

Energy-efficient and 'healthy' offices

An approach for office renovations focused on energy efficiency
and Indoor Environmental Quality



Colophon



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Graduation

MSc Architecture, Urbanism and Building Sciences
Track: Management in the Built environment

Design and Construction Management
Energy transition in the existing building stock

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Ancora Imparo
(I am still learning)



- Michelangelo, 87 years

Preface

Over the past year, I have been dedicated to this thesis. It was a lengthy process with lots of ups and downs along the way; from formulating a research focus, to finding relevant cases and, eventually, to writing a sufficient advice report. Unfortunately, private circumstances led to a delay in conducting my research and finalising my thesis. Yet, it has been a rewarding journey that has allowed me to develop myself into the graduate student I am today; I have gained a lot of knowledge, discipline, and enthusiasm for real estate management throughout this process and my entire student journey.

During the past five years of my student journey, I have met faculty members and experts in my field who have always shared their knowledge and expertise through their lectures, publications, and guidance with enthusiasm. Their contributions have broadened my understanding of the field of Management in the Built Environment and inspired me to dive deeper in the given context. This allowed me to develop myself and to make choices for the next steps in my career. I am forever grateful and humbled to be a part of a larger community that thrives on intellectual curiosity and willingness to make the built environment a place for all, by constantly setting new boundaries to guide towards a healthy living and working environment for all.

Undertaking this thesis would not have been possible without the support and guidance of numerous individuals who have played important roles in shaping my academic and personal growth. Therefore, I want to express my appreciation to both of my supervisors, Queena Qian and Ad Straub, for their encouragement, insightful feedback, and outstanding patience throughout this process. Their expertise and dedication to my research have been beneficial in refining my ideas and challenging me to reach new heights.

To my family and friends, I owe a lot of gratitude for their unwavering support, patience, and belief in my abilities. Their love and encouragement have been constant sources of motivation during the highs and lows of my academic journey. Besides, I want to thank my colleagues for their support and guidance over the past year. Not only have I had the opportunity to work in the field, they also were open to help and think along when needed.

This thesis would not have been possible without the participants who have offered their time and cooperation for data collection and analysis. Their contributions have been crucial in the development and validation of the ideas presented in this thesis. I hope that this thesis contributes to the existing body of knowledge, sparks further discussion, and inspires future researchers in their pursuit of new knowledge.

Enjoy reading,

Anja van der Ham

October 2023

Abstract

Renovation of existing buildings is proposed as a solution for buildings that do not fit the Climate Target Plan 2030. In the Netherlands, there is a new mandate requiring Dutch office buildings to attain a minimum EPC class C rating by January 1st, 2023. Recent studies indicate that 10% of Dutch office buildings are currently rated at EPC class D or lower, while numerous existing office buildings have yet to obtain an EPC rating. This situation necessitates a surge in renovation projects in the near future. However, a complex relationship exists between energy-efficient measures and Indoor Environmental Quality (IEQ) post-renovation. Healthy buildings, characterised by adequate IEQ, contribute to heightened overall satisfaction and productivity among their occupants. This research is centred on crafting an advisory report aimed at guiding the decision-making process preceding office renovations for owners of Dutch owner-occupied offices. The following main research question relates to the goal of this research: *“How can the renovation decision-making process, prior to renovation, of private owners of Dutch owner-occupied office buildings be guided with a focus on improving energy efficiency and Indoor Environmental Quality?”*. The objective is to surpass the EPC class C requirements while concurrently prioritising IEQ enhancements to boost employee satisfaction and productivity. To achieve this, several case studies were conducted through in-depth interviews with stakeholders involved in the renovation projects. This approach sought to gain insights into the decision-making processes of office owners prior to the execution of renovation practices. The findings of this research hold significance for those initiating future office renovation projects, project managers, and public authorities seeking strategies to accelerate the rate of energy-efficient and healthy office renovations. The study's outcomes indicate that the decision-making process preceding office renovations can indeed be steered towards achieving both energy efficiency and improved IEQ. This can be accomplished through a comprehensive and cooperative approach that emphasises awareness, education, regulation, and financial security.

