the smart office some bias in the answers can be expected. The barriers or problems in regard to the smart office were always less touched

upon compared to the successes. However, the interviews with the users were more rose-coloured and more critical on the smart offices. For example, many of the smart applications aimed at the user remained unused due to user unfriendliness,

Case studies

The theory gathered through the literature review on smart building was very recognizable in the different cases and helped structure the cases. Also, the connections between the smart applications and their effects, and the added values found through literature were rather quickly made due to the fact that most effects were discussed with the interviewees and sometimes, already during the interview, quite literally connected to an added value.

The aim of the cross-case analysis was to compact all the information gathered through the three cases and create one overview of the smart applications and the impacted added values. Due to the high similarity across the three cases the result of the cross-case analysis was not very surprising. The similarities across cases is simply due to smart offices being very new and the possibilities still mostly undiscovered.

Expert panel

The Expert-panel was used to research the consensus amongst stakeholders in relation the usefulness and importance of smart applications and added values respectively. The findings provided insights into what the most important values and smart applications are. This can benefit the overall perceived value of smart office. The connections made by the participants show that there is a perceived connection between smart offices, sustainability and satisfaction.

A more in-depth reflection on the process of the expert panel can be found in the Reflection document of this research since, compared to other methods, it was a very problematic process.

5.3 Research limitations

The lack of consistency across literature on smart technology (PropTech) makes it difficult to create structure. This was seen in the PropTech categories, where various terms are used for the same type of technology but also some sources listing a category that is very different and named by no other sources.

The number of interrelationships between the values make it difficult to capture everything in one single value map. This combined with the explorative nature of the research result in a value map that is relatively superficial. However, this opens opportunities for future research.

The main limitation is the innovative nature of smart offices. During multiple interviews the interviewee would answer that it was too early to have concrete results. This resulted in some of the findings being based on assumptions and expectations instead of actual quantified results. For example, multiple interviewees stated that a reduction of energy use was seen compared to the previous situation. However, it was still unclear how much the smart technology contributed to this reduction. The only example was given by Interviewee 1C (2019) who stated that, during a tender competition, a higher energy efficiency was achieved compared to other participants, with the only notable difference being the use of smart technology.

This also results in limitations regarding both the literature available and the case studies and interviewees available. There are only a limited number of investors that invest in smart buildings. As was seen in The Edge case, if one of them cannot be interviewed, it leaves a gap that is hard to fill.

The findings of the cases are mostly based interviews with stakeholders involved with those cases and might there not be applicable to other smart offices. Furthermore, the conducted interviews might not represent the rationale of stakeholders involved with traditional assets. Interviewees that are closely involved with smart office are of course already convinced of the benefits and might see the constraints differently.

The smart applications are inventoried based on the three cases only. There is not much theory or literature that substantiates the way they work and their effects. All the findings are based on the information provided by the interviewees, which might lead to bias. An example of this is the fact that controlling the temperature of the environment as a user does not work as well in the open spaces of the offices. Without the input of the office user, this would not have been known in this research.

The smart applications that have been researched and used in the Smart Value map might be outdated and not used anymore in a few years. Technology changes fast and a smart building might use completely different smart applications.

Lastly, the lack of quantifiable data restricts the convincing nature of the Smart Value Map. The theoretical connection has been made but most investors will probably still want an actual euro value before being convinced.

Chapter 6. recommendations

6.1 Recommendations for practice

- Investing in smart technology might be very beneficial depending on objectives. While it might not be feasible to redevelop an office just to make it smart, it is advised, when there are plans to either redevelop an office or build a new one, to check if the use of smart technology can contribute to one of the objectives.

- Smart offices are still new and some competitive advantage in the form of branding can still be obtained in addition to the other benefits.

- As shown by some surveys, the new generation increasingly expects their work environments to be smart and will also base their choice of future workplace based on this aspect.

- If the user is the target of a part of the smart office, make sure the applications are very user friendly or the value will diminish very quickly.

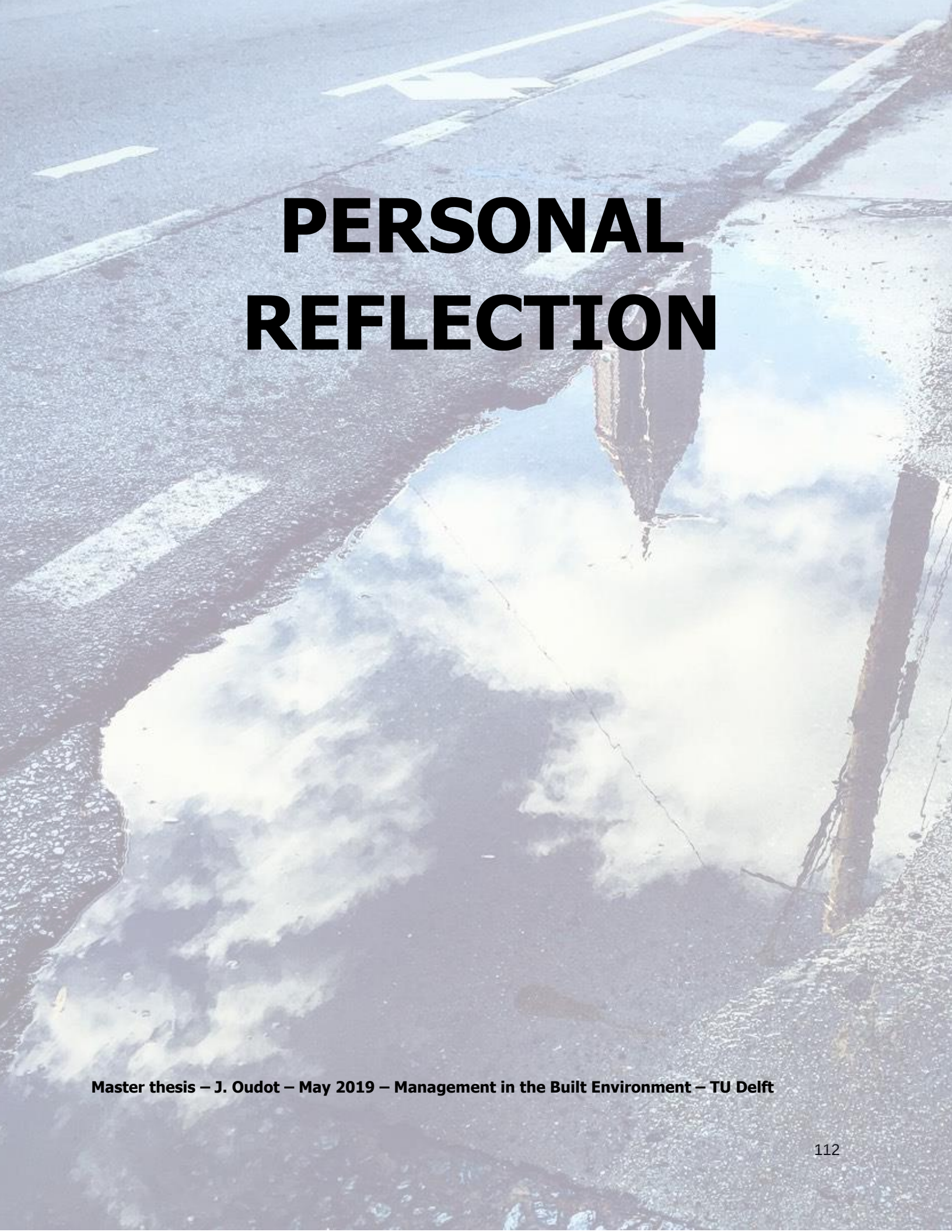
- The value of the smart applications also depends on the occupancy and size of the office. Colleague localisation and workplace finder is more useful in larger offices with no assigned seating. Adaptive maintenance, climate and lighting is especially useful for offices that are not constantly fully occupied.

