university of groningen / faculty of spatial sciences

Smart office, happy tenants?

Research on the added value of smart offices according to tenants

Student name: Michel van 't Klaphek
Student number: S4722558
Date: 21-2-2023

Master's Thesis Economic Geography
University of Groningen
Faculty of Spatial Sciences
Course code: GEMTHEG
Supervisor: dr. V.A. Venhorst

Picture on front: EDGE (n.d.)

Abstract

This thesis investigates the emergence of smart offices in The Netherlands and their added value according to pioneering tenants. Smart offices are defined as buildings with integrated aspects of enterprise, control, materials, and construction, designed to be adaptable for users and property managers (Buckman et al., 2014, p. 96). In academic literature, the benefits of such properties are presumed: the tenant perspective is not prevalent. This study uses a qualitative research approach that includes a review of scientific literature and journalistic sources, and semi-structured interviews with smart office tenants in The Netherlands.

The findings suggest that smart office features add value for tenants, albeit to varying degrees. Certain features, such as the possibility to regulate heating conditions and book meeting rooms, are more popular than others, such as virtually navigating the office and finding co-workers through a smartphone app. Additionally, some tenants use their current office for marketing and branding reasons and have downsized their overall office space by implementing new more efficient ways of working, which are made possible by smart office features.

However, smart offices also come with certain challenges. Interviewed tenants reported difficulties in processing and acting upon the vast amounts of information their buildings register. Also, not all employees interact and/or utilize smart features accordingly, causing a suboptimal office experience.

Overall, the study concludes that smart offices offer benefits for tenants, but it is difficult to evaluate their full impact given the lack of thorough evaluation. Not all smart office tenants have properly evaluated their current accommodation. This indicates that the perceived added value of smart offices is not always based on statistical data, but also on personal sentiments.

Table of contents

Chapter 1: Introduction

The office market seems to be changing. According to Deloitte (Wellener, Michalik, Ashton Manolian & James, 2018) "Technology appears to be changing the most fundamental truth about commercial real estate, namely that the value for a property is mainly based on its location". Instead, the consulting company argues that technology is increasingly being implemented to upgrade existing and to-be constructed real estate. These processes have led to the introduction of 'smart buildings', including 'smart offices'. The first so-called smart office in The Netherlands, The Edge in Amsterdam, was taken into use in 2015, hosts several multinationals (like Deloitte and Salesforce) and was featured in international media outlets including Bloomberg, CNN, and MSNBC.

Smart offices can be defined as digitally connected properties with an office destination that combine optimized building and operational automation with intelligent space management to enhance the user experience, increase productivity, reduce costs, enhance sustainability, and mitigate physical and cybersecurity risks (Oudot, 2019, p. 12). As can be derived from this broad definition, there are two significant pillars in the concept of smart buildings. First, there is the physical structure of a building. The construction component includes factors like the presence of sensors registering and operating occupancy, energy usage and lightning conditions. Second, there is a digital component. This digital layer includes factors as cloud storage, cybersecurity measures, recognition techniques (e.g., biometric access for employees) and Internet of Things-concepts (IoT) in the broadest sense of the word, like machine learning platforms and/or artificial intelligence solutions. Since IoT can be coined as a catch-all-term, in the sense of smart offices, this concept relates to the given that an ever-growing number of devices and appliances are able to communicate with each other because they have an internet connection (Salosin, Gamayunova & Mottaeva, 2020, p. 4).

Smart offices offer several 'smart benefits' over conventional office space, according to literature. Common features include the possibility of self-adjusting lightning based on the availability of natural daylight, personalized heat-settings according to the preferences of an employee, a smartphone app to book meeting rooms and automated parking systems that detects employees and/or clients. Cheng, Jiang & Xie (2018) summarize that smart buildings should aim to connect humans, provide better control of facilities, support ways to collaborate digitally and enable owners to conserve resources like floor space, energy, water, and employees.

Scientific relevance

Even though the concept of smart offices is relatively new, there is an academic foundation. This literature has defined smart office environments by focusing primarily on technical aspects. For example, Mohammadshirazi, Kalkhorani, Humes, Speno, Rike, Ramnath & Clark (2022) focus on the prediction of airborne pollutant concentrations in smart offices by using pollutant sensors and machine learning. Ruiz-Zafra, Benghazi & Noguera (2022) research the possibilities of integrating IoT-concepts into early stages of building design and Tang, Fan, Zeng & Feng made a data-driven predictive model for commercial real estate that estimates demand for power (electricity). To point out one last example, Aussat, Rosmanis & Keshav (2022) focus on power-efficient and self-calibrating smart lightning systems which adhere to modern IoT based sensor monitoring systems.

The tenants – the company that rents the smart office – point of view is not present in literature. The presumed benefits of smart office solutions, such as an increase in worker productivity and higher

(energy) efficiency, are mostly taken for granted. This scientific gap is noteworthy, since there is a strong empirical research base that shows that the motivations and experiences for tenants to (not) rent office space vary greatly (Kim & De Dear, 2013).

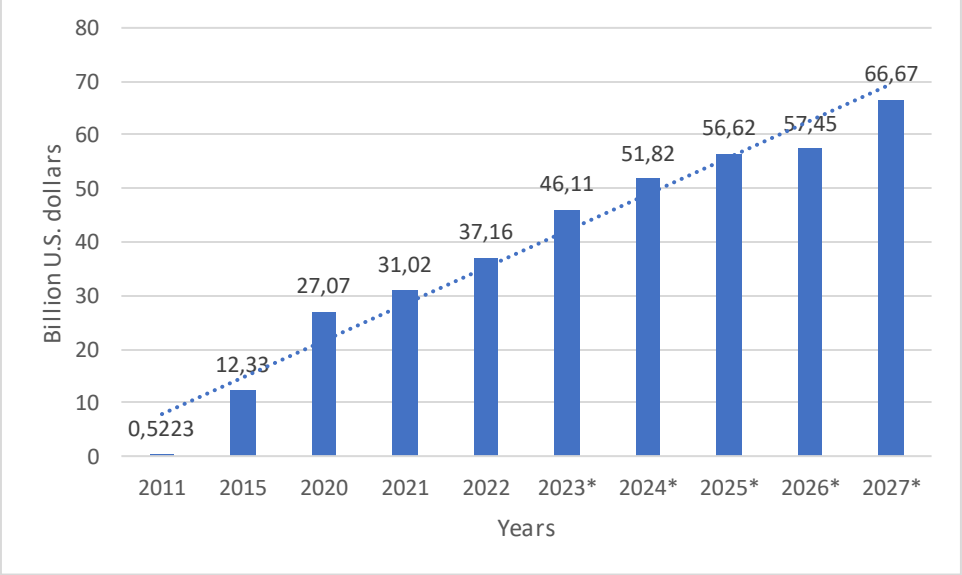
Moreover, the current literature does not elaborate on the factors and/or characteristics (such as location and energy label) that determine the attractiveness of smart offices for tenants and end-users. Empirical studies regarding this topic are scarce - for an example see Aksoy and Sema Uzunoglu (2020) - and most studies assume smart offices hold certain advantages over 'normal' offices by referring to relatively old studies, such as a highly cited paper from Le Gal, Martin and Durand (2000). Their survey-based research concludes that the main advantage of smart buildings lies in the given that end-users are flexible regarding their workplace thanks to then new innovations, as the availability of stable broadband internet connections and laptops.

Lastly, the current literature pays little to no attention to changing demands from tenants and end-users, such as the shift to hybrid working arrangements, a tight labour market an increasing focus on sustainability. Since more and more service-sector employers in Western economies are faced with an increasingly tight job market, real estate consultancies Cushman & Wakefield (2022, p. 7), JLL (2020, p. 3) and CBRE (2022) argue that firms can use smart offices and hybrid working arrangements to attract employees in 'the war on talent'.

Societal relevance

The global smart office market size is expected to reach a 66-*billion*-dollar valuation by 2027, according to estimates by market research firm Mordor Intelligence (2022). In 2021, the global market was valued at 31 *billion* dollars, coming from a mere 520-*million*-dollar valuation in 2011, as seen in figure 1.1. It is estimated that the smart office market will have a compound annual growth rate (CAGR) of 13.6 percent over the period of 2021 – 2026, contrasting sharply with the 0.9 percent CAGR of the total commercial real estate industry (Savills, 2021).

Figure 1.1: (Expected) size of global smart office market



*: forecasts of global smart office market size
Source: Mordor Intelligence (2022)

Given that commercial real estate – which can be characterized as property used exclusively for business-related purposes - is the biggest global asset class, with a total valuation of 33.9 *trillion* dollars in 2021 (Savills, 2021), smart offices can still be regarded as a relatively little submarket. This indicates the societal potential and growth path of these buildings for developers, construction companies, possible tenants, and the broader PropTech-industry (a combination of property and technology).

Next to (an expected) market growth, the scarce literature surrounding smart offices suggests these properties provide multiple benefits to tenants. Presumed benefits include an increase in synergy and collaboration amongst employees (resulting in an increase in worker productivity), better mitigation of (cybersecurity) risks, and a decrease in facility and energy costs. Based on conventional research on location behaviour of firms, tenants make rational decisions by taking all the pros and cons of office buildings into account and the decision to (not) rent an office property is mainly analytically driven (Holden, 2008).

Since the concept of smart buildings was first coined by suppliers of offices out of financial reasons and empirical underpinnings of these benefits are scarce (Van den Berg, 2019), the question remains whether this analytical decision process also applies to tenants of smart offices. In other words: what expectations did tenants of smart offices have before renting their office? And did these expectations match the reality of working in a smart property?

Research questions

This research tries to fill the current knowledge gap in smart office research by focusing on the tenants (the companies that hire smart office space). Therefore, the main question of this thesis is:

To what extent do smart offices add value for tenants?

To answer this main question, several sub questions must be answered. The sub questions are:

1. *What are the characteristics of smart offices in The Netherlands?*

According to tenants, when can an office be labelled as smart? How do you measure smartness? And where are these properties located? Given the relative infancy of the smart office concept, the research starts off by providing an overview of the Dutch smart office market. This sub question will be used to determine which characteristics make an office smart.

2. *What are the expectations of smart office tenants before renting a smart office in The Netherlands?*

Based on literature, it is presumed that smart offices offer tenants several benefits compared to conventional properties. Possible benefits include an increase in employee productivity and a decrease in facility costs. Were these presumed benefits the main drivers behind the decision to rent a smart office, or were other motivations involved? By interviewing current tenants, this sub question investigates the rationales of companies to rent smart office space.

3. *Theory versus reality: to what extent do the expectations of smart offices live up to the reality?*

Based on the previous sub question, this question examines whether the presumed benefits of smart offices are being experienced in practice? In other words: do the presumed benefits of smart offices live up to the reality?

Chapter 2: Theoretical framework

The predecessor of smart buildings: intelligent buildings

The term "Intelligent Building" was first coined in 1981 by the United Technology Building Systems Corporation (UTBS), way before the term "smart building" rose to prominence. Back then, this was mostly used as a conceptual framework to describe the possible, technologically driven future of non-domestic buildings, such as offices and warehouses. The UTBS described intelligent buildings as "buildings that provide a responsive, effective and supportive environment within which the organization can achieve its business objectives."

An academic definition of intelligent buildings was formulated by Powell (1990). In his widely cited paper, he defines intelligent buildings as: "An automated building which totally controls its own environment. This relates to the technical control of heating and air conditioning, lightning, security, fire protection, telecommunication, data services and other building operations" (Powell, 1990, p. 84). In their 2005 review of research on automated, intelligent, and smart buildings (which will be elaborated upon un further), Wong, Li & Wang show that most early definitions focus on minimizing human interaction with the non-domestic building. In general, intelligence within buildings referred to the integration of systems regarding building operation, such as the integration of a building management system (BMS) and lightning systems (Carlini, 1988; Holden 2008).

Since this first (broad) conceptualization of intelligent buildings, the definition has been reformulated by multiple scholars. More features were incorporated in the concept, especially in terms of user-interaction (Buckman, Mayfield, Beck, 2014, p. 94). That is, the ways in which the end-users (like office workers) interact with a building, such as picking the optimal light level and temperature for maximum productivity. Also, the effect of these interactions has been incorporated. For example, in 1995, the International Council for Research and Innovation in Building and Construction (CIB) defined intelligent buildings as: "Forms of dynamic and responsive architecture that provide occupants with productive, cost effective and environmentally approved conditions through continuous interaction." In this definition, the CIB states four basic characteristics of intelligent buildings: places (fabric, structure, or facilities), processes (automation, control, and systems), people (services and users) and management (maintenance and performance).

This (still rather vague) definition contrasts with later definitions, as shown by Clements-Croome (2009). In his critical review on the conceptualization (issues) regarding intelligent buildings, he shows that many (then) modern buildings were not adhering to the traditional definition of intelligent buildings, as phrased by the CIB and earlier sources. Instead, Clements-Croome observed that (then) modern buildings pushed the traditional definitions of intelligent buildings to their limits of acceptance and that the concept had to be revisited. As an alternative, he developed the following definition (Clements-Croome, 2011, p. 70): "An intelligent building is one that is responsive to the requirements of occupants, organizations, and society. It is sustainable in terms of energy and water consumptions besides being lowly polluting in terms of emissions and waste; healthy for the people working or living within it; and functional according to the user needs."