KEYWORDS | office renovations, renovation guide, Indoor Environmental Quality, healthy offices

Executive summary

Introduction & Problem statement

A report of the European Commission (2020) highlights the need for greener buildings, given that most existing buildings are not energy-efficient, often relying on fossil fuels and outdated technologies. Non-residential buildings, including public and private offices, constitute a substantial portion of the EU's building stock, and their energy intensity is on the rise. Juan et al. (2010) stated that offices have a considerable level of energy consumption compared to other building types. To align with the Climate Target Plan 2030, which aims to reduce greenhouse gas emissions by at least 55% by 2030, significant renovations are essential. In pursuit of these targets, the European Commission (2020) has emphasised the importance of enhancing information, legal certainty, and incentives for renovations. Measures like the Energy Performance Certificate (EPC) aim to inform building performance related to energy use, renewable energy sources, and energy costs. In the Netherlands, regulations require office buildings larger than 100 sqm to achieve EPC class C by January 1st, 2023. Minimum energy performance standards are seen as vital for boosting renovation rates to meet EU climate targets (Sunderland & Santini, 2020). Despite these efforts, a significant number of Dutch office buildings do not meet the required standards, as 10% of the office buildings are still labelled with EPC class D or worse (Netherlands Enterprise Agency, 2018). Besides, many office buildings remain without an official energy label, partly due to a lack of municipal enforcement (Luimstra, 2023). This situation necessitates a substantial number of renovations in the near future.

However, focusing solely on energy efficiency during these renovations can negatively impact Indoor Environmental Quality (IEQ). Research indicates a conflicting relationship between energy consumption and IEQ, where energy-efficient measures should not compromise IEQ, and IEQ enhancements should not incur additional energy costs (Roumi et al., 2021). Poor IEQ can adversely affect occupants' physical and psychological health, leading to reduced productivity (Singh et al., 2010; Mahbob et al., 2011). According to Roumi et al. (2023), the IEQ of an office building is affected by HVAC systems (Heating, Ventilation, and Air Conditioning), lighting systems, and intelligent control systems which aim at creating a pleasant indoor environment. Considering this conflicting relationship, there is a need to encourage office building renovations to achieve EPC class C without neglecting IEQ. In relation to this, Shahzad et al. (2017) mention that most office buildings are either considered as comfortable or energy-efficient. The revised Energy Performance of Buildings Directive (EPBD) emphasises the importance of energy upgrades that contribute to a healthy indoor environment (European Parliament and the Council of the European Union, 2018; Dorizas et al., 2019; Fabbri & Dorizas, 2019). Given the substantial number of offices that require energy-efficient renovations, it is essential to motivate initiators to prioritise both energy-efficiency and IEQ improvements. The existing approach in the Netherlands, focusing on achieving EPC class C by 2023, falls short in addressing IEQ and future energy performance standards. A more comprehensive approach, moving toward carbon neutrality by 2050, can prevent the need for future renovations.

The decision-making process related to renovations is a complex process involving multiple stakeholders and diverse information sources (Ribeiro & Videira, 2008). Motivations for office renovations often relate to energy-efficiency and indoor climate issues, driven by the obligation to comply with governmental standards (Jensen & Maslesa, 2015; Dorizas et al., 2019). However, research suggests that key drivers for renovation include improving thermal comfort, air quality, natural lighting, and occupant health, aspects not covered by energy labels. Existing barriers in

the renovation decision-making process include a lack of information, unclear definitions, and coordination and communication challenges among stakeholders (Konstantinou et al., 2021). These barriers highlight the potential for improvement in information provision, outcome definition, and streamlined coordination and communication. Therefore, this research aims to develop an advisory report to guide the decision-making process before renovating Dutch office buildings, in order to limit or avoid the aforementioned barriers. This report aims to guide the decision-making process on improving energy efficiency and IEQ in tandem to enhance employee productivity and satisfaction while considering long-term sustainability goals. This relates to the statement of Kwon (2020), who predicts that the demand for renovated office buildings will decrease if there is an absence of the focus on enhanced user satisfaction post-renovation. The main research question of this research is: *“How can the renovation decision-making process, prior to renovation, of private owners of Dutch owner-occupied office buildings be guided with a focus on improving energy efficiency and IEQ?”*. Additionally, several sub research questions are central in this research:

1. What does the decision-making process prior to renovations entail for private owners of Dutch owner-occupied office buildings?
2. What are the motivations and barriers of private office owners to carry out energy-efficiency renovations in Dutch owner-occupied offices?
3. To what extent are private owners of Dutch owner-occupied offices aware of the impacts post-renovation, based on IEQ and occupant’s productivity?
4. What are the motivations and barriers of private office owners to consider IEQ during the renovation process of Dutch owner-occupied offices?
5. What are specific elements and critical moments in relation to the different identified phases of the decision-making process prior to renovation of private owners of Dutch owner-occupied office buildings?