6.2 Recommendations for research

- The value map created through this research lacks the depth that can be achieved when focussing on just one part of it. Therefore, using the value map of this research as starting point, and adapting it could ultimately create a very detailed overview of the value that smart technology provides. This can be done by studying or researching specifically one of the core objectives. For example, the actual impact of smart technology on the rental levels, or the impact of the implementation of smart technology on the operating costs. This however would require measurements of the situation before the use of smart technology and measurements of the situation after the implementation of smart technology. Additionally, the impact of the smart technology would have to be isolated somehow. Also, when researching the effect on the income the use of surveys to research the willingness to pay for smart technology in office buildings might be very insightful.

- A similar research could be done from the perspective of the tenants. Their importance became clear after the cases of The Outlook and The Edge that both were developed as a result of the tenant demanding it. Therefore, it seems that most of the smart offices are developed because the users want it. Focussing on the tenants and showing them the benefits of working in a smart environment might therefore be a better way to improve adoption rates.

- Most of the smart applications have clear connections to values. For example, the adaptive climate leads relatively straightforward to energy savings since it influences quantifiable factors. The smart applications that lead to satisfaction are less easy to prove. While research has been done on the fact that having control over the environment increases satisfaction there is not yet academic research on the connection between room and locker booking, colleague and workplace finder and satisfaction. A large-scale survey amongst smart office users could provide this substantiation. The interviews with the users did however point at the connection being there, as they did see the added value of those applications.



PERSONAL REFLECTION

Topic selection

The reason to research smart buildings from an investors perspective was that, in this way, I would be able to research two topics I personally like within real estate. The stories I heard about The Edge really interested me, while my interest in the investors perspective was raised during multiple courses during the Management in the Built Environment Master. By researching the value of smart offices for investors I was able to dive deeper into smart offices while keeping in touch with the investment world. Another reason to choose the investors perspective was to align the research with my Graduation company, PingProperties. I wanted to research a topic that would also be interesting for PingProperties which simply resulted in research the value of smart offices.

Reflection on Aim

My initial idea was to create a model in Excel that could calculate the return on investment for smart technology. The idea was 'simple': If an investor invests X amount of money to make a building smart, he will earn his investment back in Y years and increase the value of the asset by Z. During my first presentation, the P1, I even presented a mock-up of the model that was made for the 'Operations' course. The idea was to compare cash flows of traditional office with the cash flows of smart office and base the model on the differences.

However very quickly I realised that it was simply not possible. First of all, no company just gives away the cash flows of their offices. Secondly, the implementation of smart technology are not really quantifiable and the actual costs are not publicly available. Due to the unavailability of cash flows and data on investment costs the whole idea to quantify smart technology had to be changed after my P2 presentation.

While reading through more literature the Value Map of Jensen & Van der Voordt (2017) helped to change the aim and align it better with the possibilities. The idea was to create a similar value map that connected smart technology with investor objectives by using added values. In the end, this value map was actually achievable given the available information and therefore resulted in the end product being a Smart Value map.

Looking back, the objective remained the same but the ambitions were toned down throughout the process due the lack of available (and accessible) information. The aim shifted from a quantitative to a qualitative model.

Both the interviewees from the Edge Olympic and The Outlook stated that the results were not yet concrete due to the building being just delivered. I think that with time, the Value Map can be quantified piece by piece and in the future transformed to a map that is more convincing for investors since the quantified value will be more apparent

While the toning down of ambitions was sometimes a bit demoralising it did challenge the way I had to structure the research and the process.

Reflection on methods

Literature review

The first stages of the literature review were fairly frustrating. The aim was to quantify the investment value of smart technology. However, no information was publicly available on any of the necessary topics. The information remained superficial and ‘vague’ and did not at all dive into the quantified costs and benefits of smart technology.

After the aim was adjusted to the possibilities, the literature review was more straightforward. By using added values as a ‘gateway’ to connect investors and smart technology the main focus of the literature review was researching the added values, of which there is more than enough literature available.

The harder part of the literature review was finding adequate information on smart buildings and smart technology. The majority of the sources are market reports composed by large companies such as KPMG and Deloitte. These kind of sources often lack the academic ‘stamp’ and are less unbiased. These sources also lacked depth, as the actual smart applications found in office were described no where in these sources.

Case studies & Interviews

The case studies ended up relying more on the interviews than I had expected and the interviews ended up going differently than expected. The Outlook interviews were done at the same time that I was doing the document review for the case. This resulted in me being less aware of information gaps. The Edge Olympic interviews were conducted after the document review which allowed me to check any information I already had and ask specific questions to enrich the case. Timeline wise it would have been better to first do all the document review possible and then do the interviews to check the information and enrich the cases.

Furthermore, each interview would derail and not follow the interview protocols. The four topics that needed to be research per case were however discussed but not in the way as described in the interview protocol. Steering the conversation was harder than expected and the enthusiasm of the interviewees made it hard to cut them off and align them with the interview protocol. I think in the end, if you strictly follow the protocol, the conversation flow is disturbed and the interview becomes less natural and enjoyable.

It is a shame that I did not end up interviewing the investors of The Edge. I did contact them but ended up interviewing the Facilities Manager of the Edge. Of course his input was invaluable but since the research was focussed on the investors it is a shame that no answers were gathered from them. This was increased after the interview with the investors of the Edge Olympic, who went quite deep into the performance of their smart portfolio and how it resulted in higher rent levels and improved tenant retention and attraction.

The biggest struggle with the interviews was to set the actual dates for the interviews. Finding interviewees was easier than expected but setting the dates took longer due to busy schedules. Some of the interviews had to be done through phone and one interviewee had to be done by mail. However, this was also due to me underestimating the time it takes to set up interviews. If this process would have started earlier, it would have been less impactful. So a recommendation for myself is to start this process earlier.

Expert panel

The expert panel started out as a Delphi-panel, with the aim to reach certain consensus level on the added values and the applications. The respondents were supposed to rank the added values and the smart applications on a scale from 1 to 8 or 9 with each ‘rank’ being only held by one value or application. However, due to some mistakes on my side the participants were able to rank the values and applications equally. Meaning that some participants scored multiple values and applications equally. This resulted in a scoring rather than a ranking as not all respondents had a clear first place or last place but rather multiple, shared, places. In the end the decision was made to name the method an expert panel, as the lack or ranking made it hard to complete is as a Delphi-panel. Using the geometric mean the results could still be ranked and some conclusion could be made.

Another ‘fail’ in the expert panel method was the lack of second responses and more importantly the lack of difference in responses. The participants were given the option to adapt their scoring based on the group average. However, out of all the participants, only one (1) participant changed the scoring of the added values. The scoring of the smart applications remained completely unchanged.

Time wise the expert panel was also problematic, the method was defined later on in the research which made the process less detailed. This led to the rounds being conducted very late in the research process. Simultaneously, I underestimated the amount of responses and the time it took for the respondents to answer.

Looking back

The research approach set up before the P2, differed from the research execution. This becomes quite clear when comparing the protocols for the interviews and case studies with the actual structures. While fairly similar, the P2 case study protocol was structured in a way that compared the input from users, managers and investors. In the end the case studies were structure in an input, output and outcome way. This was due to the gathered information not being dividable in the user, manager and investor perspectives. Also to align it better with the value map, the input, output and outcome way was preferable.

Reflection on conclusions and findings

The end-product, while very different from what I wanted it to be in the beginning, still supports my initial aim. Due to the lack of quantifiable information in the Smart Value Map the end-product is less convincing than I had hoped it would have been. While the map does connect the smart technology to the core objectives of an investor it still lacks the **actual** impact needed to convince the traditional investors. While it is theoretically substantiated that, for example, enabling climate systems to adapt automatically based on the actual use of the building can save costs, the questions remains: Yes, but how much does it save? And how much does it cost?