As the definitions expanded, the term intelligent building lost both meaning and focus, as shown by Buckman et al. (2014, p. 96) in their literature review on the topic. Obviously, this is contrary to the initial goals of these (re)conceptualizations. To regain focus and provide clarity to the concept of

intelligent buildings, several scholars came up with alternatives. Among them are Everett (2008) and Brooks (2011). The former mainly paid attention to the technical aspects of intelligent buildings while Brooks argues that intelligent buildings are equivalent to the BMS within them. Other scholars, such as Katz & Skopek (2009) and Wong & Li (2009), disagree with Brooks and argue that the BMS system is usually seen as 'just' one of the integrated tools within a building, and not the entire system itself. Yang & Peng (2011, p. 70) recognize the need to make "better buildings for the earth and people", but state that the implementation of intelligent building concepts is being constrained by a lack of understanding by scholars and industrialists alike. Yang & Peng (2011, pp. 75-76) therefore conclude that future developments in the built environment can only arise if the underlying base which the research is based on, remains constant instead of constantly changing. A clear, uniform definition will also prevent further fragmentation of terminology in the built environment (where intelligent and smart buildings where and still are often used synonymous).

To summarize: the definition of intelligent buildings has been reconceptualized on multiple occasions. However, the lack of a clear definition resulted in an unclear objective and end-goal. Accordingly, the methods to achieve this end-goal also remained rather vague. Yang & Peng (2011, p. 73) compare this situation to the confusion and ambiguity around other broadly defined concepts, such as sustainability and the definition of zero carbon homes.

From intelligent to smart

In the 2000's and 2010's, the term smart buildings gained popularity while intelligent buildings were mentioned less frequently. Initially, this concept was mainly used in business/industrial reports (see for example The Climate Group, 2008; and Powell, 2010). According to Buckman et al. (2014, p. 97), it was mainly industrial forces that pushed this concept because of financial reasons. The concept was mainly developed "to sell or rent more floor area in commercial and/or office buildings" (Buckman et al., 2014, p. 97).

During this period, the term smart building also started appearing in academic works (as in Cook & Das, 2007; Kleissl & Agarwal, 2010; and Cook & Das, 2007). As noted by Buckman et al. (2014, p. 97), this shift in terminology demonstrates the given that the terminology of that time (intelligent buildings) was not sufficient to describe and analyse the "new wave" of (non-domestic) properties that started appearing. Furthermore, the terms intelligent building and smart buildings were being used interchangeably, which further stressed the need for a clarification in terminology.

Definition of smart buildings

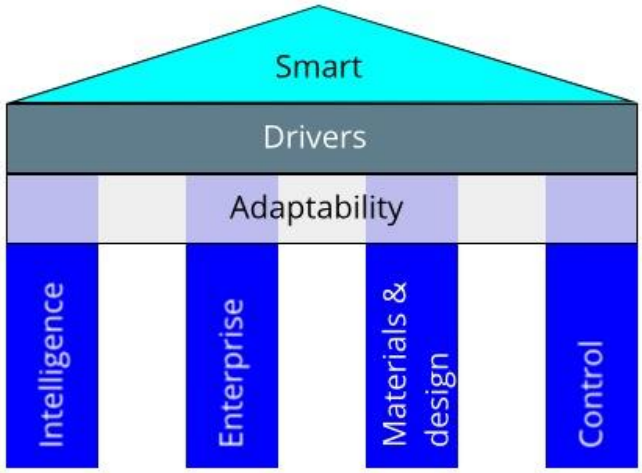
Buckman et al. (2014) try to provide this clarity by making a clear distinguishment between intelligent and smart buildings. According to them "Smart buildings are buildings which integrate and account for intelligence, enterprise, control, and materials and construction as an entire building system, with adaptability, reactivity, at the core, to meet the drivers for building progression: energy and efficiency, longevity, and comfort and satisfaction. The increased amount of information available from this wider range of sources will allow these systems to become adaptable and enable a smart building to prepare itself for context and change over all timescales." (Buckman et al., 2014, p. 96).

In their definition, they draw upon research from Drewer & Gann (1994) and Smith (2002). These scholars demonstrate that the progression of buildings throughout the centuries has leaned upon four pillars: **intelligence** (the process of gathering and responding to building operation information);

control (interaction between the occupants and the building); **materials and design** (the physical form of the building); and **enterprise** (how the building collects information and uses this to improve occupant performance).

Buckman et al. (2014, p. 96) state that with smart buildings, these four methods are developed alongside each other, using information from one step in the operation of another pillar, see figure 2.1. This contrasts with the development progress of intelligent buildings, where the pillars are mostly developed independently of one another.

Figure 2.1: Features of a smart building



Source: Adapted from Buckman et al, 2014, p. 99

The pillars of smart buildings

1. Adaptability

"Adaptability is at the heart of a smart building", according to Buckman et al. (2014, p. 99). This pillar is described as the main differentiation between previous generations and smart buildings. In an ideal situation, the adaptability pillar can utilize information gathered internally and externally from a range of sources, such as smart sensors, to prepare the property for an event *before* it takes place. An example is reacting to changing weather conditions by adjusting heating and lightning settings based on the preference of the occupant (office worker) without the person having to adjust these conditions themselves. A high degree of adaptability makes sure the smart building is *adaptive* (by preventing situations), instead of *reactive* (like intelligent buildings).

Al Dakheel et al. (2020) adds to the work of Buckman et al. (2014) by distinguishing the several timescales on which adaptability operates in smart buildings. In total, there are three timescales: short, medium and long term. Examples of short-term adaptability include the ability of a smart building to facilitate optimal building space use by integration of timetabling - such as aligning calendars and activities of colleagues – and the ability of a property to adopt to the (expected) amount of people in a room. In the medium term, adaptability within a smart building should be able to monitor and predict routines from not only an occupant point of view, but also from a facility perspective. Examples include the given that a smart building can monitor stock inventories of a certain product and maintaining pre-defined levels from the occupant (such as coffee beans). On the long term, adaptability will mainly evolve around the materials and physical design of the building to

withstand external conditions, such as the effects of climate change and the adaptation to changes in occupancy and uses.

2. Control

Another pillar of smart buildings relates to the amount of control occupants have over the facility and its conditions, such as lightning and heating (Bruckman et al., 2014). As detailed by several scholars (like Masoso & Grobler, 2010; and Fotios & Cheal, 2010), this is one of the most debated aspects regarding modern property design. This is because if a building is designed, implemented, and used 'correctly', primarily human-controlled buildings can perform accordingly, as can buildings which are fully automated.

However, both forms of smart building control show intrinsic risks which can result in less efficient property performance. On the one hand, human-controlled buildings rely on the assumption that the occupant will use the building in the way it was designed, while automated buildings are designed according to (more theoretical) conditions, occupancies and uses. Therefore, both types of control in smart buildings are susceptible to performance inefficiencies.

In smart buildings, users should be in control of the (indoor) environment. As shown by multiple studies (Kwon et al., 2019), there is not one single condition set that is suitable for all occupants. In fact, research shows that if users have some form of ownership over the controlled conditions in their workplace, this results in benefits, such as more comfort and ultimately, more occupant satisfaction. For example, Kwon et al. (2019) associated higher controllability with higher satisfaction in terms of thermal and visual comfort in office environments.

However, a buildings degree of control is far from one dimensional. Although the research is not based on occupants of smart buildings, in their empirical study regarding office user preferences, Appel-Meulenbroek, Kemperman, Van de Water, Weijs-Perrée & Verhaegh (2022) highlights several likes and frustrations. See table 2.1 for a summary of their findings regarding the controls of office environments.

Table 2.1: Office workers preferences and frustrations

Preferences	**Frustrations**
Predictable 'default' states for climate zoning and lightning systems, where the need for intervening is relatively low.	The inability to intervene in the physical settings of the office environment.
If conditions alter, office workers like to be able to quickly make corrections or interventions to get to the 'default' state	The situation wherein office workers are potentially exposed and affected by condition changes which they cannot alter.
Office workers like to 'forget' about the controls of their office environment. In other words: the default state should be good enough that office workers are not concerned about climate and lightning conditions.	Office workers don't like to work in unfamiliar settings (climate and lightning conditions) that require much intervention to make the environment habitable.

Source: Appel-Meulenbroek et al. (2022, pp. 5-9).

Earlier research also stressed the importance for office workers to be in environments that can be easily controlled (Leaman, 2000; Liu et al., 2008). Building upon this historical work, Buckman et al. (2014, p. 101) state that smart buildings should reconcile both human control and automation

techniques to provide occupants with information so that they can adapt to the building, just like the building should be adapting to their wishes. In this characterization lies the main utility of control in smart buildings: the degree of control should ultimately serve the occupant.

3. Enterprise

In the context of smart offices, enterprise consists of a combination of hardware and/or software that are used to overcome fragmented, non-compatible, non-proprietary legacy systems so that the building operation can be optimized towards its function, such as being an office building (Buckman et al., 2014, p. 102). The enterprise pillar of smart offices comprises the methods through which the specific usage information of a building is collected and the way in which it is easily comprehensible for end-users. Possible elements that comprise the enterprise pillar are business integration, enterprise management and dashboard.

An obvious example is that office workers can request a meeting room through the corresponding office smartphone-app, which is then being arranged by the enterprise system in place. Upon entering the (specific zone of) the building, the occupants will be informed about where the meeting zone is exactly located, contrary to the process of booking a room in advance and walking to the pre-defined meeting room, as in intelligent buildings.

To a large extent, the effectiveness of enterprise within the smart office concept is reliant on the quality of real-time information (gathered through all sorts of datapoints, such as sensors) about the (usage and occupancy) of the property. High-quality real-time information can increase the operation efficiency of firms, as shown by Singer (2010) and Powell (2010).

As noted by Buckman et al. (2014, p. 103), by using high-quality real-time data (about the usage of the building and occupant preferences), the operation of a building can be adapted beforehand contrary to reacted to afterwards. This will increase the comfort of office workers and reduce the property's energy consumption. This contrasts to the traditional method of heating a room once it is considered cold. Within a smart building, the enterprise system connects the hard- and software mechanics and thus being able to adapt to changing user preferences and needs.

4. Materials and construction

According to Buckman et al. (2014, p. 103), the final and last pillar of smart buildings consists of the physical materials and construction of the property. Therefore, this dimension represents the built form which is used to house all the smart functions within it. Ideally, it is constructed in such a way that the internal structure reflects the dynamic nature of a smart building by focusing on adaptability.

This matter of adaptability can focus on the direct wishes of the occupant, and to environmental (climatic) forecasts. Firstly, the internal structure of a smart building could be adapted to climate forecasts through the ability to replace features in the future to account for dynamic conditions. Secondly, the materials and construction dimension of smart buildings can be used for the preferences of occupants. For example, based on occupancy data available from the enterprise system (pillar three), a smart building should be able to close zones during periods of known low user activity.

Conclusion

To conclude: "Smart buildings are intelligent buildings with integrated aspects of enterprise, control and materials and construction, implemented both individually and as a system to be adaptable (Buckman et al., 2014, p. 104). In this definition, it is stated that smart buildings are occupant-based (instead of being technologically focused, such as its predecessor) and strive to create active participants by incorporating feedback both to and from occupants about their building use. In addition to this, smart buildings provide methods for inherent control through integrated enterprise and intelligent systems. In the end, the building should empower the occupant to make their own comfort decisions whilst maintaining a basis of regulated control. If this possibility of manual control is not present, the occupant must be informed. Furthermore, they state that the lower boundaries of smart buildings are the upper boundaries of intelligent buildings. In other words, where the definition of intelligent building stops, the definition of smart buildings begins.

Preferences of occupiers and office users

Preferences and wishes of tenants (employers) and users (employees) play a role in deciding whether to relocate to a new office space (Aksoy & Uzunoglu, 2020; Buckman et al., 2014; Kim & De Dear, 2013). To what extent this is true for smart offices will be examined in this research. Since literature shows that employers and employees can influence each other's relocation movements, the preferences and wishes of both are analysed in the following section.

Preferences of employers: what does the (smart) office tenant want?

Fundamentally, tenants require office space that meets their needs. In their study on determinants of satisfaction amongst tenants of offices in the United Kingdom, Sanderson & Edwards (2016) list the following aspects: the building quality itself; the satisfaction of employees; the location of the property; the (quality and quantity of) amenities; and communication with the property manager. The decision whether a tenant chooses to (not) rent a specific property, ultimately primarily depends on whether the tenant has the feeling that the amount of rent and service charges provides value for money. This value judgment is highly subjective.

Furthermore, Sanderson & Edwards (2016, p. 104) show that responsibility and sustainability are important determinants among tenants. This could, among other things, be reflected by the building itself given the situation that properties need to meet the requirements of occupants. An example of this is reflected in a building's energy label, it's facilities and amenities, and/or facility costs.

Another determinant of whether tenants rent an office building is related to (an expected increase) in employee productivity, as shown by Sanderson & Edwards (2016, pp. 127-129). Related to this, is the so-called '3-30-300'-rule. Coined in 2016 by global real estate consultancy JLL, this rule of thumb states that on average *one square foot* (0,10 square meter) costs 3 dollars of energy, 30 dollars of rent and 300 dollars on salaries for employees. Therefore, a 10 percent reduction in energy costs reduces the overall costs by 0,3 dollar, while a 10 percent increase in employee productivity accounts for a 'cost reduction' of 30 dollars. The main take-away of this rule of thumb is that an office with a relatively low rent that reduces (or at least, doesn't increase) worker productivity, altogether can be more expensive than a more expensive office that does increase productivity.

Preferences of employees: what does the (smart) office user want?

Smart offices offer all sorts of 'smart features' to its occupants, like adjustable lightning conditions and indoor tracking of colleagues. However, little is known about the expectations and preferences

of smart office users regarding those uses (Haapakangas, Hallman, Mathiassen & Jahncke, 2018, p. 116). As noted by Tuzcuoglu, De Vries, Yang & Sungur (2022), it is essential to obtain an overview of which (attributes within) smart features are important to office occupants, as it is widely acknowledged that user preferences and expectations can significantly influence user experiences (Kim & De Dear, 2012; Van der Voort & Van Wegen, 2005). An example is the given that many sensors within smart buildings register all sorts of personal data, which could lead to privacy concerns among users. It is wise to take this dynamic into account since it could lead to less interest in using the smart feature in the first place (Tuzcuoglu et al., 2021, p. 4).