Methodology

This research is qualitative in nature, involving non-numerical data collection and analysis. It employs the qualitative research method of semi-structured in-depth interviews as part of a case study approach. The case study projects are selected based on a non-probability, self-selection sampling by using pre-determined case selection criteria. The case selection criteria are derived from the theoretical framework, aligning with different thematic elements. General criteria such as construction year and building type are also considered. These criteria ensure that various aspects of the research are covered by the selected cases. The target group comprises owners

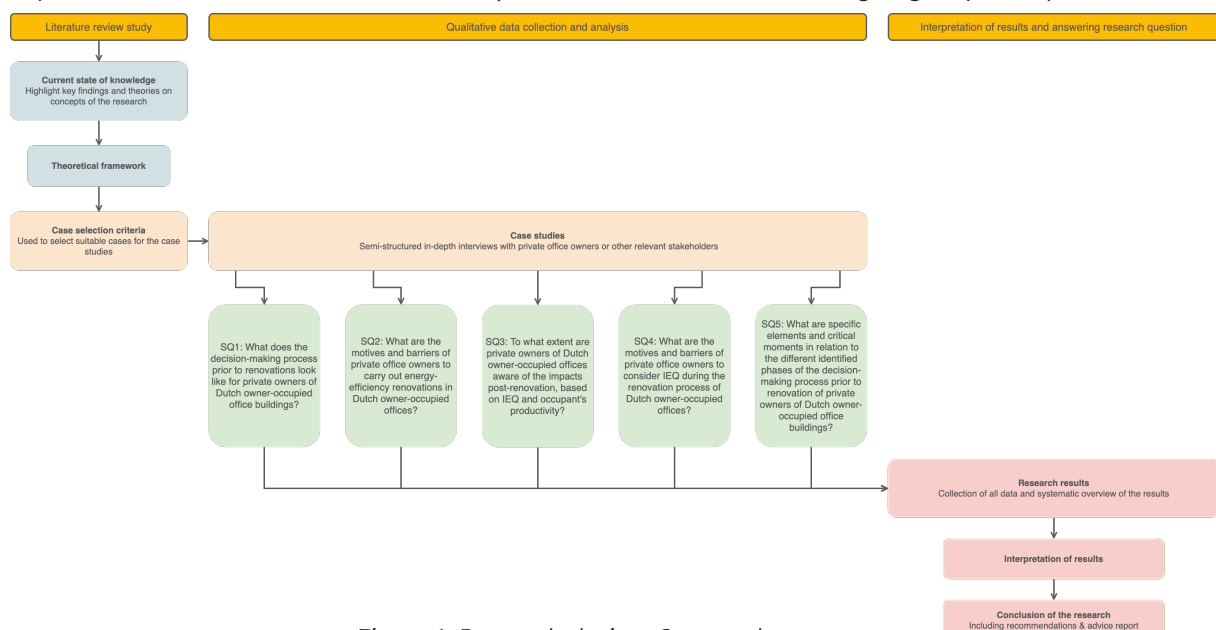


Figure 1. Research design. Own work.

of Dutch owner-occupied offices undergoing or planning renovation, primarily to meet the EPC class C requirement. The cases encompass owner-occupied office buildings already renovated or scheduled for renovation in the near future. These cases allow for an analysis of the decision-making processes of office owners concerning energy-efficiency and IEQ renovations, assisting in identifying missing aspects and guiding future office renovation initiators. Figure 1 illustrates the research design of this research. Data collection is conducted through in-depth semi-structured interviews with office owners and other relevant stakeholders. The research employs an analytic induction method for data analysis, involving the formulation and testing of hypotheses based on initial investigations.