The same can be said for ‘Satisfaction’. The findings pointed out that ‘Satisfaction’ is very important. Tenant satisfaction as well as employee satisfaction. The findings also pointed out that many of the smart applications increase satisfaction. The question still remains: To what extent does it increase satisfaction?

Hopefully these questions will be answered in the (near) future, maybe even by using my Value Map to select the smart applications that increase satisfaction or decrease cost.

Other findings

I found it very surprising that most of the smart offices were realised due the tenant demanding them. I initially targeted the investors since I thought that they would be the ones taking the initiative. However, it seems that large corporate tenants like Microsoft and Deloitte are very effective triggers for the development of smart buildings. Many investors would be all too happy to develop a smart office if it meant signing a lease contract with a tenant like that. So in the end, maybe convincing large corporate tenants might be a better approach to increase adoption rates of smart offices. On the flip side, OVG Real Estate proves that an investors is also more than capable at driving innovation in real estate.

In the end, I hope my Smart Value Map will be able to at least convince someone of the benefits of smart offices, or be used as a reference for future research

Literature:

Interview sources

The Edge

Interviewee 1A – Facility Manager. (2019, March 21). Phone interview.

Interviewee 2A – Deloitte Employee. (2019, March 14). Personal interview

The Outlook

Interviewee 1B – Project Manager. (2019, March 11). Personal interview

Interviewee 2B – Microsoft employee. (2019, March 16). Personal interview

The Edge Olympic

Interviewee 1C – IoT engineer. (2019, April 3). Personal interview

Interviewee 2C – Development manager. (2019, April 3). Personal interview

Interviewee 3C – OVG Real estate employee. (2019, April 3). Personal interview

Interviewee 4C – Fund manager. (2019, April 23). Email interview.

Additional interview

Interviewee 1D – Asset manager. (2019, March 13). Phone interview

Other sources

Allen, Joseph G., Piers MacNaughton, Usha Satish, Suresh Santanam, Jose Vallarino, and John D. Spengler. (2015). "Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments." Environmental Health Perspectives 124 (6): 805-812. doi:10.1289/ehp.1510037. http://dx.doi.org/10.1289/ehp.1510037.

Baum, A. (2017). Proptech 3.0: The future of the industry. Retrieved from: www.sbs.ofxord.edu

Beyrouthy, C. (2008). Models, solution methods and threshold behaviour for the teaching space allocation problem. (PhD), University of Nottingham, Nottingham.

Blakstad, S.H. (2001) *A strategic approach to adaptability in office buildings*. Trondheim, Norwegian University of Science and Technology, Faculty of Architecture, Planning and Fine Arts, Department of Building Technology.

Boga, S.R.C.; Kansagara, B.; Kannan, R. (2017) Integration of Augmented Reality and Virtual Reality in Building Information Modeling: The Next Frontier in Civil Engineering Education. In Mobile Technologies and Augmented Reality in Open Education; Kurubacak, G., Altinpulluk, H., Eds.; IGI Global: Hershey, PA, USA, 2018; pp. 1037–1066. Retrieved from: https://www.igi-global.com/chapter/integration-of-augmentedreality-and-virtual-reality-in-building-information-modeling/178245.

Boyd, T. (2006). "Can we assess the worth of environmental and social characteristics in investment property?"

BPIE (2017). *Is Europe ready for the smart building revolution?* Retrieved from: http://bpie.eu/wp-content/uploads/2017/02/STATUS-REPORT-Is-Europe-ready_FINAL_LR.pdf

Brand, S. (1994). *How Buildings Learn*. New York: Viking.

Buckman, A. H., Mayfield, M., & Beck, S. B. M. (2014). What is a smart building? Smart and Sustainable Built Environment, 3 (2), 92-109. doi:10.1108/SASBE-01-2014-0003

Cadman, D., 2000, The vicious circle of blame, Cited in: Keeping, M., 2000, What about demand? Do investors want 'sustainable buildings'? Retrieved from: http://www.rics.org/Practiceareas/Builtenvironment/Sustainableconstruction/ what_about_the_demand_20000101.html

CB insights (2017). Early-Stage Real Estate Tech: 120+ Companies Building the Industry's future. Retrieved from: https://www.cbinsights.com/research/real-estate-tech-startup-market-map-early-stage/

Charles R, Reardon JT, Magee RJ: Indoor air quality and thermal comfort in open-Plan offices. In *Construction technology updates*, Volume 64. Institute for Research in Construction (IRC): National Research Council of Canada ISSN; :1206–1220.

Chen, X.; Lu, W. Scenarios for Applying Big Data in Boosting Construction: A Review. In Proceedings of the 21st International Symposium on Advancement of Construction Management and Real Estate; Springer: Singapore, 2018; pp. 1299–1306. 78.

Christensen, K., Melfi, R., Nordman, B., Rosenblum, B., & Viera, R. (2014). Using existing network infrastructure to estimate building occupancy and control plugged-in devices in user workspaces. International Journal of Communication Networks and Distributed Systems, 12 (1), 4-29. doi:10.1504/IJCNDS.2014.057985.

Crouzet, F. (1996). *The industrial revolution in national context: Europe and the USA.* Cambridge University Press.

Deloitte (2016). Smart buildings: How IoT technology aims to add value for real estate companies. Deloitte University Press.

Deloitte (2017). How IoT Technology aims to add value for real estate companies. Retrieved from: https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/real-estate/deloitte-nl-fsi-real-estate-smart-buildings-how-iot-technology-aims-to-add-value-for-real-estate-companies.pdf

Deloitte. Sustainable Real Estate: Responsible Property Investment. Available online: https://www2. deloitte.com/lu/en/pages/sustainable-development/solutions/sustainable-real-estate.html (accessed on 4 April 2018)

Den Heijer A (2011) Managing the university campus. PhD thesis Delft University of Technology, Eburon academic book publishers, Delft.

Den Heijer, A. (2011), Managing the University Campus: Information to support real estate decisions. Doctoral Dissertation, Delft University of Technology.

Den Heijer, A. C. (2011). Managing the university campus: information to support real estate decisions. (PHD thesis), Delft University of Technology, Delft.

Den Heijer, A. C., & Tzovlas, G. (2014). The European campus heritage and challenges. Delft: Delft University of Technology.

Den Heijer, A.C. (2003) *Inleiding vastgoedmanagement*. Delft, Publikatieburo

Dewulf, G. and H. de Jonge (1994) *Toekomst van de kantorenmarkt 1994-2015*. Delft, TU Delft.

Dijkstra, M. Blockchain: Towards Disruption in the Real Estate Sector: An Exploration on the Impact of Blockchain Technology in the Real Estate Management Process. Master's Thesis, Delft University of Technology, Delft, The Netherlands, 2017.

Donovan, N.; Gray, A.; Shaw, R. (2018). The Internet of Things and the Real Estate Sector. Retrieved from: https://www.dlapiper.com/en/australia/insights/publications/2018/03/the-internet-of-things-and-the-real-estate-sector/

Du, D.; Li, A.; Zhang, L.(2014). Survey on the applications of big data in Chinese real estate enterprise. Procedia Comput. Sci. 2014, 30, 24–33.

Savills, 2017. How much is the world worth. *Residential property.* Retrieved from: https://www.savills.co.uk/blog/article/216300/residential-property/how-much-is-the-world-worth.aspx

Esfandiari, Masoud & Zaid, Suzaini & Ismail, Muhammad. (2017). Investigating the Indoor Environment Quality Parameters and Their Relationship with Occupants' Satisfaction in Office Buildings: A Review. Journal of Design and Built Environment. 17. 181-194.