So-called knowledge workers have various needs in terms of (smart) office buildings. In their literature review on the essential needs of knowledge workers in office environments, Budie, A ppel-Meulenbroek, Kemperman & Weijs-Perrée (2019) distinguish three pillars: physical needs, functional needs, and psychological needs. The first essential need encompasses physical, environmental needs such as working in a comfortable climate and having the autonomy to make personal decisions regarding this climate. Furthermore, functional needs address facets like the ability for an office worker to concentrate and interact with co-workers and focus on utilizing their cognitive abilities to complete (complex) tasks. Lastly, psychological needs mostly address the need for privacy, personalization, and autonomy.

Smart buildings and sustainability

One of the most important aspects of smart buildings relates to sustainability. As formulated by Al Dakheel et al. (2020, p. 2), these buildings sustain their performance "with respect to energy, water, waste and pollution for the current and future generations." Omar (2018, p. 2905) adds to this, building on the work of Clements-Croome (2013), that smart buildings should be healthy places to live and work in, meet (environmental) regulations, be adaptable and give value for money.

As observed by Omar (2018, p. 2903), globally, the built environment is accountable for 36 – 44 percent of energy consumption - varying on the definition of 'built environment' - and almost 30 percent of greenhouse gas emissions (such as C02 and methane) is produced by buildings. Calculations performed by the European Union (CBRE, 2022b) show that almost 50 percent of these emissions are caused by so called "utility buildings", such as offices. To meet (global) ambitions of reducing greenhouse gas emissions, it is therefore obvious that offices must become more sustainable. Given the sustainability perspective of smart buildings, herein lies an obvious opportunity for smart offices.

Europe's sustainable ambitions

All over the world, sustainability policies are being put into place. An example is the Energy Performance of Buildings Directive (EPBD) program from the European Union. This initiative is part of the 'Fit for 55' climate package and one of its primary goals is to reduce European emissions by at least 50 percent in 2030 (compared to 1990). The Fit for 55 package is part of the European Green Deal (sometimes also phrased as the Paris Goals), a plethora of policies that have one overarching goal: for Europe to become the first climate neutral continent by 2050. This aligns with the target of the Intergovernmental Panel on Climate Change (IPCC), which is to reach global stabilized CO2 levels by 2050 (Omar, 2018). The EPBD speaks of 'nearly Zero-Energy Buildings' (nZEBs) and not only aims to reduce energy consumption in newly constructed utility buildings, but also in current office stock.

This is because up to 90 percent of the existing European building stock will still be standing and in use in 2050. Thus, there is a clear need to upgrade the sustainability of all buildings, including offices.

To reach the goals of the European Green Deal, each EU member state is tasked with formulating a plan with concrete steps to reduce greenhouse gas emissions. Also, a roadmap with intermediate goals per decade (2030, 2040 and 2050) and accompanied deadlines must be included. The European Commission must review the action plans of EU member states no later than 2025. Although the Dutch action plan has not been officially reviewed yet, the first major milestone relates to office buildings. Starting from 2023, all Dutch (smart) office buildings were required to have at least energy label C (Rijksdienst voor Ondernemend Nederland, 2022). From 2030, energy label A is required.

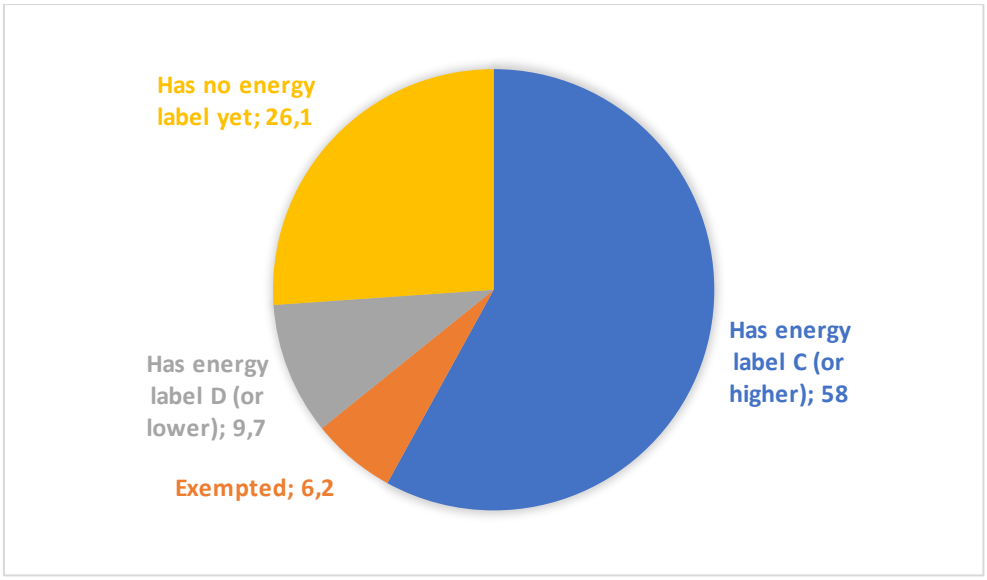
How (smart) offices can achieve climate goals

A global survey conducted by the World Business Council for Sustainable Development (WBCSD) in 2009 showed that global energy consumption by buildings can be minimized radically. Omar (2018) notes that by making buildings smarter, energy usage will be more efficient. By doing this, scarce natural limited resources are being preserved and the effects of the built environment on climate change are being mitigated (to some extent). Al Dakheel et al. (2020, p. 6) provide a framework for increasing the 'smartness' of buildings by developing a quantified guideline to improve energy efficiency. To build a new nZEB - or transform an existing property into one - three key steps must be implemented: application of passive strategies; energy-efficient technologies; and renewable energy sources (RES) integration. Passive strategies include insulating a building, installing smart sensors, and providing sufficient shading. Energy-efficient technologies include installing advanced Heating, Ventilation and Air Condition (HVAC) systems. RES technologies include getting energy from natural sources such as solar, wind, hydro, and biomass.

How sustainable is the Dutch office market?

According to research by CBRE (2022b), as of 2022, 58 percent of Dutch offices holds at least energy label C and therefore meet EU regulations, see also figure 2.2. Meanwhile, 9,7 percent has label D (or lower), 6,2 percent has no energy label because these offices are in monumental estates (and are therefore exempted) and 26,1 percent doesn't hold any energy label. This last group is not expected to meet EU regulations in time, mainly since the process of getting an energy label is delayed by labour market shortages in the construction sector. The Dutch government organization for supporting entrepreneurs (Rijksdienst voor Ondernemend Nederland, 2022) estimates that most of the offices without an energy label need extensive renovation to meet the EU guidelines. Furthermore, the process of 'labelling' the Dutch office market is delayed by a new EU method (installed in 2020) for calculating the energy efficiency of properties.

Figure 2.2: Energy labels in the Dutch office market



Source: CBRE (2022b).

There are substantial geographical differences in the sustainability of Dutch offices. Based on data from CBRE (2022b), office buildings in the greater Randstad region (Amsterdam, The Hague, Rotterdam, and Utrecht) mostly meet EU regulations. Utrecht leads the rankings, since 95 percent of the offices holds at least energy label C. For Haarlemmermeer, where airport Schiphol is located, and Amersfoort, these numbers are respectively 91 and 89 percent. The top five is completed by Amsterdam (89 percent) and The Hague (88 percent), the two Dutch cities with the biggest total supply in office space. This contrasts starkly with the situation outside of the Randstad region. CBRE (2022b) research shows that offices in Heerlen, Hilversum, Arnhem, Nijmegen, and Tilburg are not expected to meet the EU regulations in time. In Heerlen and Hilversum for example, only 52 and 63 percent of office buildings are in possession of energy label C (or better).

Conclusion

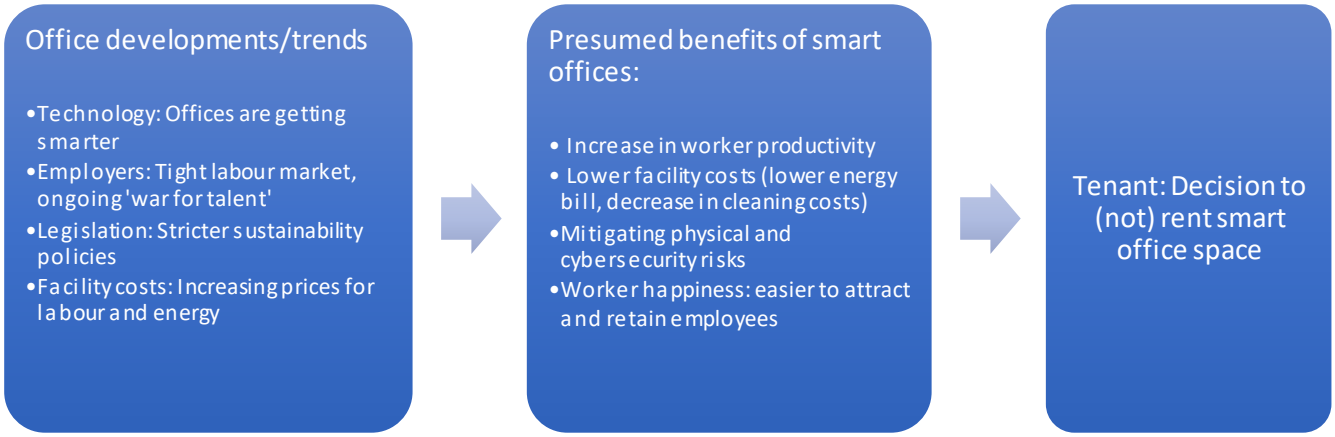
To summarize, the 'smartness' of a building is resembled by smart features that are applied to one or more of the pillars of smart buildings (adaptability, control, enterprise and materials and construction). Based on literature review, the following checklist is used to determine whether an office can be labelled as smart. Figure 2.3 illustrates the conceptual model of this thesis.

Table 2.2: Checklist - When is an office smart?

Pillar	**Is the building able to account for …**	**Indicators**
Adaptability: A smart office is adaptive instead of reactive	Adaptability on the short term?	Can the building integrate calendars of occupants (timetabling) to optimize building space use? Can the office adapt to changes in the (expected) number of people in an area/ a room?
	Adaptability on the medium term?	Is the office able to predict and monitor routines of occupants (for example on a daily/weekly basis)?

		Is the office able to adapt to (seasonal) occupation changes, for example when there are (temporary) changes in the number of employees that work from home?
	Adaptability on the long term?	Can the office adapt to climate change? For example, by changing and replacing (modular) components? Is the office able to adapt to permanent changes in occupancy use and/or use of physical environment (switching uses from office destination to something else)?
Control: The amount of control must serve the occupant	Giving occupants the optimal amount of control over the building?	Can the office inform occupants of the likely temperature within the building before employees set off from home? Is the office able to inform occupants about varying conditions in the building? Can the occupant change the automatic control systems of the building, for example by changing a pre-booked room?
Enterprise: The extent to which the hard- and software in an office are connected	The overcoming of fragmentation, non-compatible and non-proprietary legacy systems?	Is there an automatic booking system? For example, when entering the building, are occupants informed where the booked room is located? Are workplaces occupant tailored? So, are occupants able to control HVAC preferences, such as indoor weather conditions? Do booked rooms account for the number of people who are (likely) to attend? For example, do they adjust the HVAC conditions to maximize productivity?
Materials and construction: The built form of the smart office	Changing preferences for accommodation in use and climate?	Is the building structure adaptive to future climate expectations? For example, by being able to replace features in the future to account for change? Is the building able to close zones during known periods of low occupancy?

Figure 2.3: Conceptual model



Chapter 3: Methodology

This chapter details the research strategy of this thesis, including method choice, analysis method and empirical strategy.

Research strategy: qualitative approach

This thesis uses qualitative research methods. Whereas quantitative research methods are mostly based on the systematic and structural analysis of (large) datasets, qualitative methods apply a micro-perspective and focus on descriptions, opinions and/or specific experiences of persons (Boeije, Scheepers & Tobi, 2016). Consequently, this is one of the main reasons this thesis applies the qualitative approach. These methods allow the possibility of exploring relatively new phenomena (as seen in table 3.1) while focusing on personal expectations and motivations.

Furthermore, the qualitative method is preferred because this method incorporates both structured and flexible research methods, namely literature review and in-depth, semi-structured interviews (Boeije et al., 2016, p. 92). By asking loosely formulated questions, interviewees have the possibility of sharing opinions, statements and/or subjects that, in their opinion, are important. This personal perspective is useful in investigating research questions that are (partly) based on personal reflections, such as in this thesis.

Table 3.1: Smart offices in The Netherlands

Smart office name	**Location**	**Taken into use?**
The EDGE	Amsterdam	Yes
EDGE Olympic	Amsterdam	Partly
EDGE West	Amsterdam	Yes
The Flow	Amsterdam	Yes
The Outlook	Amsterdam (Schiphol)	Yes
MM25	Rotterdam	Yes
Stadskantoor (stadhuistoren)	Eindhoven	Yes
Wonderwoods	Utrecht	No, still under construction
Tree House	Rotterdam	No, still under construction

Sources: Appel-Meulenbroek et al. (2019), Facto (2018), Randall (2015), Schellekens (2019), Tuzcuoglu et al. (2021), Van Eesteren (2017) & Van den Berg (2019).