	Planning phase				
	Become aware	Getting interested	Gaining knowledge	Consider options	Making a decision
<i>Decision-making aspects prior to renovation</i>					
Case 1	Tripled energy bill in a short period of time. Focus on lowering energy bill and aiming to consequently obtain EPC class C.	Not specifically mentioned after becoming aware.	Consult an advisor. Inspiration from vertical wind turbines of a client. Conversation with the municipality about wind turbines. Growth in interest after inspiration.	Aiming for the option with the biggest foreseen impact on a decrease of their energy bill costs. Not opt for the cheapest option.	Interviewee is initiator and office owner, makes final decision based on highest reward in terms of a decrease in energy bill costs.
Case 2	Organisation wants to focus on sustainability as an integral part of their total business operation, including their properties.	Interest for improved energy-efficiency in their office grew because it is part of the integral sustainability assignment.	Knowledge in-house because of hiring a sustainability manager. Consult additional advisors when necessary.	Establishment of a multi-year renovation strategy to ensure financial feasibility of different interventions.	Interviewee is sustainability manager; advises the initiator/office owner upon possible interventions.
Case 3	Because of EPC class C obligation. The office building does not comply yet and is in need of an energy-efficiency upgrade.	Not specifically mentioned after becoming aware.	Consult an advisor.	Only consider options presented in advice report.	Interviewee is initiator and office owners, makes final decision based on advice report.
Case 4	Several merging organisations needed to be housed at one location. Major office renovation needed for improved functional layout, consequently aiming for improving energy-efficiency to obtain EPC class C in time.	Not specifically mentioned after becoming aware.	Establishment of a project team with several bodies of knowledge in-house. Consult additional advisors when necessary.	Establishment of a multi-year renovation strategy to ensure financial feasibility of different interventions.	Interviewee is project leader of the renovation; advises the initiator/office owner upon possible interventions.
Case 5	Because of EPC class C obligation. The office building does not comply yet and is in need of an energy-efficiency upgrade.	Not specifically mentioned after becoming aware.	Consult an advisor.	Only consider options presented in advice report.	Interviewee is initiator and office owners, makes final decision based on advice report.

Table 1. Decision-making aspects, allocated to different decision-making phases. Own work.

Results

The decision-making processes of the participants involved in sustainable or energy-efficient office renovations is discussed by using a combination of discussion-making frameworks as found in literature to identify the different phases in the decision-making process of the participants. Table 1 provides an overview of the identified decision-making phases and its aspects, in relation to the different case projects.

In addition to identifying the different phases in the decision-making process, the interviews with the stakeholders of the case study projects revealed several motivations and barriers related to energy-efficient renovations. Some office owners were motivated by the need to prepare for future regulations, such as EPC class requirements. Others cited the desire to enhance their organisation's image and align with broader sustainability goals as key motivators. However, several common barriers emerged. A lack of knowledge was a significant hurdle, as office owners often considered renovation outside their core activities and sought external consultants for guidance. This lack of knowledge also translated into a lack of initiative for energy-efficient renovations, particularly among smaller organisations. Financial considerations played a crucial role, with some organisations hesitating to invest extensively due to uncertainty about the return on investment. Extensive renovation measures, like installing solar panels or mechanical ventilation systems, were seen as challenging and costly. To address financial concerns, some organisations developed multi-year renovation strategies to ensure financial feasibility. However, smaller organisations found it challenging to implement such strategies. Additionally, delays in renovation execution were encountered due to material delivery times and the unavailability of resources and labour, impacting project timelines.

The second part of the interviews focused on the concept of IEQ and its influence on office occupants. Initially, none of the interviewees were familiar with the IEQ concept, so they were provided with an introduction to IEQ and its aspects, such as air quality, thermal comfort,

acoustic comfort, and lighting comfort, and how these aspects affect the health, satisfaction, well-being, cognitive function, and productivity of office users. All interviewees indicated a profound understanding of the consequences of poor IEQ on productivity and job satisfaction after the introduction. Some renovations included measures that improved IEQ aspects, such as ventilation, ergonomic comfort, and personal control over workplace conditions. However, these improvements were not the primary motivation during the renovation process. Health and well-being of employees were recognized as important factors, with some interviewees emphasising the need to prioritise the health of employees as they spend a significant amount of their time at the office. Regarding job satisfaction and user satisfaction post-renovation, some interviewees expressed curiosity but mentioned that such aspects were not formally measured. They relied on informal feedback from employees to gauge satisfaction. When asked whether they would have made different renovation choices if they had been aware of IEQ aspects before the renovation, most interviewees mentioned the importance of employee health and well-being as factors that would influence their decisions. Barriers to considering IEQ during the renovation process included differences in personal preferences among employees for temperature, ventilation, and lighting, as well as a lack of knowledge about IEQ. The advisory third parties engaged during renovations typically did not include IEQ considerations in their reports, and participants often relied on these advisors for guidance. Additionally, a lack of initiative to address IEQ issues was common among interviewees, with a focus on achieving specific goals, such as meeting EPC class requirements or ensuring a return on investment.