Ferren, B., Entin, R., Millsaps, K., Cocosa, D., Edwards, M., Darragh, A., 2015. Proceedings of the 17th Annual Realcomm/IBcon Conference. 9-10 June 2015. Marriot Rivercenter, San Antonio, Texas.

Future Workforce Study (2018). *Networking the smart office that millennials demand*. Retrieved from: https://www.neweggbusiness.com/smartbuyer/networking/smart-office-technology-millennials/

Geltner, D., Miller, N. G., Clayton, J., & Eichholtz, P. (2001). Commercial real estate analysis and investments. (Vol. 1):Cincinnati, OH: South-western

Geraedts, Rob. (2016). FLEX 4.0, a practical instrument to assess the adaptive capacity of buildings.

Gibler, K.M. and Lindholm, A.L. (2012), "A test of corporate real estate strategies and operating decisions in support of core business strategies", Journal of Property Research, Vol. 29 No. 1, pp. 25-48

Gil-Garcia, J. R., Pardo, T. A., & Nam, T. (2015). What makes a city smart? Identifying core components and proposing an integrative and comprehensive conceptualization. Information Polity, 20(1), 61-87.

Global real estate experts (2018). *Everything you need to know about proptech for smart buildings.* Retrieved from: https://www.globalrealestateexperts.com/2018/03/everything-you-need-to-know-about-proptech-for-smart-buildings/

Gobbo Jr, Jose & Goretti Zago Nunes de Souza, Maria & Gobbo, Simone. (2016). Barriers and challenges to smart buildings concepts and technologies in Brazilian social housing projects. International Journal of Sustainable Real Estate and Construction Economics. 1. 10.1504/IJSRECE.2017.10005278.

GRESB (2017). Driving property returns through tenant resident engagement. Retrieved from: https://gresb.com/driving-property-returns-through-tenant-resident-engagement/

Henri J, Marius W, Tenner A. The influence of controllable task lighting on productivity: a field study in a factory. Appl Ergon. 2007;38:39–44. doi: 10.1016/j.apergo.2006.01.005.

Huang , Y.H. , Robertson , M.M. , & Chang , K.I. (2004). The role of environmental control on environmental satisfaction, communication, and psychological stress effects of office ergonomics training . Environment and Behavior , 36 , 617 – 637 .

Ibrahim, I., Wan Yusoff, W. Z., & Sultan Sidi, N. S. (2011). An effective management use of lecture room by space charging model. International Journal on Social Science, Economics and Art, 1 (2), 131-138.

IDC (2017). IDC Forecasts Worldwide Spending on the Internet of Thinigs to Reach $772 Billion in 2018. Retrieved from: https://www.idc.com/getdoc.jsp?containerId=prUS43295217

ING (2018). Technology in the real estate sector. Retrieved from: https://www.ing.nl/media/ING_EBZ_PropTech-Technlogy_in_the_real_estate_sector-June_2018_tcm162-148619.pdf

Inogate (no date). Yerevan State University of Architecture and construction. *Smart/Intelligent Buildings.* Retrieved from: http://www.inogate.org/documents/Lecture%20Building%20EE%203%20ENG.pdf

James Dearsly (2017) UK Proptech Map, Retrieved from: http://www.jamesdearsley.co.uk/uk-property-technology-companies-ecosystem/

Jensen P.A., (2010) "The Facilities Management Value Map: a conceptual framework", Facilities, Vol. 28 Issue: 3/4, pp.175 188, https://doi.org/10.1108/02632771011023131

Jonge, H. de, Arkesteijn, A.C., Den Heijer, A.C., Putte, H.J.M. van de, & Vries, J.C. de. (2009). Corporate real estate management. Designing a Real Estate Strategy. Delft. Delft University of Technology.

Kasim, R., Nor, H. M., Masirin, M., & Idrus, M. (2012). Assessing space utilisation for teaching and learning facilities at the higher education institution: a case study of G3 building, Universiti Tun Hussein Onn Malaysia. OIDA International Journal of Sustainable Development, 4, 125–134.

King, J. (2018). Energy impacts of smart home technologies. Retrieved from: https://aceee.org/sites/default/files/publications/researchreports/a1801.pdf

KPMG (2017). Bridging the gap. *How the real estate sector can engage with PropTech to bring the built and digital environments together. Retrieved from: https://home.kpmg/content/dam/kpmg/nz/pdf/November/proptech-bridging-the-gap.pdf*

KPMG (2018). The road to opportunity. *An annual review of the real estate industry's journey into the digital age.* Retrieved from: https://home.kpmg/content/dam/kpmg/uk/pdf/2018/09/kpmg-global-proptech-survey.pdf

KRUMM, P. J. M. M. 1999. Corporate Real Estate Management in Multinational Corporations, Nieuwegein, ARKO Publishers

Krumm, P., Dewulf, G., and Jonge, H. de (2000) What is Corporate Real Estate? in, G. Dewulf, P. Krumm, and H. de Jonge (ed.), Successful Corporate Real Estate Strategies, ARKO Publishers

Leaman, A. and Bordass, Bill (2000) Productivity in buildings: the killer variables. Workplace Comfort Forum, 1–10.

Leather , P. , Beale , D., & Sullivan , L. (2003). Noise, psychosocial stress, and their interaction in the workplace . Journal of Environmental Psychology , 23 , 213 – 222 .

Lee , Y.S. , & Brand , J.L. (2005). Effects of control over office workspace on perceptions of the work environment and work outcomes . Journal of Environmental Psychology , 25 , 323 – 333 .

Leegstandmonitor (2018). Uitkomsten per Gemeente. Retrieved from: https://public.tableau.com/profile/centraal.bureau.voor.de.statistiek#!/vizhome/DASHBOARDLEEGSTAND/Welkom

Li, C.Z.; Hong, J.; Xue, F.; Shen, G.Q.; Xu, X.; Luo, L. (2016). SWOT analysis and Internet of Things-enabled platform for prefabrication housing production in Hong Kong

Lin, T., & Evans, A. (2000). The Relationship between the Price of Land and Size of Plot When Plots Are Small. *Land Economics,76*(3), 386-394. doi:10.2307/3147036

Lindholm, A.L. (2008). A constructive study on creating core business relevant CREM strategy and performance measures. Facilities, Vol. 26 (No. 7/8), Pg. 343-358.

Lovinus, A. (2018). *Networking the smart office that millennials demand.* Retrieved from: https://www.neweggbusiness.com/smartbuyer/networking/smart-office-technology-millennials/

Macmillan, S (2006) Added value of good design, Building Research & Information, 34:3, 257-271, DOI: 10.1080/09613210600590074

Markets and markets (2017). *Smart office market worth 46.11 billion USD by 2023.* Retrieved from: https://www.marketsandmarkets.com/PressReleases/smart-connected-offices.asp

Mautz, R. (2012). Indoor positioning technologies. (Habilitation thesis), ETH Zurich, Zurich.

MIPIM (2017). The World's leading property market. Retrieved from: https://codetiburon.com/app/uploads/2017/07/mipim-2017-PropTech_landscape.jpg

Musa, M. F. B., Baharum a, Z. A., (2012) Corporate Real estate (CRE): Public Institution of Higher Learning in Malaysia. Procedia – Social and Behavioral Sciences, vol. 36, pg. 273-279

Nase, I. (2018) AR0880 Real Estate Valuations 2018/2019 Q1 Week 1.1a: Course introduction. *Investor's investment criteria.* PowerPoint Presentation slide 23.