Research methods

As said, this thesis is characterized by an explorative and inductive character and makes use of desk research (study of literature) combined with in-depth interviews as part of case studies.

Multiple case study research

This thesis uses a multiple case study research approach. By doing this, the complex and specific characteristics, motivations, and dynamics of multiple cases can be explored and thoroughly observed. The research is explorative in character since there are only few offices in The Netherlands that either label themselves as “smart” or are being labelled as such. The cases are selected by the author based on existing academic literature and journalistic cases. Flyvberg (2006, p. 4) calls this selection method a “information-oriented selection.”

Three smart offices are researched by performing case studies: The Edge (Amsterdam), MM25 (Rotterdam) and Edge West (Amsterdam), see table 3.2. Randall (2015) profiles The Edge in business publication Bloomberg while Schellekens (2019) researches the MM25 building from an academic perspective. Van den Berg (2019) details the Edge West building in her master thesis.

Table 3.2: Case studies

Name	Location	Developer	Tenant(s)
The EDGE	Amsterdam	EDGE	Deloitte, AKD, Henkel, Edelman, Salesforce
EDGE West	Amsterdam	EDGE	Alliander N.V, APG Groep N.V., Intertrust Netherlands B.V., Signify, Boehringer Ingelheim
MM25	Rotterdam	EDGE	Croonwolter&dros, Coca-Cola, Regus

Sources: Randall (2015), Schellekens (2019) & Van den Berg (2019).

Lund (2014, p. 224) describes a research case as "… an edited chunk of empirical reality where certain features are marked out, emphasized, and privileged while others recede in the background. As such, a case is not "natural", but a mental, or analytical construct aimed at organizing knowledge about reality in a manageable way." Therefore, some scholars argue that the results of case studies are highly dependent on local context and not generalizable. Other scholars, such as Flyvbjerg (2006), argue that the main advantage of case studies lies within the highly local context. By employing a micro perspective, the object can be more thoroughly researched comparing to quantitative methods. Therefore, case studies are often used to investigate the complex dynamics and motivations behind (personal) choices, such as decisions regarding business location strategy.

Summarizing: in a multiple case study research, it is possible to take the complex and specific characteristics, dynamics, and motivations of several cases into account (Bryman, 2008, p. 53). This increases the validity of this research.

Case 1: The Edge
Location: Amsterdam
Tenants: Deloitte, AKD, Henkel, Edelman, Salesforce

The oldest Dutch smart office is The Edge building in Amsterdam (Randall, 2015). It opened its doors in 2015 and the main tenant is global accounting and consultancy firm Deloitte. Since then, several other tenants joined, such as cosmetic multinational Henkel, lawyer firm AKD and Salesforce, which sells cloud computing software to businesses.

The Edge packs thousands of smart sensors, had the highest BREAAM certificate in the world (since then overtaken by the Bloomberg headquarters in London (BRE Group, 2020)) and offers several smart technologies to its occupants (JLL, 2020). For example, the garage system can recognize number plates and guides employees/visitors to the parking location that is best suited for their situation (which is, among other things, based on their day schedule). The Edge is widely regarded as one of the smartest and sustainable office buildings in the world (CBRE, 2022b), and is therefore explored in this thesis.

Case 2: Edge West
Location: Amsterdam
Tenants: Alliander N.V, APG Groep N.V., Stichting Pensioensfonds ABP, Intertrust Netherlands B.V., Signify, Boehringer Ingelheim, Athoma

Just like MM25, the Edge West has also been renovated into a smart office building. The building originates from the 1970's and the renovation was completed by the end of 2021. Tenants include energy company Alliander, financial services provider Intertrust and Signify, formerly known as Philips Lightning.

Edge West is equipped with smart sensors, employees have a smartphone app to book rooms and the building uses 'digital twin' methods. Real-life data is being used as input for simulation models. In these simulations, possible interventions (in terms of building adjustments) are first modelled digitally, before taking 'real' actions. Furthermore, the building holds two sustainability/wellness certifications: BREEAM Outstanding and WELL Platinum.

Edge West is one of newest Dutch smart offices since it was taken into use at the end of 2021 and is not fully rented out yet (Hentenaar, 2022).

Case 3: MM25
Location: Rotterdam
Tenants: Croonwolter&dros, Coca-Cola, Regus

The MM25 building is in Rotterdam – MM25 refers to the address: Marten Meesweg 25 - and was originally constructed in 1990, but completely renovated in 2018. Firms Coca-Cola and Croonwolter&dros have moved in since then. Regus, which rents out flexible working places, has also taken residence in MM25.

The smart office is labeled as smart by Hanff (2018) and Schellekens (2019) since the HVAC systems are completely automated by using input data from sensors. Using a smartphone app, employees and facility managers can check occupation levels of rooms in real time and an algorithm prioritizes the cleaning of rooms based on the occupancy levels. Furthermore, employees can adjust HVAC conditions to their own preference and the building structure is semi-modular, increasing the range of possible future uses.

Semi-structured interviews

The main empirical base of this thesis is formed by semi-structured interviews. These interviews were conducted with business executives – persons that are/were (partly) responsible for location strategy decisions within their firm - of smart offices in The Netherlands and their input was used to answer the research questions. The interviews are characterized by a semi-structured character, which implies that the questions and sentence structure are, to some extent, flexible (Boeije et al., 2016). After transcribing and decoding the interviews, the answers of interviewees were used for answering the research questions.

This interview method has certain advantages and disadvantages. One advantage is that the interviewee has the possibility to enrich his or her answer with personal insights, opinions and (expert) statements on the matter, which makes it a flexible and sensitive method. However, this

flexibility could also result in lesser reliability of the given answers, partly because it's more difficult to compare answers.

In total, 42 requests for interviews have been sent. This resulted in the following conducted interviews:

Case study	Company of interviewee	Date and time
The Edge	Deloitte	25-11-2022 | 16:02
MM25	Croonwolter&dros	28-11-2022 | 09:12
The Edge West	Alliander	27-10-2022 | 13:39
The Edge West	APG	19-10-2022 | 11:56
The Edge West	Signify	15-11-2022 | 16:09

The names of interviewed individuals are not shown in the public version of this thesis because of privacy reasons. Full names and contact details are only known to directly involved university staff, e.g., the supervisor. The same applies to the anonymous table shown below.

Personal communication

Besides semi structured interviews, there has been personal communication with (potential) respondents through e-mail and/or social media (LinkedIn and Twitter). These communication methods have been used to get in touch with potential interviewees, verify statements and to make sure respondents have the possibility to make additions.

Casestudy	Company of contact person	Date and time
Edge West	Signify	18-10-2022 | 18:10
Edge West	Signify	16-11-2022 | 10:44*
Edge West	Alliander	18-10-2022 | 18:15
Edge West	Alliander	25-10-2022 | 12:25*
Edge West	APG	18-10-2022 | 19:12
Edge West	APG	19-10-2022 | 12:12*
MM25	Coca-Cola	2-12-2022 | 17:02*
MM25	Croonwolter&dros	11-10-2022 | 09:47
MM25	Croonwolter&dros	19-10-2022 | 12:34*
The Edge	Deloitte	2-11-2022 | 14:13
The Edge	Deloitte	5-11-2022 | 18:02*

*= Time of first moment of contact since messages have been sent back and forth.

Interview guide

The interviews are semi-structured according to a interview guide, which is part of the appendices of this thesis (see appendix G). An interview guide contains broad themes, topics, and a plethora of possible questions and can be regarded as the backbone of the interview.

Desk research

Besides interviews, this research also used desk research methods, including the (analysis) of academic sources (such as papers), high-quality journalistic products and several business reports. Desk research has been used to identify smart offices in The Netherlands, describing and analysing

the history of property development and investigating business location strategies from an investor's perspective.

1. Literature research

Despite its novelty, the smart office concept has a scientific research base. Buckman et al. (2014) assessed the history of smart buildings and distinguishes this concept from its predecessor, intelligent buildings. Clements-Croome (2011) and Tuzcuoglu et al. (2021) analysed smart buildings from an employee perspective, while Haapakangas et al. (2018) makes the case for relating productivity and employee well-being in smart buildings. From a technical and sustainable perspective, Yang & Peng (2011) stressed the importance of making data-based office decisions, while Wong & Li (2009) developed a analytic model for integrated building management systems (IBMS). Al Dakheel et al. (2020) examined the main smart building features and listed the key performance indicators.

2. Documents

Document analysis relates to the systemic analysis and evaluation of documents (Bowen, 2009). Altheide (2010, p. 128) adds that qualitative document analyse is about "discovery and description, including searching for contexts, underlying meanings, patterns and processes". For this research, several documents have been reviewed. These were mostly produced by global real estate advisory firms. For example, CBRE (2022a) lists the main benefits of renting smart office space, while CBRE (2022b) examined the current energy labels of the Dutch commercial property market. JLL (2016) lists several scenarios for the future of the PropTech industry while Deloitte (2020) examines ways to transform existing properties into smart buildings.

3. Journalistic sources

Lastly, journalist sources were used in this research. On a regular basis, smart offices get featured in high-quality media outlets. These publications, mostly in the form of articles, have been used to outline the development time scale, portray the iterative character of smart offices and as input for the interview guide.

Randall (2015) wrote about the launch of The Edge building for outlet Bloomberg, while Hermus (2021) details the ways in which Deloitte is experimenting with hybrid working forms for newspaper NRC. Tomusk (2022) revisits The Edge and analyses what could have been differently. Hanff (2018) outlines the sales and development process of the MM25 building for business publication Vastgoedmarkt while Gispen (2021) documents the lay-out of the Croonwolter&dros headquarters. Hentenaar (2019) describes the renting out process of the Edge West building for Vastgoedjournaal and Diekman (2022) specifies the smart technologies this building offers.

Operationalization of research questions

This part operationalizes the main thesis question, including sub question. The central research question – to what extent do smart offices add value for tenants? – was researched by formulating the following sub questions:

1. What are the characteristics of smart offices in The Netherlands?

This research question has been partially answered in the theoretical chapter of this thesis. However, as shown in the theoretical framework, the terminology of smart offices, and smart buildings in general, is currently non-aligned. Therefore, these concepts were discussed with the interviewees to

enrich and/or nuance the theoretical principles. This method is derived from Burawoy (1998). In his highly influential paper, he details a research method, which focuses on detailed studies of cases to extract guiding, general principles from specific (personal) observations. The literature base was used to extract expectations, while interviewees (tenants) were asked about their reflections on smart offices. Interviewees were asked to describe when, in their eyes, an office can be classified as 'smart' and which features are most important.

2. What are the expectations of smart office tenants before renting a smart office in The Netherlands?

Based on literature, there are several motivations for tenants to choose smart office space over conventional property. Since every property search is unique, interviewees were asked to enrich this theoretical perspective by adding their own insights. In other words: what were the expectations of tenants of renting their current smart office space before they made this decision? Why did they choose this property over a conventional office? Was this mainly due to an expected increase in worker productivity, lower facility costs, branding reasons, a combination of factors or something different?

3. Theory versus reality: to what extent do the expectations of smart offices live up to the reality?

The last sub question investigates whether the presumed benefits of smart offices are being experienced by tenants in practice. For example, based on literature, smart office technology bolsters the potential to improve worker happiness and productivity while lowering facility and utility costs. Does this match with the practical observations from tenants? In other words: do the presumed benefits of smart offices live up to reality?

Reliability and validity

According to Bryman (2015), well-done research must be reliable. This indicates that if the research would be repeated, the same results will be generated. In qualitative research it is however difficult to completely guarantee reliability since it observes from the researcher perspective and his or her personal frame of reference. Fortunately, the results can increase in reliability by implementing trivialization. In this case, the motivations of several smart office tenants from different locations were consulted. By consulting the opinions of different people (belonging to different case studies), the reliability of research results is increased.

The concept of validity relates to the integrity of research conclusions. In other words: do the research findings truly relate to the given that the researcher claims to measure? There are four types of validity, as laid out by Bryman (2015):

1. Construct validity
2. Internal validity
3. External validity
4. Ecological validity

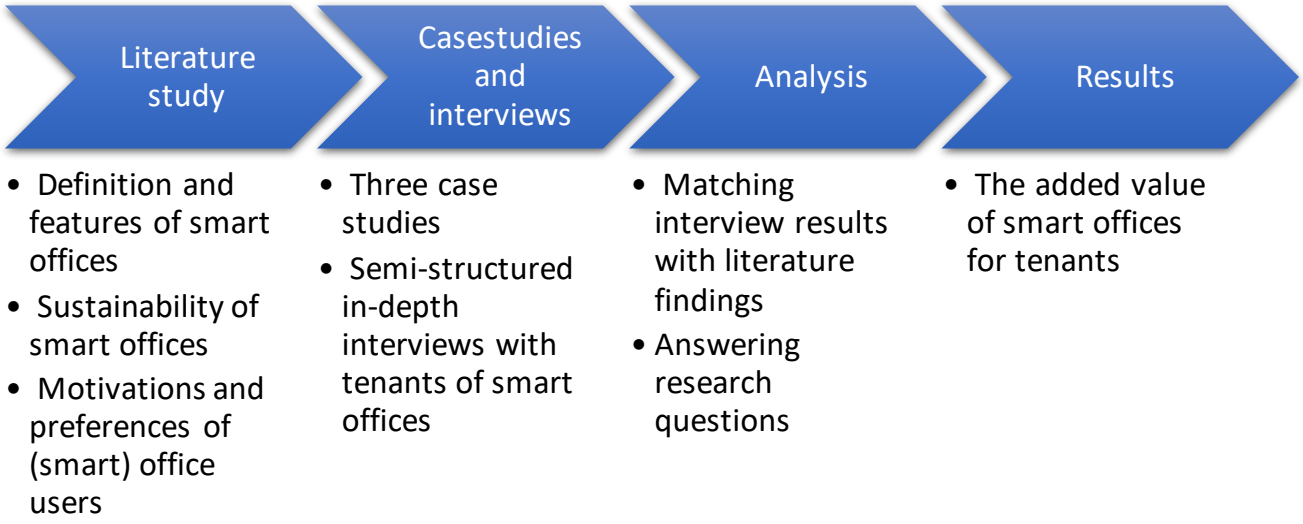
The first type states that the research results should be reliable. The second type, internal validity, relates to the possibility of causality. In other words: could it be that independent variable explains the observed variation in the dependent variable? External validity states that results should be generalizable and applied to larger groups than the group or persons observed. Lastly, ecological

validity states that the research strategy (including methods, materials and setting) of the research must be as close to 'real-world' settings as possible.