The data collection and extensive elaboration of the research results eventually helped to develop a decision-making scheme that is generalised for this research. This scheme is presented in figure 2. The decision-making scheme incorporates red diamonds that emphasise critical junctures in the pre-renovation decision-making process. These pivotal instances were pinpointed through insights gathered through the interviews with stakeholders from the case study projects.

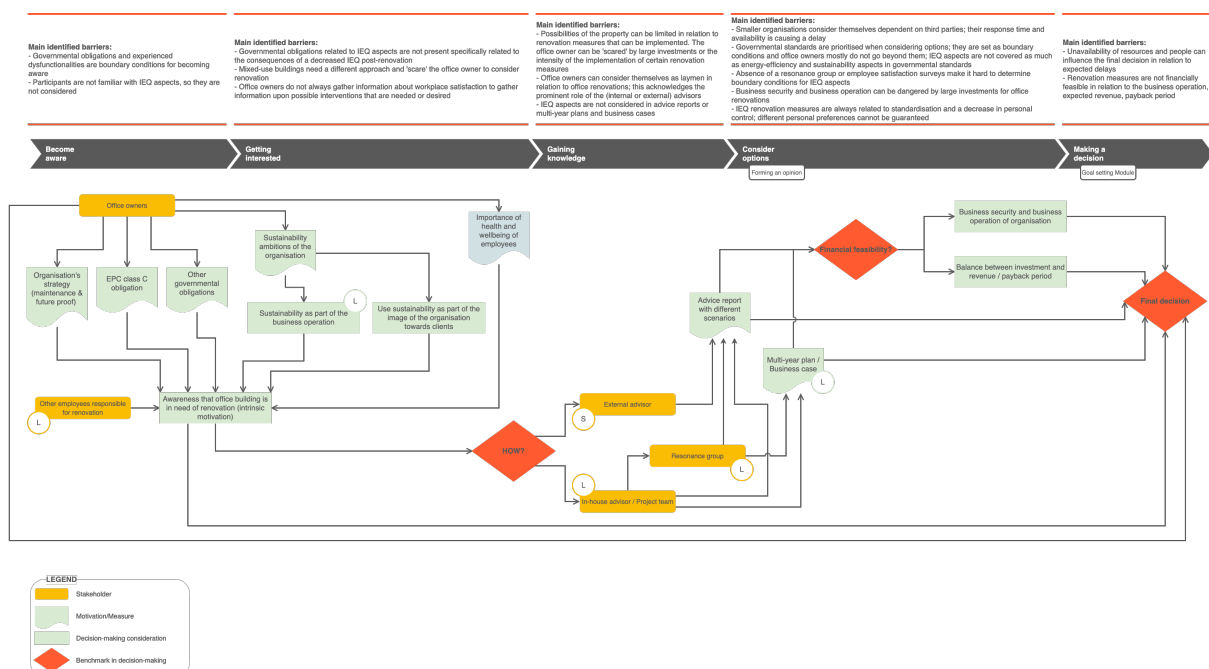


Figure 2. Decision-making scheme based on research results. Own work.

Discussion & Conclusion

The results are initially interpreted and evaluated, with a focus on the benchmark moments identified within the decision-making process. These benchmark moments include 'HOW?', 'Financial feasibility?', and 'Final decision', each of which is elaborated upon to provide a comprehensive interpretation of the research outcomes.

During interviews, participants from smaller organisations expressed similar reactions to the impending EPC class C obligation, primarily questioning themselves how they were able to carry out the renovation and where to start. They faced apprehension about large investments and approached the renovation process with caution. Office owners hired advisors who provided advice reports with multiple renovation scenarios. The advisors played a prominent role in their decision-making, and the advice report was often considered the only viable option. In terms of decision-making stages before renovation, all case projects had primary team members or client teams involved. The client team typically included the office owner and external advisors. However, differences were observed between smaller and larger organisations. Smaller organisations had simpler client teams, with the owner making decisions based on the advisor's recommendations. In contrast, larger organisations had more complex client teams, sometimes involving internal advisors or project teams. These differences reflected variations in the scale and professionalism of the renovation process.