NewsgenApps (2018). 6 VR and AR Statistics: Shaping the Future of Augmented Reality with Data. Retrieved from: https://www.newgenapps.com/blog/6-vr-and-ar-statistics-shaping-the-future-ofaugmented-reality-with-data.

Nguyen, Hong-Trang & Gray, Matthew. (2016). A Review on Green Building in Vietnam. Procedia Engineering. 142. 313-320. 10.1016/j.proeng.2016.02.053.

O. Nourse, Hugh & Roulac, Stephen & Lundstrom, Stellan. (1993). Linking Real Estate Decisions to Corporate Strategy. Journal of Real Estate Research. 8. 475-494.

O. Pickup. 2016. *How to build an office of the future.* Retrieved from: https://www.raconteur.net/business-innovation/how-to-build-an-office-of-the-future

Oligschläger, P. (2018) Smart tech developments changing the real estate industry. An interview with Wouter Truffino of Holland ConTech & PropTech. Retrieved from: https://www.compact.nl/articles/smart-tech-developments-changing-the-real-estate-industry/

Peter Mescellany (2012) The marriage of Stewart and Jesse. Retrieved from: https://www.peterme.com/archives/00000323.html

PlaceTech (2018). Trends Q2 2018. Retrieved from: https://placetech.net/wp-content/uploads/2018/07/PLACETECH-Q2-TRENDS-REPORT-FULL.pdf

Remøy, H (2010). A study on the Cause of Office Vacancy and Transformation as a Means to Cope and Prevent. Delft University Press.

RICS (2015). Breaking the circle of blame for sustainable buildings. Retrieved from https://www.joinricsineurope.eu/uploads/files/Sustainable%20buildings...BreakingtheViciousCircleofBlame.pdf

Ristaniemi, E, Lindholm, A. (2011). Added value of corporate real estate management in industrial premises.

Robertson, W. 2014. Why commercial real estate is ripe for disruption in 2015. Retrieved from: http://www.forbes.com/sites/groupthink/2014/12/16/why-commercialreal-estate-is-ripe-for-disruption-in-2015/

Roof, K, Oleru, N. (2008). "Public Health: Seattle and King County's Push for the Built Environment". J Environ Health. 75:24-27.

Rossini, P. Using expert systems and artificial intelligence for real estate forecasting. In Proceedings of the Sixth Annual Pacific-Rim Real Estate Society Conference, Sydney, Australia, 23–27 January 2000

Roulac, S. (2011) Corporate Property Strategy is Integral to Coproate Business strategy. Journal of Real estate Research. 22. 129-152.

Schwab, K. (2015). The Fourth Industrial Revolution: What It Means and How to Respond. Retrieved from: https://www.foreignaffairs.com/articles/2015-12-12/fourth-industrial-revolution.
Schwab, K (2016). The fourth industrial revolution. Retrieved from: https://luminariaz.files.wordpress.com/2017/11/the-fourth-industrial-revolution-2016-21.pdf

Serraview. (2015). Managing workplace utilization. IoT & other technologies for tracking workplace utilization. Retrieved from info.serraview.com

Shulman, D. Technology vs. Commercial Real Estate: Retail, Office and Hotel Markets Face Major Disruptions. 2014. Available online: http://www.anderson.ucla.edu/lib/email/documents/econ_letter_june_2014.pdf

Smith, M. 2015. A tech revolution in commercial real estate: Available https://www.linkedin.com/pulse/tech-revolution-commercial-real-estatematthew-smith [September, 14, 2015].

Space Management Group. (2006). Space utilisation: practice, performance and guidelines. Retrieved from smg.ac.uk

Takin, M.; Peng, J.; Sepasgozar, S.; Ebrahimi, H. A Framework for Using Advanced Visualization Tools for Residential Property Management. In Proceedings of the International Symposium on Automation and Robotics in Construction, ISARC, Taipei, Taiwan, 28 June–1 July 2017; Vilnius Gediminas Technical University, Department of Construction Economics & Property: Vilnius, Lithuania, 2017.

Ticleanu, Cosmin & Littlefair, Paul. (2015). A summary of LED lighting impacts on health. The International Journal of Sustainable Lighting. 1. 5. 10.17069/ijsl.2015.12.1.1.5.

Tilleman, R. (no date). Picture of The Edge. Retrieved from: https://www.breeam.com/case-studies/offices/the-edge-amsterdam/

TU Delft. (2016). Campus NL - Investeren in de toekomst (in opdracht van de VSNU en 14 universiteiten). Delft: TU Delft, Faculty of Architecture, Department of Management in the Built Enviroment (MBE).

Ullah, F.; Sepasgozar, S.M.E.; Wang, C. A Systematic Review of Smart Real Estate Technology: Drivers of, and Barriers to, the Use of Digital Disruptive Technologies and Online Platforms. *Sustainability* **2018**, *10*, 3142.

Ullah, Fahim & M. E. Sepasgozar, Samad & Wang, Cynthia. (2018). A Systematic Review of Smart Real Estate Technology: Drivers of, and Barriers to, the Use of Digital Disruptive Technologies and Online Platforms. Sustainability. 10. 3142. 10.3390/su10093142.

Valustrat (2019). Demand for smart offices in Dubai is growing. Retrieved from https://valustrat.com/media-relations/demand-for-smart-offices-in-dubai-is-growing-alroeya

van der Voordt, T. (2017). Facilities management and corporate real estate management: FM/CREM or FREM? *Journal of Facilities Management*, *15*(3), 244-261. DOI: 10.1108/JFM-05-2016-0018

Van der Voordt, T., & Jensen, P. A. (2017). Benchmarking of workplace performance. ERES 2017: 24th Annual Conference of the European Real Estate Society , Delft, Netherlands.

Van Est, R. & Kool, L. (2015). Werken aan de robot samenleving. Retrieved from: https://www.tno.nl/media/5754/werken_aan_de_robotsamenleving.pdf

Van Gool, P., Brounen, D., P. Jager en R.M. Weisz (2007) Onroerend goed als belegging. Groningen/Houten: Wolters Noordhoff [4th edition]
Van Meel, J., Martens, Y. & Van Ree, H. J. (2010), Planning office spaces: a practical guide for managers and designers, London, Laurence King Publishing Ltd.

Varcoe, B. (1993). Facilities systems — What of the future? Facilities, 11(10), 7-11. doi:10.1108/EUM0000000002258

Venture scanner (2016). Real estate Technology Q2 Update in 15 visuals. Retrieved from: https://www.venturescanner.com/blog/real-estate-technology-q2-update
Wagstaff, T. (1996). Productive use of IT in support of FM solutions. Facilities, 14(1/2), 43-46. doi:10.1108/02632779610108503

Wang, S.; Feeney, M.K. (2006). Determinants of information and communication technology adoption in municipalities. Am. Rev. Public Adm. 2016, 46, 292–313.

Warburton, D. The Role of Technology in the Real Estate Industry. Ph.D. Thesis, University of Cape Town, Cape Town, South Africa, 2016.

Willem G. Keeris, (2008) "A different look on risks by property investments", Journal of European Real Estate Research, Vol. 1 Issue: 2, pp.151-161,https://doi.org/10.1108/17539260810918721 Greer (1997)
Winson-Geideman, K.; Krause, A.; Lipscomb, C.A.; Evangelopoulos, N. Real Estate Analysis in the Information Age: Techniques for Big Data and Statistical Modeling; Routledge: Abingdon-on-Thames, UK, 2017. 77.
Wise, N. (2016). Outlining triple bottom line contexts in urban tourism regeneration. Cities 2016, 53, 30–34.

Zhilong, T.; Bowen, T.; Yu, H. (2015). Applications and Business Models of the Internet of Things Technology in the Real Estate Field. China Real Estate.