Since there is limited knowledge around the topic of smart buildings, and smart offices in general, it is difficult to state whether research results meet the internal validity requirement. On the contrary is the factor of external validity, since the analysed cases cover a big part of the Dutch smart office market. The first and last types of validity, construct, and ecological validity, are also met since the study was conducted in everyday practice.

Empirical strategy

In conclusion, the empirical strategy is as follows:



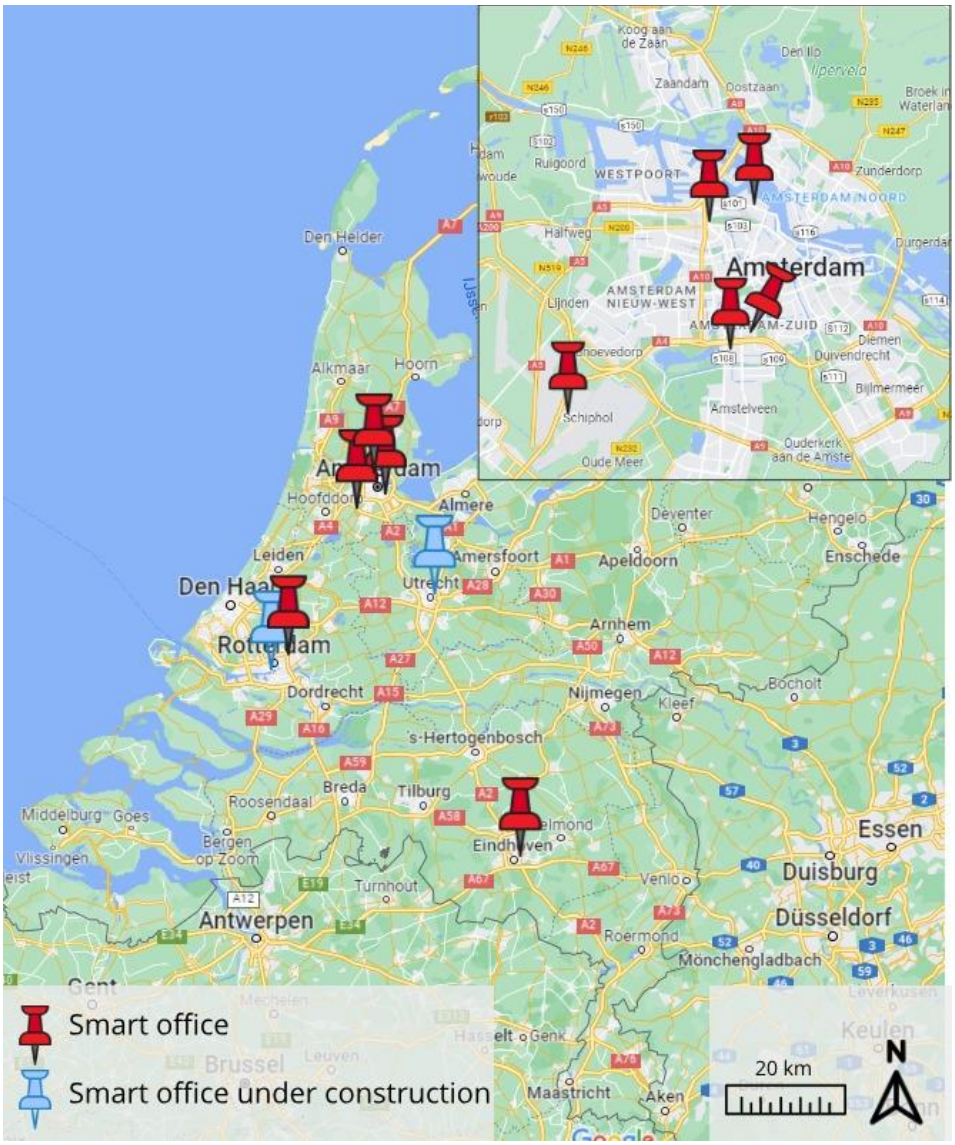
Chapter 4: Results

Interview results for all sub questions are discussed in the following sections. Each section ends with a conclusion.

1. What are the characteristics of smart offices in The Netherlands?

The characteristics of Dutch smart offices vary greatly. From a locational perspective, it is noteworthy to mention that all current smart offices (under construction) are in the Randstad area, and more specifically Amsterdam, see also figure 4.1. The only exception is the municipal city hall in Eindhoven (Stadskantoor). Off all the smart offices in the Randstad area, most properties are in Amsterdam, in or around the Zuidas area. This location is seen as the most highly regarded commercial real estate area of The Netherlands (JLL, 2020).

Figure 4.1: Smart offices (under construction) in The Netherlands



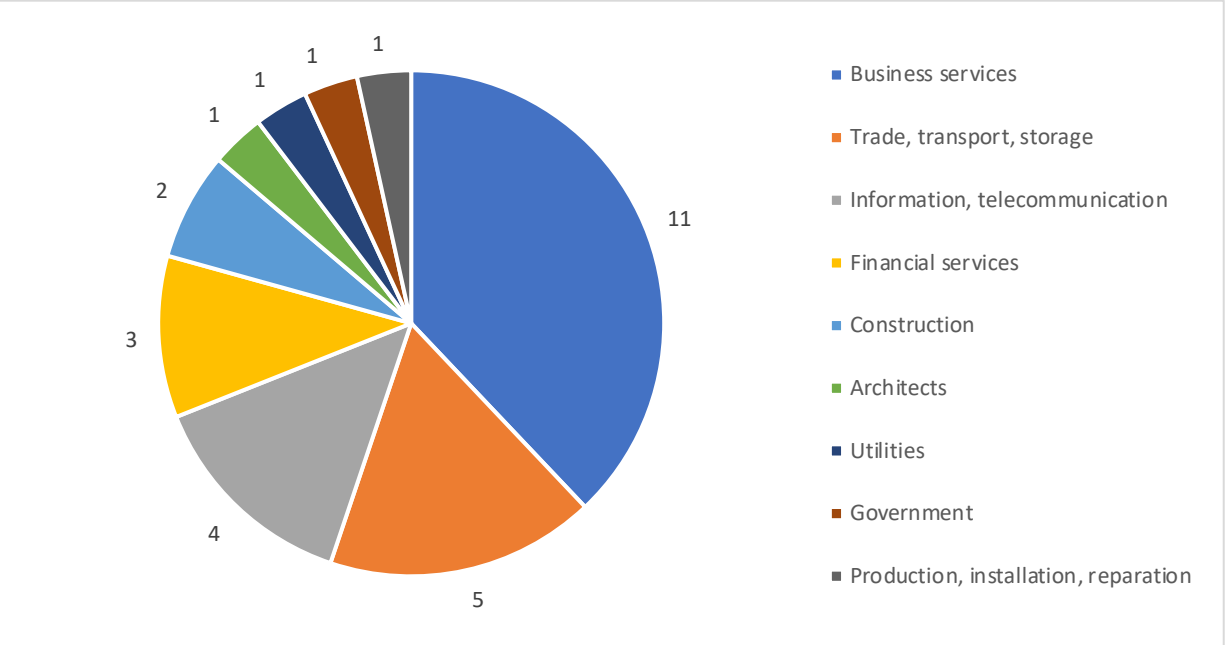
Sources: Interviewees, Hentenaar, 2019; Randall, 2015; Schellekens, 2019; Wright, 2020.

Profile: Who rents a smart office?

Dutch smart offices are mostly rented by firms that offer business services - such as consultancies (Deloitte) -, communications/personal relationships agencies (Edelman) and legal services (AKD), as

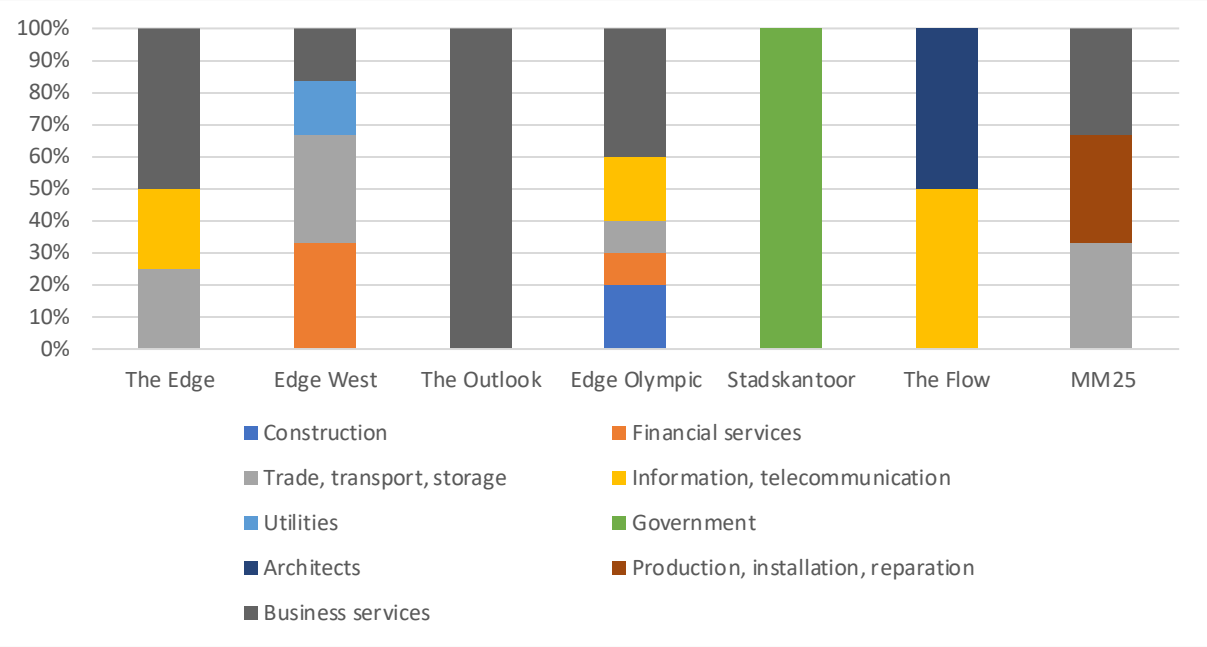
shown in figures 4.2 and 4.3. Smart offices are also occupied by firms that are active in trade and transport, such as Henkel, the multinational behind personal beauty and healthcare products from brands as Persil and Schwarzkopf. Lastly, Dutch smart offices are rented by companies in the sectors of information and telecommunication, such as software provider Salesforce, and financial service suppliers, such as insurance company Athora, known for its brands Reaal and Zwitserleven.

Figure 4.2: Sectors of Dutch smart office tenants (total)



Sources: BREEAM NL, 2022; CBRE, 2022b; Diekman, 2022; Hermus, 2021; Interviewees; Randall, 2015; Schellekens, 2019; Tomusk, 2022; Tuzcuoglu et al., 2021; Van den Berg, 2019; Wright, 2020.

Figure 4.3: Tenant composition per smart office



Who develops smart offices?

Most Dutch smart offices are developed by EDGE, formerly known as OVG Real Estate, see also table 4.1. This Dutch firm describes itself as a real estate development company with the mission of "pioneering the future of our built environment" (appendix A). The company believes that, in the future, all buildings need to be digitally connected to mitigate contemporary challenges, such as the consequences of climate change. Therefore, sustainability is one of the core principles of EDGE. The company pledged to be net zero by 2050, meaning that all their (new and already constructed buildings) are climate neutral.

Table 4.1: Characteristics of Dutch smart offices

Characteristic / Smart office	**The Edge, Amsterdam**	**Edge West, Amsterdam**	**Edge Olympic, Amsterdam**	**The Outlook, Amsterdam**	**The Flow, Amsterdam**	**Stadhuistoren, Eindhoven**	**MM25, Rotterdam**
Construction type	New construction	Renovation	Renovation	Renovation	New construction	Renovation	Renovation
Developer	EDGE	EDGE	EDGE	Schiphol Real Estate	ToBeDeveloped	Consortium !MPULS	EDGE
Gross floor area (m2)	51,608	74,300	12,367	41,432	7,409	11,232	16,200
Sustainability label (BREEAM)	Outstanding (91,38%)	Outstanding (87,69%)	Excellent (79,11%)	Very Good (61,65%)	Excellent (72,30%)	None	None
Energy label	A	A	A	A	A	A	A
Wellbeing label	None	WELL Platinum	WELL Platinum	None	WELL Platinum	None	None

Smart office features	Sensors measure C02, light, motion, sound, and humidity Predictive maintenance Real time occupancy Valve pipe heating regulations Lockers Robot security guard Rainwater storage Automatic parking system Ethernet-powered LED-lightning	Sensors measure C02, light, motion, sound, and humidity Predictive maintenance Real time occupancy	Sensors measure C02, light, motion, sound, and humidity Predictive maintenance Real time occupancy Automatic parking system	Sensors measure C02, light, motion, sound, and humidity Predictive maintenance Real time occupancy	Sensors measure C02, light, motion, sound, and humidity Predictive maintenance Real time occupancy Facial recognition for entry (and measuring temperature for COVID-19 regulation) 360-degree meeting room	Sensors measure C02, light, motion, and humidity Predictive maintenance	Sensors measure C02, light, motion, sound, and humidity Predictive maintenance Real time occupancy Heat resistant glass Rainwater storage
Smartphone app features	Regulating heating and lightning Booking rooms Finding co-workers	Regulating heating and lightning Booking rooms Finding co-workers	Regulating heating and lightning Booking rooms Finding co-workers	Regulating heating and lightning Booking rooms	Regulating heating and lightning Booking rooms Finding co-workers	Regulating heating and lightning	Regulating heating and lightning Booking rooms Finding co-workers

	Predictive planning						
Number of sensors	28,000	12,000	1,600	520	700	350	800
Technology platforms	Mapiq EDGE Next	Mapiq EDGE Next	Mapiq EDGE Next	bGrid Mapiq Microsoft Azure Cloud	DARWIN	Internal system Microsoft Azure Cloud	bGrid Mapiq
Year completed	2014	2021	2018	2018	2020	2019	2018

Sources: Appendices; Diekman, 2022; EDGE, 2019; Gispen, 2019; Hermus, 2021; Randall, 2015; Schellekens, 2019; Tomusk, 2022; Van den Berg, 2019; Wright, 2020.