Financial feasibility emerged as a critical benchmark moment in the decision-making phase. Smaller organisations expressed concerns about significant financial investments and the potential disruption to their business operations. This apprehension stemmed from their smaller size, fewer employees, and lower annual revenue. They perceived large investments as threats to their business security. Larger organisations, on the other hand, ensured financial feasibility through the establishment of business cases or multi-year plans, supported by internal advisors. These plans assessed financial investments in relation to operational costs. However, one case project involving a social housing association had to balance investments in office renovation against investments in housing stock maintenance due to rental income allocation.

The final benchmark moment in the decision-making process was the final decision itself, made by office owners. This decision was influenced by factors such as an organisation's strategy for the office building, governmental obligations, sustainability ambitions, and employee health and well-being. Advisors, advice reports, multi-year plans, business cases, and financial feasibility also played roles in influencing the final decision. In relation to case study projects, the consideration of IEQ consequences was notably lacking. IEQ was not a primary focus of the renovation projects. Instead, the main motivations were centred around energy cost reduction and compliance with EPC class C obligations. While many renovation measures had the potential to improve IEQ, there was limited awareness among office owners and employees regarding the monitoring and assessment of IEQ factors. In relation to the interpretation of the research result, figure 3 was drawn up to provide a summary of the barriers, indicating which stakeholders and measures could be involved to lower the chance of these barriers to occur during the decision-making processes of office owners before renovation of their property. Figure 3 is illustrated on the next page.

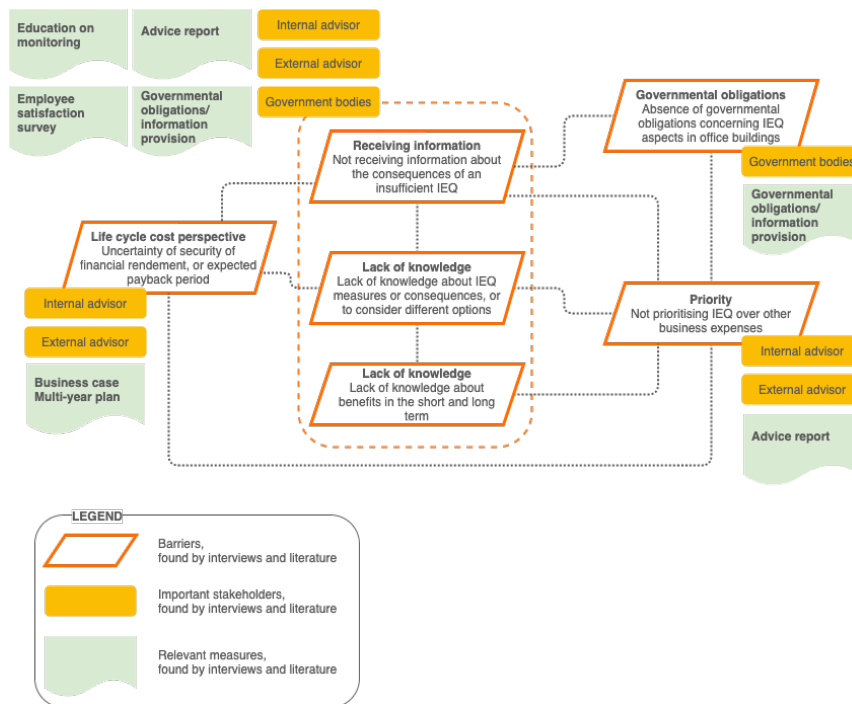


Figure 3. Summary of the interpretation of the results, focused on enhancing IEQ considerations during decision-making processes prior to office renovations. Own work.

To conclude this research, the primary research question is answered by establishing an advice report, designed to guide private owners of owner-occupied offices in making renovation decisions that concurrently enhance energy efficiency and IEQ. The main research question of this research is: “How can the renovation decision-making process, prior to renovation, of private owners of Dutch owner-occupied office buildings be guided with a focus on improving energy efficiency and IEQ?”. The advice report presents key strategies and considerations grouped according to different decision-making phases.