Zhou, L.; Shi, L.; Zhang, S. Database Construction of Real Estate Assessment Based on Big Data. In Proceedings of the 4th International Conference on Computer, Mechatronics, Control and Electronic Engineering, Hangzhou, China, 28–29 September 2015; Atlantis Press: Paris, France, 2015; pp. 92–96

Appendix I – Interview Protocol

Interviewee 1B **– Project manager Schiphol Real estate**

Introduction

- What was your role in the development of the project?
- Who initiated the development and who participated?

Smart

- What are the most important smart implementations in this building?
- What did Microsoft specifically want to change after the transformation?
- What was Schiphol's view on the smart building?
- What was Microsoft view on the smart buildings?
- Were the workers involved before and after?
- What were the expectations of the effects of the smart implementations?
- What are the results; do they match the expectations?

Added value

- What were the triggers or drivers that resulted in the 'smart' part of the building?
- What were the drivers from the side of Microsoft; the user?
- What were the (most) important drivers?
- Specifically in the process of developing The Outlook; what were the most important drivers?

Barriers

- What were the biggest barriers/discussions in regards to the smart technologies?
- How do you see the added value of a smart building; both professionally as personally?

Appendix I – Interview Protocol

Interviewee: 1A - *Continuous Improve & Innovation manager*

Company: **CBRE Global Workspace Solutions**

Role: **Daily management of The Edge Amsterdam**

Introduction

Thank the interviewee for his time and ask permission to record the interview.
Short introduction on the interviewer.
General introduction on the graduation research topic, the goals of the interview and the expectations.

- What is your function at CBRE GWS?
- What is your function in regards to The Edge office building?
- What are the main tasks of the daily management when it comes to office buildings?

Smart buildings & value

- What are the most important differences in the management of The Edge and other office buildings?
- What are, management wise, the implementations that make this building 'smart' or how it differentiates itself from non-smart assets?
- How do you perceive the added value of these smart technologies implanted in The Edge?
- Was The Edge the first 'smart' asset managed by CBRE?
- Were there any reasons or discussion when 'receiving' the asset?
- What is CBRE GWS's vision when it comes to smart assets?
- How does CBRE GWS's see the added value of a building being smart?
- As a day to day manager how much of your time is contact with tenants or users?
- How do the users and tenants perceive the value of the office being smart?

Drivers & Barriers

- When it comes to daily management, what are the most important aspects or value drivers. What is important or vital for an office to score well on?
- What are some barriers or negative points that are associated to the building being 'smart'?
- Have some of these barriers been overcome?
- How do you see the added value of a smart building; both professionally as personally?

Appendix I – Interview Protocol

Interviewee 2B - Employee at Deloitte, The Edge Amsterdam.

Questions:

- How long have you been working in this office building?
- Did you work for Deloitte *before* they settled in this office?
- Have you worked in an office that is not recognized as 'smart' before?
- What are the main difference in the way of working between this office and previous offices?
- What are the positives of this particular office?
- What are the negatives?
- How often do you use the smart implementations?
    - Find your colleague
    - Adaptive climate
    - Adaptive lighting
- How do you personally perceive the smart environment that the office offers you?
- Did this office building change your perception of Deloitte?
    - Did this office help you to stay or come to Deloitte?
- Often these smart environments are said to improve concentration, productivity and health; Do you feel that this is true?
- Smart offices are also said to be developed to support an office workstyle where interaction is stimulated; do you feel that this office supports you better?
- What is your overall perception on this office as a working environment, would you go back to a 'regular' office, or would you rather stay in a 'smart' office?

Appendix I – Interview Protocol

Interviewee 1C – IoT Engineer EDGE Technology

Research questions:

What is your role within EDGE Technologies?

What buildings have you been closely involved with; The Edge Olympic?

What are common application when it comes to smart buildings?

What applications are 'found' in the The Edge and/or in The Edge Olympic

What are the differences between The Edge and The Edge Olympic in terms of smart applications?

- Lessons learned from The Edge?

What was the main driver for the smart side of The Edge Olympic?

What are the current trends and conviction when it comes to smart applications?

- Which ones are here to stay, which ones are less useful and which ones will be useful?

Wherein lies the added value of smart technology when it comes to office buildings?

What is your own perspective when it comes to smart technology in offices?

What are the drivers that are most influences by the smart technology (according to list)?

What are the most impactful/useful applications as of now (according to list)?

Case specific questions:

The Edge

- Unique smart applications in The Edge?
- Added value of the smart part of the office in the edge? Mostly branding?

The Edge Olympic

- Unique smart applications in The Edge Olympic?
- Where is the focus put on and why?
- Added value of the smart part of the office in the edge? Mostly health?
- Is there proof that the smart applications work as expected?
- What are the lessons learned in terms of smart technology?
- What are the barriers currently?
- What are the main drivers that drive the implementations of smart technology?
- How to deal with technological obsolescence?

Appendix I – Interview Protocol

Interviewee 2C – OVG Real estate Development manager

EDGE/OVG question
What are the general drivers or triggers when it comes to the development strategy of EDGE/OVG – see list?

When developing a business case, what is the most important?

The Edge
What was your role in the development of The Edge?

What were the drivers or the triggers for developing The Edge as a smart office?

- Duurzaamheid was toen al 'geaccepteerd' maar smart was vrij nieuw; waarom werd deze stap gezet?

The Edge Olympic
What was your role in the development of The Edge Olympic?

What were the drivers or the triggers for developing The Edge Olympic as a smart office?

- What convictions or 'proof' was there that a smart office was the right choice?

What were the main difference in the development of The Edge and The Edge Olympic?

- What had to change? What had to stay the same? What is new?

Trends
Do you see a shift towards value instead of upfront cost?

Do you see a trend that focusses more on the user?

How do you see the 3 – 30 – 300 rule of thumb when it comes to operating expenses?

Financial
How does smart add value to office buildings?

- Higher market value? Better branding for leasing?

What were some of the financial analysis done before the development of smart buildings?

- Does this differ compared to 'normal' buildings?

How does the smart technology influence the feasibility?

- Are the returns better or worse?

Where does the value of smart technology develop itself?

In the end, is implementing smart technology worth it from a purely financial perspective?

Appendix I – Interview Protocol

Interviewee 3C – Employee at EDGE Olympic/OVG Real Estate

Use of smart application

Do you work full-time in this office, 5 days a week?

Have you worked in The Edge also?

Have you ever working in a non-smart office?

What makes the Edge Olympic a smart building for you?

Biggest difference between non-smart and smart?

- Upside but also downside

Biggest difference between The Edge and The Edge Olympic?

- Upside but also downside?

What is important for you when it comes to an office?

- Able to control environment? Indoor air quality?

Does your preference goes to an office with smart technology?

Appendix I – Interview protocol

Interviewee 4C – Fund manager CHOP Venture

Questions

Introduction

- What is your role/position within Nuveen?
- (How) Are you involved with smart offices or smart buildings?

Added value and drivers

- What are the general investment drivers when assessing an investment; what are the most important aspects? (growth potential, sustainability, potential income etc.)
- What are the reasons for investing in smart office; for example when acquiring The Edge Olympic? (branding reasons for example?)

Smart technology

- How do you perceive the value of the technology that makes it a smart office; for example the sensors that collect building data or the Internet of Things network?
- Where were the expectations of the acquired smart asset in terms of investment performance?

Results

- What are the general results of the acquired smart assets in terms of investment performance; if possible compared to other non-smart assets?

Appendix I – Interview Protocol

Interviewee 1D – Bouwinvest, Asset manager

Questions:

- Wat zijn de focuspunten van BouwInvest op het gebied van vastgoedinvesteringen?
- Wat is uw eigen rol binnen BouwInvest?
- Wat is het risicoprofiel van BouwInvest?
- Met welke tijdsperspectief investeert BouwInvest in hun kantoren/vastgoed?
- Wat zijn de veel voorkomende ‘knelpunten’ die een investering niet aantrekkelijk maken?