Technology: Smart office features

EDGE is not only a commercial real estate developer. The firm also offers a software suit for managing such properties, called EDGE Next. This platform integrates all the data that sensors capture in one or multiple dashboards. It allows tenants, employees, and other stakeholders (as facility managers) to get insights into how the building is being used, and tips on how to improve the efficiency (appendices A & D). EDGE Next informs tenants about a building's sustainable performance, facility costs, employment wellbeing, asset usage and maintenance. EDGE Next is closely integrated with Mapiq, an office smartphone app (appendices A & E). This app offers employees and tenants several features, such as digitally navigating the office, book workspaces and meet up with co-workers.

To unlock all the features of this app, employees must grant the Mapiq app permission to their personal calendars (appendices A, D & E). By doing so, Mapiq can give personalized tips and insights based on the (expected) workday of the employee. One interviewee (appendix A) gave the following example: 'At the end of a working day, the app can give you the suggestion to exercise for half an hour in the gym because of current traffic jams. By doing so, it reduces travel time, or at least to use our travel time in a smarter way.' Another interviewee (appendix D) mentioned that Mapiq can reschedule meetings between co-workers based on schedules: 'If the original meeting should take place at 10:00 hours, but my co-worker has another meeting planned at 10:20 hours, then Mapiq suggests planning the meeting at 09:45 hours so there is enough time between the meetings.'

bGrid is one of main competitors of EDGE Next (appendix B). Fundamentally, this real estate data platform works the same. bGrid sensors capture office statistics such as temperature, humidity, light intensity, sound intensity and C02 air concentration. The platform can be connected through other Building Management Systems (BMS), such as Mapiq, and offers several smart building features such as (meeting) room bookings, finding co-workers and the ability to manage HVAC conditions.

"When is an office smart?"

According to all interviewees, it is difficult to determine when an office can identify as 'smart'. This is mostly due to lack of standardization: there is no formal institution that holds the power to grant quality marks for the degree of 'smartness' a building holds. There are several organizations that certificate (parts of) smart buildings, but according to interviewees, as of now, there is no widely recognized institution yet. For other building factors these quality marks do exist. For example, the BREEAM certificate determines the sustainability of a building while the WELL certificate measures whether buildings have a positive impact on human health and wellbeing, see also table 4.1.

Similarities

There are, however, similarities between all the Dutch smart offices. For one, all buildings hold energy label A, which is mandatory by 2030. Furthermore, they are all equipped with a BMS and an accompanying smartphone app. Because of this, they share a baseline of certain 'smart features': the ability to control HVAC conditions, book meeting rooms and find co-workers. Also, all Dutch smart offices offer predictive maintenance by checking whether a (meeting) room has been used and informing cleaning services whether this space needs to be cleaned.

Different levels of technology

The degree of smart features differs greatly within Dutch smart offices. For example, in The Edge building, employees can change HAVC settings on the microlevel: the heating is regulated through valves in the pipes above workspaces (appendix A). One valve impacts the heating of four desks. The tenant, Deloitte, has implemented such precise measures, because the number one complaint facility management received before moving to the smart office related to heating: employees were either too warm or too cold. Since then, facilitative staff received severely less complaints, according to the interviewee. In other smart offices, such as the MM25 building, changing the temperature impacts between ten to twenty desks (appendices B & C). In the Edge West building, heating changes impact between twelve and twenty workspaces (appendices D, E & F).

Another example is the fact that not all smart offices offer real time occupancy. In the MM25 building, for example, real time occupancy can only be achieved if all employees check in at their workspaces by scanning a QR-code. This doesn't happen, according to the interviewee from Croonwolter&dros (appendix B). In The Edge and Edge West buildings, this challenge was mitigated by installing motion beacons, which register whether a workspace is used, or not.

Conclusion

Smart offices in The Netherlands are mostly located in the Randstad area, with the majority in Amsterdam. They are primarily rented by firms who are active in the business services, trade and transport, information and telecommunication, and financial sectors. Most Dutch smart offices are developed by EDGE, a real estate company that prioritizes sustainability and offers a software platform called EDGE Next for managing smart offices. EDGE Next integrates data from sensors and offers insights on building usage, sustainability, facility costs, employee wellbeing, asset usage, and maintenance. It is integrated with the smartphone app Mapiq, which allows employees to digitally navigate the office, find available workplaces, and receive personalized tips and insights based on their work schedule. Overall, Dutch smart offices aim to improve efficiency and sustainability using technology.

2. What are the expectations of smart office tenants before renting a smart office in The Netherlands?

At the start of their search, most smart office tenants didn't expect to specifically rent smart office space. Out of six interviews, four tenants stated that it was not a conscious decision to rent such an accommodation, see also table 4.2. An interviewee (appendix F) characterized this by the following statement: "The so-called smartness hasn't had any impact in our decision to rent this office. While making this decision, we've looked at different factors, such as a decent price to quality ratio, an accessible location, and our history with this building."

Table 4.2: Did you expect to rent a smart office?

Conscious decision to rent a smart office	Unconscious decision to rent a smart office
1. Deloitte 2. Signify	1. Alliander 2. APG 3. Coca-Cola 4. Croonwolter&dros

Source: Appendices

Sustainability

On the other hand, for two tenants it was a conscious decision to rent a smart office: Deloitte and Signify. These companies had expectations as to what a smart office should offer. Asked about this, the interviewee of Signify (appendix D) said the following: "For us, it was a very conscious decision to rent a smart office. Smart sensors can increase people's happiness, and thus their productivity. Our organization is all about technological innovation, so it makes perfect sense our offices resemble this vision." Deloitte's motivations co-align, as expressed by the interviewee (appendix A): "For us, it was absolutely a conscious decision to rent a smart office. An office needs to optimally facilitate employees and the best way to reach this goal, in our opinion, is through technology."

The companies that did make a conscious decision in renting smart office space, had expectations regarding sustainability for their new accommodation. For example, Deloitte wanted to decrease its facility costs, improve the indoor climate and the sustainability score of its office. The firm was actively involved in the design phase of the newly constructed building and worked alongside developer EDGE to implement smart technologies (such as LED-powered Ethernet-cables). The interviewee of Deloitte (appendix A) stated that such "… smart technologies can elevate the office experience". Signify (appendix D) also firmly believes that technology is fundamental for increasing office quality. The manufacturer of smart lighting systems was involved in the transformation project of their current office space, already before the decision to rent it was made. Whilst looking for new office space, one of their main wishes related to sustainability: their new office had to be climate neutral. According to the interviewee, this process starts by creating a baseline: measuring the inputs and outputs of an office. In their opinion, this can only be done by implementing smart building technologies.

The office reinvented: collaboration, hotdesks and synergy

Besides Alliander and APG, there is one expectation that interviewees had whilst looking for new accommodation: the wish to increase collaboration and synergy among employees. Four out of six interviewees mentioned that they believe the conventional role of the office is changing – from a place where people 'simply' do their work to a social, inviting hub that inspires collaboration and offers hybrid working facilities - and modern office space should accommodate this.

Most interviewees mentioned the expectation of hybrid working and hotdesking. The latter refers to the situation wherein there are not enough individual workplaces for all employees. For example, the interviewee of Deloitte (appendix A) mentioned that their office space includes around 1000 individual hot desks, while catering to almost 2500 fulltime employees. By explicitly creating a shortage of desks, the company tries to motivate employees to make conscious decisions in where and how they work. The interviewee said: "We only want employees to book an individual desk if they really need to use it, for example because they must concentrate on complex tasks. If their work mostly involves meeting and social activities, we'd rather see them use social hubs." In similar fashion, Signify and Coca-Cola also incorporated hot desking in their new way of working. The Signify interviewee (appendix D) said the following "In our opinion, the open office plan is the future. It stimulates vital communication between co-workers. However, there need to be separate zones for different types of works. Spaces for team projects should not be mixed too much with spaces for concentration, because this can cause friction."

Furthermore, some interviewees mentioned that it's a firm's task to create and exciting and stimulating office environment which employees (partly) prefer over other workspaces, such as their home. This is best illustrated by the interviewee from Signify (appendix D): "Now more than ever, employees need a reason to come to the office. Offices can become smaller, but they also need to be more attractive and offer a wider variety of workspaces and possible activities."

Less office space

Several interviewees (appendices A, B & D) mentioned that hotdesking enabled them to shrink their overall office usage (in terms of square meters). By using their office space more efficiently, Deloitte, Signify and Croonwolter&dros were able to downsize their total office space. Illustrating, the latter was able to downsize from 18,000 m2 of total office space (previously scattered over thirteen separate locations), to 8,000 m2 in the current location. Signify also actively pushes of total office space, without disclosing specifics (appendix D). The interviewee said "Many of our offices were and are underused and the business environment is changing rapidly. Therefore, we look at the conditions and terms for every individual office location and, in a lot of cases, make the decision to rent less office space."

Hotdesking can be part of a bigger plan: a new way of organizing office spaces. Several interviewees (appendices A, B & C) stated that, while moving to the new office space, they also wanted to introduce a new ground plan. In these plans, there are distinct zones for office activities, such as 'social hubs' where co-workers can meet each other and hold meetings, or 'concentration zones' with a no-sound policy. Smart technologies have the potential to play a role in facilitating this new way of working. For example, employees can find co-workers through their smartphone app and can reserve (meeting) rooms or workspaces from there. Deloitte and Signify specifically stated these expectations of a (potential) smart office space, while other interviewees didn't specify these smart features.

The big picture

The smartness of an office can be part of the decision to rent it but is not the leading force. Interviewees mentioned expectations such as a good price to quality ratio, certain office characteristics (such as large, open floor spaces), specific locations and sustainability.

All interviewees mentioned that the big picture of an office is most important: individual characteristics are not driving the decision. The interviewee of APG (appendix F) explained this opinion by stating the following: "The big picture must fit perfectly. You're not moving the whole company every week, so all factors are important. Sustainability is very important, of course, but you also want a high-quality work environment." Furthermore, the interviewee also mentioned an easily reachable location, enough parking space for employees and visitors and a payable rental price. This sentiment is matched by companies who made a conscious decision to rent smart office space, Deloitte and Signify. The former says that "… the smartness of a building serves the greater purpose of empowering people, instead of the other way around." (appendix A).

Lastly, timing was important. All six interviewees mentioned that (one of) their previous office lease contract(s) was about to expire, and that this triggered the search for a new accommodation. No tenant was actively looking for new (smart) office space before their contract was about to expire.

Conclusion

Most current smart office tenants didn't specifically set out to rent smart office space. Only two interviewees made the conscious decision to specifically rent smart office space. They did this mostly because of sustainability and believe that smart office features hold the ability to empower employees. Most interviewees expressed the desire for increasing collaboration and the incorporation of modern (hybrid) working facilities in their (smart) office. Some interviewees opted for the incorporation of hybrid working facilities, such as hotdesking, while others went with more traditional office arrangements. Lastly, the degree of 'smartness' of an office is not the primary expectation in the decision to find smart office space. Other expectations, such as a decent price-to-quality ration, reachable location, specific office characteristics, and the availability of parking spaces carry more weight.

3. Theory versus reality: to what extent do the expectations of smart offices live up to the reality?

All interviewed Dutch smart office tenants use smart building technologies, albeit to a degree. The interviewees mention that their employees use a smartphone app (Mapiq) to unlock the smart features that their office has to offer. According to most interviewees, these technological features make office life smoother. The interviewee from Alliander (appendix E) illustrates this by pointing out that Mapiq saves time by automatically setting up meetings between co-workers, including finding a suitable meeting space and time.

Not all smartphone features are used extensively. For example, the function to find co-workers is not popular among interviewees. This mostly relates to the given that the office of tenants is not big enough to make this function useful. In practice, it's often more efficient to look for somebody on the office floor or send that person a text message. Deloitte and Croonwolter&dros (appendices A & B) rent relatively large smart office floors but are also not avid users of this feature. This is because that not all employees are sharing their indoor location with the app, therefore making the feature less useful.

Decreased facility costs

Smart offices can decrease the office energy bill. According to Deloitte (appendix A), their overall facility costs have decreased almost 40 percent since moving to their current (smart) office. This statistic is achieved by implementing several sustainability measures, such as heat resisting glass, underground water storage (which stores water for cooling the building in the summer and warming it in the winter) and an innovative lightning system, wherein cables transport electricity and an internet signal at the same time. Coca-Cola and Signify also state that their facility costs have decreased, without sharing specific data. According to the interviewees (appendices C & D) this is achieved by more effectively utilizing office space. For example, if several sections or rooms of an office are not used, facility staff can close these spaces off.