The first phases evolve around becoming aware and getting interested. This phase emphasises the importance of raising awareness about energy efficiency and IEQ. It advocates providing informative resources about IEQ and its implications, particularly on employee well-being. It highlights the role of education in helping office owners understand the benefits of integrated renovations, which not only yield financial advantages but also enhance user satisfaction and productivity. Additionally, it underscores the significance of conducting regular employee satisfaction surveys to trigger awareness and potential renovations. In the phase of gaining knowledge, the role of advisors takes centre stage. It suggests a shift in their role from merely providing information on energy efficiency to educating office owners about IEQ-related renovation measures. Education for advisors is also emphasised, with a call for the government to support this by providing updated IEQ information based on recent studies. Advisors are encouraged to play a more active role during the decision-making phase where office owners explore their renovation options. They should assist in selecting an integrated approach that simultaneously improves energy efficiency and IEQ. This phase also stresses the importance of conducting a comprehensive life cycle cost analysis, which considers not only initial investment but also long-term operational and maintenance costs. The establishment of multi-year plans or business cases is recommended to ensure financial feasibility. Finally, the final decision phase underscores the significance of making a decisive commitment to renovation measures that prioritise both energy efficiency and IEQ. It reinforces the importance of implementing the aforementioned key strategies and considerations in the decision-making process, ultimately leading to well-informed and holistic renovation decisions. Limitations & Recommendations

Limitations & Recommendations

Throughout the course of this research, several limitations emerged that influenced the study's outcomes. Due to the chosen case study research method, the sample size was inherently small and lacked diversity among the selected case projects. This limitation restricted the breadth of perspectives on the decision-making processes of private owners of owner-occupied offices and may have obscured valuable insights. The constrained access to case projects primarily resulted from time constraints and the execution of the case studies during the summer season. This made it challenging to engage office owners whose properties aligned with the case selection criteria and were willing to participate within the stipulated time frame. Notably, for two of the case projects, timely contact with the office owners proved elusive, leading to gaps in the data. To address these limitations and broaden the understanding of this topic, it is advisable to conduct longitudinal studies that monitor decision-making processes and outcomes over an extended period, rather than relying solely on retrospective questioning of office owners.

A second limitation stemmed from the fact that data collection relied on self-reported information from the study's participants. This introduced the potential for response bias and inaccuracies in the data. The study also revealed a notable lack of awareness among participants regarding Indoor Environmental Quality (IEQ). While this finding is important, it also underscored the limitations in exploring IEQ-related decision-making processes for office renovations. To mitigate this limitation and delve deeper into IEQ, it is recommended to conduct more in-depth IEQ studies with a specific focus on improvement measures and their effects on office occupants. These studies could benefit from interdisciplinary collaboration, involving experts from fields such as architecture, engineering, psychology, and public health, to comprehensively address the intricate nature of office renovations that aim to enhance IEQ.

Another limitation pertained to the limited availability of relevant literature on office renovations and IEQ. This scarcity of literature compelled the study to construct a decision-making scheme based on processes identified in renovations of different building types and owner categories. Additionally, IEQ, as a topic of interest, had limited existing literature. To address these gaps, conducting in-depth IEQ studies, as previously suggested, is crucial.

Lastly, the study highlighted the role of governmental obligations in raising awareness among office owners about the consequences of inadequate IEQ. However, before introducing such obligations, it is essential to assess the effectiveness of existing governmental policies related to energy efficiency and IEQ in office buildings. It is crucial to determine whether these policies drive meaningful changes in practice and, if not, how they should be adjusted to achieve their intended outcomes.

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Introduction

This introduction chapter examines the research context by providing background information on key concepts pertinent to this research. It comprehensively elaborates the problem statement to underscore the research's purpose and significance. Furthermore, this chapter justifies the research scope in order to establish a coherent contextual narrative. The chapter culminates by enumerating the research questions that guide this research.



Introduction

A report of the European Commission (2020), focused on an approach towards “greening our buildings”, emphasises that most of the existing buildings are not energy-efficient. This is due to the fact that most of these buildings are heated and cooled by fossil fuels, and “use old technologies and wasteful appliances” (European Commission, 2020, p. 1). In 2016, around 40% of the total building stock of the EU was covered by non-residential buildings of which an average of 30% belonged to public and private offices (European Commission, 2016). Overall, the energy intensity of these buildings is increasing (European Commission, 2020). A lot of these buildings will still be standing decades from now. Renovation of the existing building stock is an opportunity to redesign buildings in order to make them fit in the Climate Target Plan 2030, which was also proposed by the Commission. The Climate Target Plan 2030 aims to cut net greenhouse gas emissions in the EU by at least 55% by 2030 compared to 1990 (European Commission, 2020).