Value

- Wat zijn belangrijke waardes voor BouwInvest?

Smart

- Heeft bouwinvest smart gebouwen in hun portefeuille?
- Hoe ziet u de meerwaarde van smart gebouwen op het gebied van investeringwaarde?
- Hoe ziet BouwInvest de meerwaarde van smart gebouwen?
- Wat zijn de resultaten van enige smart gebouwen in jullie bezit?
- Wat zijn de knelpunten?
- Wat zijn juist de positieve punten?

Appendix II – Case study Protocol

Image of the building

NAME OF THE CASE

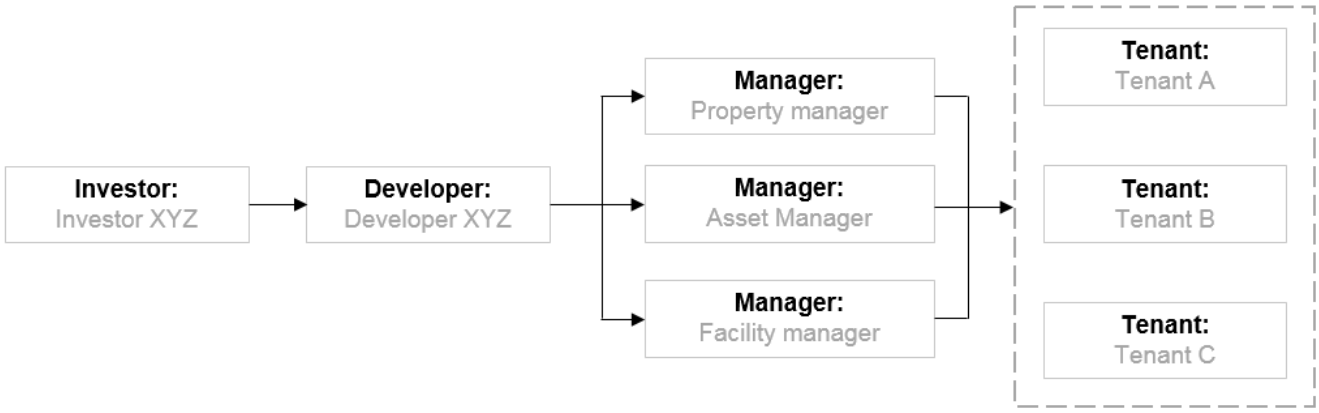
Building description:

Short description on the building, how it is branded etc.

Key facts:

Location	
Address	
City	
Physical	
Size:	
Delivery date:	
Development type:	
Building type:	
Sustainability	
Energy label:	
BREAAM rating:	
WELL rating:	
Other:	

Stakeholders:



What makes it smart:

Explanation of the implementations that have been used to create the smart building.

Investment	Management	Use

Drivers

Value bearing attributes in relation to the smart building.

Investment	Management	Use

Expectations and results:

Explanation on the drivers that motivated the stakeholders to create a smart building.

Investment	Management	Use

Barriers:

Value bearing attributes in relation to the smart building.

Investment	Management	Use

Appendix III – Expert-panel questions

Usefulness of smart application *

Score each smart application on the left according to their perceived usefulness. 9 being the application with the highest usefulness and 1 the lowest. Applications can share a position.

	9	8	7	6	5	4	3	2	1
Climate adapting to actual use	○	○	○	○	○	○	○	○	○
Lighting adapting to actual use	○	○	○	○	○	○	○	○	○
Colleague localisation (through phone)	○	○	○	○	○	○	○	○	○
Workplace finder (through phone)	○	○	○	○	○	○	○	○	○
Room & locker booking (through phone)	○	○	○	○	○	○	○	○	○
Controllable climate (through phone)	○	○	○	○	○	○	○	○	○
Controllable lights (through phone)	○	○	○	○	○	○	○	○	○
Maintenance notifications in devices	○	○	○	○	○	○	○	○	○
Maintenance adapting to actual use	○	○	○	○	○	○	○	○	○

Appendix III – Expert panel questions

Importance of value drivers

	8	7	6	5	4	3	2	1
Sustainability (in terms of energy efficiency)	○	○	○	○	○	○	○	○
Productivity (productivity of users)	○	○	○	○	○	○	○	○
Satisfaction (satisfaction of tenant or users)	○	○	○	○	○	○	○	○
Risk (related to marketability, liquidity etc.)	○	○	○	○	○	○	○	○
Health (well-being of users)	○	○	○	○	○	○	○	○
Culture (culture amonst users)	○	○	○	○	○	○	○	○
Branding (public/professional perception)	○	○	○	○	○	○	○	○
Adaptability (in terms of building performance)	○	○	○	○	○	○	○	○

What is an association you see, or expect, between values and applications.

Use the value drivers and smart applications found above. Multiple applications can be choosen per value. An example can be: Satisfaction is improved by controllable lighting and temperature.

	inability	Health	Productivity	Culture	Branding	Risk	Satisfaction	Adaptab
Adaptive climate	○	○	○	○	○	○	○	○
Adaptive lighting	○	○	○	○	○	○	○	○
Adaptive maintenance	○	○	○	○	○	○	○	○
Colleague localisation	○	○	○	○	○	○	○	○
Workplace finder	○	○	○	○	○	○	○	○
Room & locker booking	○	○	○	○	○	○	○	○
Controllable temperature	○	○	○	○	○	○	○	○
Controllable lights	○	○	○	○	○	○	○	○
Maintenance notifications	○	○	○	○	○	○	○	○

Appendix IV – PropTech categories with sources

James Dearsley UK	SBS (A. Baum)	Venture Scanner
Big Data	Smart buildings	Property management
Software Providers	ConTech	Construction management
Lending P2P	RE Fintech	Facility management
News	Shared economy	Portfolio management
Property Management	Information	Home services
VR and AR	Managment	Commercial RE Serach
IoT		Long-term rentals
Online agents		Short term rentals
Payment		Real estate agent tools
Artificial Intelligence		Indoor Mapping
		IoT Home

ING (2018)	JLL Asia	KPMG (2018)/Holland C&T
Rental platforms	Project Development	Digitizing processes
Space as a service	Property Management	Flexible workspaces
Sales platforms	Brokerage and leasing	Healthy workplace
Administrative management	Investment & Financing	Innovative Construction
Smart buildings		Internet of Things
		Funding
		Sustainability
		VR & 3D
		Platforms

CB Insights	MIPIM (2017)
Listing and Search	Smart buildings
Leasing	Smart city sustainability
Marketplace	Market place
Investment	Crowdfunding
Property information	Contech
Data, valuation & analytics	3D/VR
Management	Data & Reserach