Furthermore, facility staff used predictive occupancy to determine which office days are (not) popular. Coca-Cola (appendix C) notes that Friday is the day where relatively few people work in the office, allowing facility staff to close certain sections of the office beforehand, saving heating costs. For the other interviewees (Alliander, APG and Croonwolter&dros) it is not yet known whether their facility costs have decreased.

More productivity?

The same applies to another expectation most smart office tenants had: the wish to increase collaboration amongst employees and increase synergy (and thus productivity). Although all interviewees have stated that their current (smart) accommodation has increased employee happiness and collaboration, it is difficult to measure this statement in data metrics. Evidence for these sentiments is mostly based on anecdotes.

Some interviewees (appendices C, D & E) mentioned that smart buildings make office work easier. Also, it makes the communication process between employees and computers (such as BMS) more natural. Furthermore, all interviewees state user comfort and satisfaction has increased after moving into the smart office. Three tenants (Coca-Cola, Deloitte and Croonwolter&dros) have employee feedback regarding the office satisfaction level. However, there is only a certain amount of feedback

given the fact that smart offices are relatively new and/or the fact that most interviewees are relatively junior smart office tenants. The only exception is Deloitte, which has been a smart office tenant since 2015.

Marketing

Besides collaboration among employees and lower facility costs, interviewees mentioned another experience about renting smart office space: marketing and branding. Croonwolter&dros, an installation and infrastructure company, uses their office to showcase HVAC installations to (possible) customers, for example. "We are a technical service provider, so we also use our office as a showcase building", says the interviewee (appendix B). "We try to show what's possible in terms of real estate technologies. That's why all our ceiling installations are visible, instead of polished away. When a customer has a question about LED lightning systems or ventilation techniques, we can just invite them to our office and show how it works in practice."

Degree of smartness differs

As mentioned earlier, the degree of smartness between smart offices differs. The baseline of smartness is defined by the availability of a smartphone app and a BMS. However, some offices are equipped with more complex technologies. For example, when employees exercise in the fitness area of The Edge building, their generated electricity is used for powering the building. Another example includes the given that the coffee machine is connected to the BMS, which resulted in insights regarding the coffee preferences of employees and guests. In the first months after moving to The Edge building, it became clear that cappuccino was the preferred warm drink of choice, and other drinks were less popular. This resulted in a more streamlined purchasing process for Deloitte's facility staff, based on reliable data.

Challenges of smart offices

Smart buildings do not only offer benefits, but also challenges. Deloitte (appendix A) experienced several challenges after moving into their smart office. One of the main technological problems was that the booking system was misused. "People booked two workspaces just to be sure they had a parking spot for their car, or completely forgot to book a meeting room, which resulted in overbooked rooms", according to the interviewee. And even when employees booked rooms accordingly, they most often forgot to check-in through the QR-code. "Just after moving here, we expected that between twenty and 40 percent of the employees would check-in. The actual check-in rate was around ten percent", according to the interviewee. "We found out that some human behaviour is hardwired and that it's very difficult to change this through technology. Just because you offer people smart technologies, doesn't mean they will use it accordingly."

Deloitte also experienced another behavioural challenge. After moving to The Edge building, the firm noticed that many employees were using the personalized lockers on a permanent basis. As said before, this smart office works with hot desks: no employee has an individual working space. Therefore, personal belongings need to be stored in one of the lockers, which are in multiple places of the building. Soon after moving to The Edge building, however, the facilitative staff of Deloitte noted that many employees began to see lockers as their own, individual asset.

What to do with all the data?

A more fundamental challenge of smart offices relates to data. Interviewees from Deloitte, Croonwolter&dros and Signify stated that registering data about office usage is one thing but making

sense of this information and effectively using it is a second. In the words of the Deloitte interviewee (appendix A): "It is still challenging to make sense of all the data." This statement relates to the given that the office collects vast amounts of information through its sensors, and this information is visually represented through dashboards. These dashboards display varieties of real-time data points, such as the amount of people in the building, energy usage (per section) and temperature heat maps. In theory, this gives facility staffers unique insights into how the building operates and act upon this information. However, this way of thinking does not necessary align with office dynamics. As the interviewee of Deloitte (appendix A) said: "What if, suddenly, we get a call from a customer who wants to have a meeting with us and we decide to book a room in this just closed section, because there are no other rooms available? What happens if we arrive at that meeting room and discover it hasn't been cleaned yet, although the dashboard says otherwise, because of human fault?"

Croonwolter&dros and Signify are also having difficulties making sense of the output of information, albeit to a lesser degree. However, they still struggle with managing the output of their smart office statistics. The interviewee of Signify (appendix D) says the following: "Let's say we find out that some employees use more energy than other employees, because they like to increase the heating. Is it then our responsibility as a company to try to change this behaviour, or should we let employees completely be themselves? No, smart building technologies have not put an end to the everlasting debate around the office thermostat."

Long-term assessment

The most 'senior' Dutch smart office tenant is Deloitte. This company has been renting their smart accommodation since 2015 and can therefore provide a unique long-term assessment. Asked about their experiences, the Deloitte interviewee (appendix A) said the following: "If we would develop The Edge today, I think we would redo almost everything." This statement doesn't relate to the given that the fundamentals of the office were wrong, but that the development process and technology have radically changed in recent history. Back then, all smart features and infrastructure were specially designed and built for The Edge building. "It was a real on-site Research & Development process, with commissioning taking months", as the Deloitte interviewee says. The company soon discovered that the technological infrastructure, such as Ethernet-powered LED-lightning, was costly and aged fast. Furthermore, all sensors in the building register a specific metric, such as humidity or the number of people in a room. As of now, most smart sensors can register multiple datapoints, instead of one. By doing so, (fairly) new smart offices need less sensors, reducing costs. "The network infrastructure can be outdated the moment you install it", says the Deloitte interviewee. Therefore, companies should opt for open and flexible (technological) BMS standards, as Zigbee or Matter. With these protocols, it is possible to replace sensors and update the smart infrastructure of a building, instead of completely replacing it. This is advisable given the fact that sensors have a relatively short lifespan, according to the interviewee.

Do smart offices add value?

Most smart office tenants state that they are happy with their current accommodation and that their office adds value. This sentiment can be illustrated by the interviewee from Coca-Cola (appendix C): "According to our survey, employees like the office. They think it looks modern and feels fresh. Also, they value flexible working approach." Coca-Cola does stress that moving into the new office required a certain change of mentality. "Before moving into this office, around 80 percent of the

employees were working from a permanent, fixed desk. In our current office, nobody has a permanent desk. This caused some stress amongst employees in the first few months after moving. People booked the same desk five days in a row, and did this on Monday morning, directly after the schedule slots opened."

Croonwolter&dros also changed its way of working while moving into the new (smart) office. The interviewee said (appendix B): "Before moving, around 60 percent of the floor space was destined for individual use, and 40 percent was communal space, such as for meetings and events. Now, these numbers have switched. The office has become a more social place, where teams gather to brainstorm and to create new ideas. Individual tasks have become more hybrid: co-workers can carry these out from their home, the library or from somewhere else."

Added value based on what?

Only one interviewee is not sure whether their smart office ads value: APG. This company mentions that they haven't done any proper evaluation of the office space and is therefore unable to answer the question whether it adds value (appendix F). This answer is noteworthy, since only halve of interviewees have evaluated their (new) smart office space: Coca-Cola, Deloitte and Signify. These companies have evaluated the new accommodation, including a survey among employees. According to them, the outcomes are positive, without disclosing further specifics.

The other interviewees haven't properly evaluated their smart office yet. Despite, Alliander and Croonwolter&dros (appendices B & E) do share the opinion that their current (smart) office space adds value. Their argumentation is mostly built upon anecdotal evidence, such as positive stories from employees.

Conclusion

All Dutch smart office tenants interviewed utilize smart building technologies in their office spaces, with most of those technologies being accessed using a smartphone app. These technologies have a positive impact on office life, with several tenants citing decreased facility costs and increased employee satisfaction as benefits. While it is difficult to measure the effect on productivity with data (capture by sensors), many of the interviewed tenants reported that their smart offices add value. Specifically, smart offices have led to increased collaboration and synergy amongst employees, according to the interviewees. Furthermore, several tenants use their smart offices for marketing and branding purposes, either showcasing their office space or advising customers about smart office possibilities.

Chapter 5: Conclusion and discussion

Since 2015, multiple so-called smart offices have opened their doors in The Netherlands. Given the uncertainty regarding the motivations of pioneering companies renting such properties and their presumed benefits, this thesis focused on the perspective of smart office tenants. The main question of this thesis is:

"To what extend do smart offices add value for tenants?"

To answer this question, a qualitative research approach was used. This approach comprises three methods: studying scientific literature, researching high-quality journalistic sources, and having semi-structured interviews with smart office tenants as part of a multiple case study research.

Smart offices can be defined as: "… intelligent buildings with integrated aspects of enterprise, control and materials and construction, implemented both individually and as a system to be adaptable" (Buckman et al., 2014, p. 104). Although Dutch smart offices vary greatly in 'degrees of smartness', the baseline is formulated by the availability of a smartphone-app for employees and (facility) staff and a BMS. Through this smartphone-app, employees are offered a range of smart office features, such as the possibility to regulate HVAC settings and reserve (meeting) rooms. The BMS comprises the 'digital layer' of the office building, including the sensors that register datapoints.

The use of smart office features varies between tenants, with interviewees finding certain features more useful than others. Most tenants do state that these features have added value since they improved office life, sustainability (and thus decreased facility costs), and increased employee satisfaction. Furthermore, some tenants use their smart office for marketing and branding reasons and were able to downsize their overall office space by implementing new ways of working, like hotdesking and hybrid working. However, it is difficult to back-up these claims with data since halve of the interviewed smart office tenants hasn't properly evaluated their current property (yet).

Furthermore, not every smart office tenant made a conscious decision to rent such office space over conventional property. A minority of tenants were specifically set out to rent smart office space due to their focus on sustainability and wish to implement technological features. Most tenants based their decision on more traditional real estate factors, such as a decent price-to-quality ratio, good location, and specific office characteristics (like open floorplans). There is one similarity between all tenants. Whilst looking for new office space, all tenants shared the same expectation: to increase collaboration and synergy amongst employees.

Smart offices do not only offer benefits, but also challenges. The main challenge is that registering office data is one thing, but making sense of this information and effectively using it is a second. Multiple tenants stated they are having difficulties with processing the vast amounts of information their sensors register and acting upon it. Also, office users (employees and guests) are not always using the smart features accordingly, creating a suboptimal office experience.

Concludingly, smart offices seem to add value for most tenants, albeit to varying degrees. Only one tenant was not sure whether their smart office space adds value, citing a lack of a thorough evaluation. This explanation is noteworthy, since only halve of the interviewed tenants have evaluated their smart office property, for example by surveying employees or a management

evaluation. Therefore, the answer to whether smart offices add value for tenants is not always based on numbers, but also on sentiments.

Discussion

The interviews were done with tenants: business executives that were (partly) responsible for the firms (re)location decision to the current smart office. Given their position within the firm, their answers relating to the central question of this thesis may not be neutral. As became clear during this thesis, some of the interviewed tenants used their smart office space for marketing and branding reasons, for example because they consult in smart office concepts or sell required (technical) infrastructure. Therefore, it seems unlikely that they would reflect negatively on their location decision, since this goes against (a part of) their business model. This possible subjectivity doesn't negatively affect the validity of the results, though. The interview results might be subjective, but the initial goal of the research was met: to gain insight in the expectations and motivations by tenants. Businesses don't necessarily act in a purely rational way, since decisions can be influenced by emotions (Haapakangas et al., 2018, p. 119).

This subjectiveness does have implications for possible policies. Since the motivations of smart office tenants to rent such office space are varied, just as the backgrounds of tenants, it is difficult to draw general conclusions for policy recommendations.

Also, given the semi structured interview approach of this thesis, interviewees can nuance or add statements according to their own insights. Although this potentially increased the richness of this thesis, it also made it more difficult to compare answers between interviewees and to formulate one, overarching answer to the main question of this thesis. Therefore, the degree to which smart offices add value for tenants are personal and highly dependent on context.

Furthermore, the information from interviewees had to be taken at face value. In other words: there was no possibility to fact check everything the interviewee says. Multiple tenants stated that their smart office adds value and that they have (some form of) evaluation to back this statement up, but these reports were confidential. For example: one interviewee (appendix A) claimed that their smart office had reduced facility costs by 40 percent. This and similar statements could not be verified by the author. However, since this thesis focuses on the perspective of tenants, which is personal by nature and does not necessarily have to be data-driven, this given does not undermine the reliability and validity of the research.

Further research

There are multiple avenues for further research. This thesis illustrated that the Dutch smart office market is characterized by varying degrees of smartness. Out of practical reasons, this thesis therefore formulated a checklist based on literature to check whether an office can be considered as such. Obviously, fellow researchers could follow-up on this and investigate when and how an office can label itself as smart. This avenue is especially interesting given the lack of institutionalized governance regarding the topic of smart buildings, and technology in real estate in general. As of now, there is not one widely recognized organization that holds the power to certificate smart buildings in the way that, for example, properties must adhere to standardized, unformal energy label rules. Therefore, nobody exactly knows how (not) smart a certain building is.