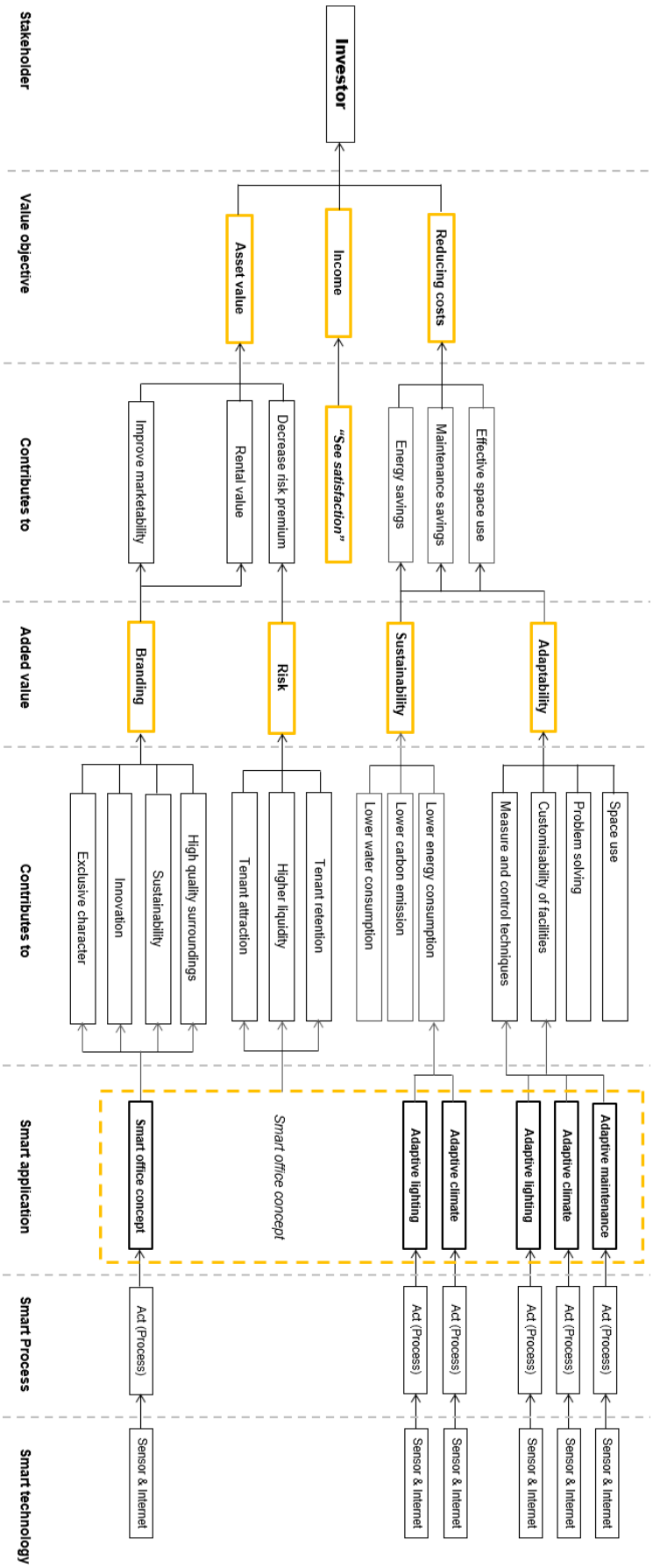
Appendix V – Added Values overview with sources

Added Value point	Macmillan (2006)	Nourse & Roulac (1993)	De Jonge (1996)	Lindholm (2006)
Health	Social			
Satisfaction		Promote HR objectives		Increase employee satisfaction
Cost reduction	Use	Occupancy cost minimization	Cost reduction	Reduce costs
Productivity		Facility and control production, operations & service delivery	Increase productivity	Increase productivity
Flexibility		Flexibility	Increase flexibility	Increase flexibility
Sustainability	Environmental			
Culture	Cultural	Facility managerial process and knowledge work	Changing the culture	
Innovation				Increase innovation
Branding	Image;	Promote marketing message	PR and marketing	Promote marketing and sales
Asset value	Exchange	Promote sales & Selling process	Increase of value	Increase value of assets
Risk			Risk reduction	

Added Value point	Jensen (2010)	Ristaniemi (2011)	Roulac (2001)	Lindholm (2008)
Health		Promote employee health & safety		
Satisfaction	Satisfaction	Improve employee satisfaction	Promote HR objective	
Cost reduction	Cost	Cost control	Minimize occupancy costs	Decreasing costs
Productivity	Productivity	Enhance productivity	Facilitate production, operation and service delivery	Increase productivity
Flexibility	Adaptability		Increase flexibility	Increase flexibility
Sustainability	Environmental	Reduce environmental impact		
Culture	Culture	Support interaction	Facilitate management process & knowledge work	Participating in strategic process
Innovation				Increase innovation
Branding		Realise company brand	Promote marketing message, sale & selling process	Promoting marketing & sales
Asset value	Economic Social; Spatial	Ensure social and economic sustainability.	Capture the real estate value creation of business	Increase value of assets
Risk	Reliability	Risk control		

Added Value point	Jensen & Van der Voordt (2017)	CoreNet 2016 survey	Den Heijer (2012)
Health	Health & Safety	Enhancing employee well-being	Improving quality of place
Satisfaction	Satisfaction	Enhancing employee satisfaction	Increasing user satisfaction
Cost reduction	Cost	Reducing real estate costs	Decreasing costs
Productivity	Productivity	Improve employee efficiency and productivity	
Flexibility	Adaptability	Enabling flexibility	Increase flexibility
Sustainability	Sustainability	Supporting environmental sustainability	Reducing footprint
Culture	Culture		Supporting culture; stimulating collaboration
Innovation	Innovation & Creativity	Encouraging and supporting employee innovation and creativity	Stimulating innovation
Branding	Image	Promoting marketing, sales and organisational brand	Supporting image
Asset value	Value of Assets	Increasing the value of the organisation's real estate assets.	Increasing real estate value
Risk	Risk		Controlling risk

Appendix VI – Smart Value Maps



Appendix VII – Smart Value Map

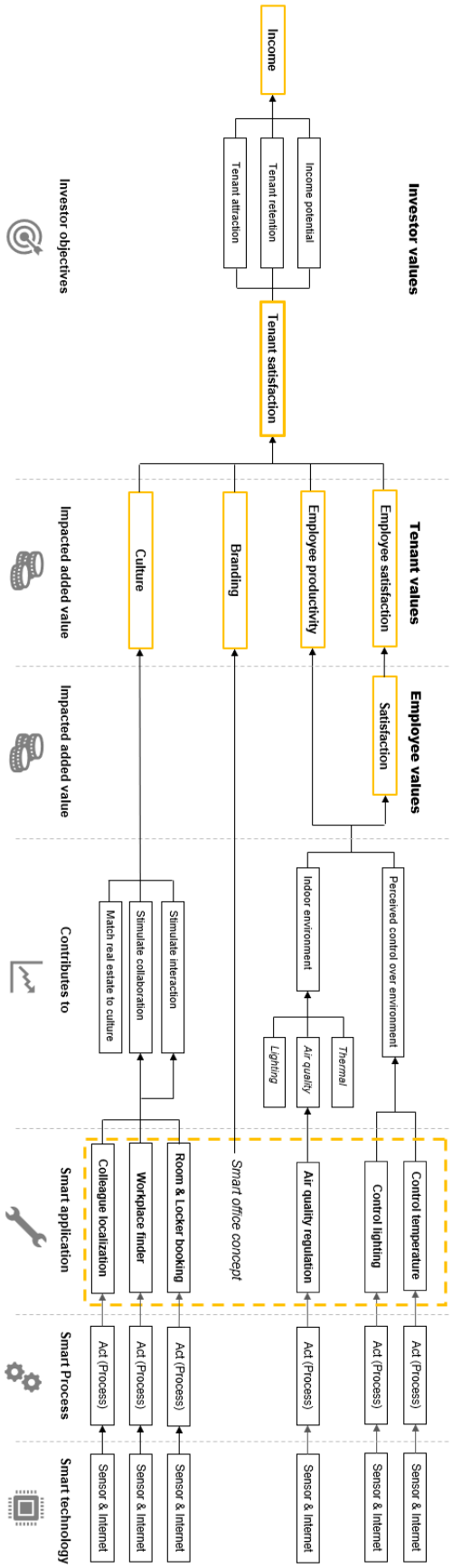


Figure 103. Connecting smart technology to satisfaction. Own ill. (2019)