Follow-up research can also focus on the longevity of smart offices. As of now, the most senior Dutch smart office building was taken into use in 2015, which is, especially by real estate standards, a short term. The interviewee of Deloitte (appendix A) stated that if they would have to develop their current smart office today, they would redo almost everything. This sentiment mostly relates to the given that the technology sector has rapidly changed over the last years. For one, the quality of sensors greatly increased. Thus, it could be interesting for researchers to keep monitoring the performance of smart offices and longevity over longer periods of time.

Lastly, follow-up research can focus on the location behaviour of smart offices. Deloitte (Wellener et al., 2018) stated that "technology appears to be changing the most fundamental truth about commercial real estate, namely that the value for a property is mainly based on its location." The consulting company then argues that the implementation of smart office features can be more relevant to the price dynamics of commercial real estate than a locations property, which historically is one of the biggest elements of an office's prize. It goes without further saying this is a very interesting question to research, especially from an economic geography point of view. For example, does the implementation of smart office features 'overshadow' the value of location? And do smart offices follow a different location pattern than conventional properties?

Bibliography

ABC Global Status (2021). *Why the built environment?* Retrieved on 6-7-2022 from https://architecture2030.org/why-the-building-sector/

Aksoy, M. & Uzunoglu, S.S. (2020). Assessments of user satisfaction in an intelligent office building in Istanbul. *Journal of Facilities Management*, 18(3), 325-340. DOI 10.1108/JFM-05-2020-0030

Al Dakheel, J., Del Pero, C., Aste, N. & Leonforte, F. (2020). Smart buildings features and key performance indicators: A review. Sustainable Cities and Society, 61 (2020).

Apanaviciene, R., Vanagas, A. & Fokaides, P.A. (2020). Smart Building Integration into a Smart City (SBISC): Development of a New Evaluation Framework. *Energies*, 13(9), 21-29. doi: 10.3390/en13092190

Appel-Meulenbroek, H.A.J.A., Budie, B., Kemperman, A.D.A.M. & Weijs-Perrée, M. (2019). Employee satisfaction with the physical work environment: The importance of a need based approach. *International Journal of Strategic Property Management*, 23(1), 36-49. https://doi.org/10.3846/ijspm.2019.6372

Appel-Meulenbroek, A., Kemperman, A., Van de Water, A., Weijs-Perrée, M. & Verhaegh, J. (2022). How to attract employees back to the office? A stated choice study on hybrid working preferences. *Journal of Environmental Psychology*.

Berg, B.E. van den (2019). Smart Offices. Retrieved on 20-9-2022 from https://studenttheses.uu.nl/handle/20.500.12932/34320

Boeije, H., Scheepers, P. & Tobi, H. (2016). *Onderzoeksmethoden*. Amsterdam: Boom Uitgevers.

BREEAM NL (2022). *Projecten*. Retrieved on 19-12-2022 from https://www.breeam.nl/projecten/

BRE Group (2020). *One of the world's highest BREEAM-rated major office buildings. Bloomberg, London*. Retrieved on 4-1-2023 from https://bregroup.com/case-studies/breeam-new-construction/one-of-the-worlds-highest-breeam-rated-major-office-buildings-bloomberg-london/

Brooks, D.J. (2011). Intelligent buildings: an investigation into current and emerging security vulnerabilities in automated building systems using an applied defeat methodology. *Australian Security and Intelligence Conference*, Security Research Institute Conferences, 16-26.

Buckman, A.H., Mayfield, M. & Beck, S.B.M. (2014). What is a Smart Building? *Smart and Sustainable Built Environment*, 3(2), 92-109.

Burawoy, M. (1998). The Extended Case Method. *Sociological Theory*, 16(1), 4-32.

Carlini, J. (1988). The Intelligent Building Definition Handbook. Washington DC: IBI.

CBRE (2022a). *Five Trends Shaping Our Future Workspaces*. Retrieved on 6-7-2022 from https://www.cbre.nl/en-gb/insights/articles/five-trends-shaping-our-future-workspaces

CBRE (2022b). *Nederlandse kantoren naderen belangrijk klimaatstation*. Retrieved on 2-8-2022 from https://insights.cbre.nl/nederlandse-kantorenmarkt/.

Clements-Croome, D. (2011). Sustainable intelligent buildings for people: A review. *Intelligent Buildings International*, 3(2), 67-86.

Cook, D.J. & Das, S.K. (2007). How smart are our environments? An updated look at the state of the art. *Pervasive and Mobile Computing*, 3(2), 53-73.

Cushman & Wakefield (2022). *Office of the future revisited*. Retrieved on 05-07-2022 from https://www.cushmanwakefield.com/en/insights/office-of-the-future-revisited

Diekman, A. (2022). Edge Amsterdam West volledig verhuurd met komst Athora. *PropertyNL*, 28-9-2022

EDGE (2019). EDGE Olympic received WELL Platinum. Retrieved on 19-12-2022 from https://edge.tech/article/press/edge-olympic-received-well-platinum

Everett, R. (2008). The 'building colleges for the future' program. Delivering a green and intelligent building agenda. *New Review of Information Networking*, 14(1), 3-20.

Facto (2018). Central Office VodafoneZiggo omgevormd tot Smart Building. Retrieved on 20-9-2022 from https://www.facto.nl/9726/smart-building-vodafoneziggo

Fotios, S.A. & Cheal, C. (2010). A comparison of simultaneous and sequential brightness judgements. *Lightning Research & Technology*, 42(2), 183-197.

Ghaffarianhoseini, A., Al Waer, H., Ghaffarianhoseini, A., Clements-Croome, D.J., Berardi, U. & Tookey, J. (2017). Intelligent or smart cities and buildings: a critical exposition and a way forward. Intelligent *Buildings International*, 10(1), 1-8. DOI: 10.1080/17508975.2017.1394810

Gispen (2021). Hoofdkantoor Croonwolter&dros. Retrieved on 4-1-2023 from https://www.gispen.com/nl/projecten/alle-kantoor-projecten/croonwolter-dros/

Haapakangas, A., Hallman, D.M., Mathiassen, S.E. & Jahncke, H. (2018). Self-rated productivity and employee well-being in activity-based offices: The role of environmental perceptions and workspace use. *Building and Environment*, 145(2), 115-124.

Hanff, P. (2018). *OVG verkoopt Kantoor MM25 in Rotterdam*. Retrieved on 20-9-2022 from https://www.vastgoedmarkt.nl/133813/ovg-verkoopt-kantoor-mm25-rotterdam

Hentenaar, R. (2019). Slim kantoor EDGE Amsterdam West trekt vierde grote huurder aan. *Vastgoedjournaal*, 14-2-2019.

Hermus, S. (2021). Bij Deloitte bouwen ze nu het kantoor van de toekomst, de heel nabije toekomst wel te verstaan. *De Volkskrant*. 6-8-2022

Holden, J. (2008). Introduction to Intelligent Buildings: Benefits and Technology. Walford: BRE Global

JLL (2016). *A surprising way to cut real estate costs*. Retrieved on 4-1-2023 from https://www.jll.ca/en/trends-and-insights/workplace/a-surprising-way-to-cut-real-estate-costs

JLL (2020). *The future of global office demand*. Retrieved on 6-7-2022 from https://www.jll.nl/nl/trends-inzichten/onderzoek/future-of-office-demand

Katz, D. & Skopek, J. (2009). The CABA building intelligence quotient programme. *Intelligent Buildings International*, 1(4), 277-295.

Kim, J. & De Dear, R. (2013). Workspace satisfaction: The privacy-communication trade-off in open-plan offices. *Journal of Environmental Psychology*, 36, 18-26. http://dx.doi.org/10.1016/j.jenvp.2013.06.007

Kwon, M., Remøy, H., Van den Dobbelsteen, A. & Knaack, U. (2019). Personal control and environmental user satisfaction in office buildings: Results of case studies in the Netherlands. *Building and Environment*, 149, 428-345.

Le Gal, C., Martin, J., Durand, G. (2000). *Smart Office: An Intelligent and Interactive Environment*. In: Nixon, P., Lacey, G., Dobson, S. (eds) Managing Interactions in Smart Environments. London; Springer. https://doi.org/10.1007/978-1-4471-0743-9_10

Liu, K., Lin, C. & Qiao, B. (2008). A multi-agent system for intelligent pervasive spaces. *Proceedings of IEEE International Conference on Service Operations and Logistics, and Informatics*, 1005–1010

Masoso, O. T. & Grobler, L. J., (2010). The dark side of occupants' behaviour on building energy use. *Energy and Buildings*, 42(2), 173-177.

Mohammadshirazi, A., Kalkhorani, V.A., Humes, J., Speno, B., Rike, J., Ramnath, R. & Clark, J.D. (2022). Predicting airborne pollutant concentrations and events in a commercial building using low-cost pollutant sensors and machine learning: A case study. *Building and Environment*, 213(2022), 108833, https://doi.org/10.1016/j.buildenv.2022.108833

Powell, J.A. (1990). Intelligent Design Teams Design Intelligent Buildings. *Habitat International*, 14(3), 83-94.

Powell, K. (2010). Selling (and Buying) Smart Building Solutions. *Connectivity Week*, Santa Clara, California, United States.

Randall, T. (2015). *The Smartest Building in the World: Inside the connected future of architecture*. Retrieved on 12-01-2022 from https://www.bloomberg.com/features/2015-the-edge-the-worlds-greenest-building/

Rijksdienst voor Ondernemend Nederland (2022). Ruim de helft van de kantoren niet klaar voor energielabel C. Retrieved on 30-08-2022 from https://www.rvo.nl/nieuws/ruim-de-helft-van-de-kantoren-niet-klaar-voor-energielabel-c

Ruíz-Zafra, Á., Benghazi, K., & Noguera, M. (2022). IFC+: Towards the integration of IoT into early stages of building design. *Automation in Construction*. DOI:10.1016/j.autcon.2022.104129

Sanderson, D.C. & Edwards, V.M. (2016). Determinants of satisfaction amongst tenants of UK Offices. *Journal of Corporate Real Estate*, 18(2), 102-131.

Salosin, A., Gamayunova, O. & Mottaeva, A. (2020). The effectiveness of the Smart Office system. *Journal of Physics: Conference Series 1614 (2020).* doi:10.1088/1742-6596/1614/1/012028

Schellekens, M. (2019). *Smart Offices: Het begin van een nieuwe generatie kantoren*. Retrieved on 20-9-2022 from https://files.vastgoedbibliotheek.nl/Server/getfile.aspx?file=docs/MSRE/19-2/Schellekens_MR.pdf

Tomusk, K. (2022). Revisiting the iconic Edge building eight years on. *PlaceTech*. 21-10-2022

Tuzcuoglu, D., De Vries, B., Yang, D. & Sungur, A. (2021). What is a smart office environment? An exploratory study from a user perspective. *Journal of Corporate Real Estate.* 24(1).

Voort, D.J.M. van der & Wegen, H.B.R. van. (2005). *Architecture in Use*. First edition. London: Routledge.

Wang, Z., Wang, L., Dounis, A.I. & Yang, R. (2012). Multi-agent control system with information fusion based comfort model for smart buildings. *Applied Energy*, 99, 247-254.

Wellener, P., Michalik, J., Ashton Manolian, H. & James, G. (2018). *Smart Buildings: Four considerations for creating people-centered smart, digital workplaces.* Retrieved on 22-03-2022 from https://www2.deloitte.com/br/en/pages/technology-media-and-telecommunications/articles/smart-buildings.html

Wong, J.K.W. & Li, H. (2009). Development of intelligence analytic models for integrated building

management systems (IBMS) in intelligent buildings. *Intelligent Buildings International*, 1(1), 5-22

Wong, J.K.W., Li, H. & Wang, S.W. (2005). Intelligent building research: a review. *Automation in Construction*, 14(1), 143-159.

Wright, E. (2020). The sensors that brought EDGE's workforce back by May. *EGI Radius*. 5-8-2022

Yang, J. & Peng, H. (2011). Decision support to the application of intelligent building technologies. *Renewable Energy*. 22(3), 67-77.

Appendices

Appendices A till F are confidential. These appendices showcase the full transcriptions of the interviews with tenants. Interviewed tenants have participated on the condition of anonymity and therefore these transcripts are not publicly available. Obviously, the involved university staff (supervisor and second reader) can access these appendices.

Appendix G

Interview guide used to interview tenants.

What are the characteristics of smart offices in The Netherlands?

- Are you familiar with the term smart office?
    - When, in your eyes, can an office classify as smart?
    - Was it a conscious decision to rent a smart office?
- According to literature, smart offices are defined by 4 pillars (adaptability, control, enterprise, and materials & construction): to what extent are these 4 pillars present in your office?
    - Adaptability
    - Control
    - Enterprise
    - Materials & construction

What are the expectations of smart office tenants before renting a smart office in The Netherlands?

- Smart offices offer certain benefits, according to literature. Before renting this office, what did you expect from a smart office?
- Did you expect one of the follow presumed benefits of smart offices?
    - Increase in worker productivity?
    - Increase in happiness of employees?
    - Less facility costs (for example, a lower energy bill and/or decrease in cleaning costs)?
    - Mitigation of physical and cybersecurity risks?
    - Easier to attract/ retain employees?
        - War on talent
- Are there any other motivations for you as a tenant to rent out a smart office space?
- Did you take other (conventional) offices in consideration?
    - Why did you choose this smart office over conventional properties?

Theory versus reality: to what extent do the expectations of smart offices live up to the reality?

- To what extent do you use the facilities of your smart office? In other words, are the presumed benefits met?
    - Increase in worker productivity?
    - Increase in happiness of employees?
    - Less facility costs (for example, a lower energy bill and/or decrease in cleaning costs)?
    - Mitigation of physical and cybersecurity risks?
    - Easier to attract/ retain employees?
        - War on talent
- In your opinion, what smart office features are most important?