In order to reach the set targets, the European Commission (2020) has focused, among others, on strengthening the information, legal certainty, and incentives for renovation. Implementing an Energy Performance Certificate (EPC), or energy label, is a great example of strengthening the information about building performances when it comes to energy performance, share of renewables and energy costs (European Commission, 2020). The Netherlands Enterprise Agency (2018) published an amendment to the 2012 Building Decree for Dutch offices regarding the energy labels in 2018; office buildings larger than 100 sqm should have EPC class C by January 1st 2023. The implementation of minimum energy performance standards is seen as a trigger to increase the renovation rates which are needed to meet the climate targets of the European Union (Sunderland & Santini, 2020). However, not all 96,000 Dutch offices have to comply with the minimum energy performance standard; only offices who are not listed as monuments, not demolished, renovated, or expropriated within 2 years, have at least 100 sqm of usable surface, of which at least 50% is dedicated to office functions, have the obligation to comply by 2023 (Sunderland & Santini, 2020; Netherlands Enterprise Agency, 2018). Sunderland and Santini (2020) stated that more than half of the offices in the Netherlands are obligated to undertake action by either registering for an EPC, or improving the building itself to meet the required standard, or both. Unfortunately, on July 1st, 2023, only 59% of the Dutch office buildings are classified with EPC class C or better, 10% of the office buildings have an EPC class D or worse, and 31% of the office buildings do not have an EPC yet (Netherlands Enterprise Agency, 2018). A recent news article discusses the office buildings that do not have an energy label yet and mention the expectation that approximately 30% of these buildings will receive an EPC class C (Stil, 2022). This leaves many office buildings with a need for renovation in the near future. Due to a lack of municipal enforcers, a lot of these office buildings are still in use without an official warning and no fines have been issued (Luimstra, 2023).

1.1 Current office renovations and Indoor Environmental Quality

According to Juan et al. (2010), offices have one of the highest levels of energy consumption in relation to other building types. Energy consumption will increase because of “both the expansion of built area and new energy uses” (Juan et al., 2010, p. 291). In order to reach global sustainability and set national and European targets, it is important to improve energy efficiency in existing buildings (Juan et al., 2010). When offices are renovated in order to reach the minimum energy performance standards, the focus lies on retrofitting energy saving or energy-efficiency measures. The steps that have to be taken to reach energy label C are considered easy to carry out and the payback period is rather short (Netherlands Enterprise Agency, 2022b). The easiest

energy-efficiency measures that are mentioned by practitioners in the article of the Netherlands Enterprise Agency (2022b) are roof and facade insulation, insulated windows, and LED lighting. Measures such as the improvement of ventilation systems and the installation of solar panels are listed as more drastic. These renovation measures are related to the energy consumption of a building but there is also a relation with Indoor Environmental Quality (IEQ). The IEQ of a building consists of four aspects: thermal and acoustic comfort, indoor air quality, and adequate levels of lighting (Dorizas et al., 2019). These aspects are regulated through several building service systems such as HVAC systems (Heating, Ventilation, and Air Conditioning), lighting systems, and intelligent control systems which are used to create a pleasant indoor environment (Roumi et al., 2023). These systems require energy consumption which results in a conflicting interest between energy consumption and IEQ; a sustainable retrofit should not neglect a building's IEQ and, moreover, the improvement of IEQ should not require extra energy costs (Roumi et al., 2023). This conflicting interest is also discussed by Shahzad et al. (2017), stating that "most buildings are either comfortable or energy efficient" (p. 1542) and this often leaves human comfort unnoticed in buildings with many sustainable strategies. When retrofitting sustainability measures during the renovation of buildings, the IEQ and satisfaction of users is mostly ignored and the focus lies on energy efficiency (Roumi et al., 2023). Asere and Blumberga (2018) discuss a similar conflicting relationship between Indoor Air Quality (IAQ) and energy efficiency. Their research showed that energy efficiency measures reduce energy consumption but IAQ is also reduced which results in a loss of productivity for the building users. On the other hand, when IAQ is improved by the installation of mechanical ventilation, the energy consumption of the building increases as well. IAQ is one of the aspects related to the quality of the indoor environment. When considering the impact, the IEQ of offices on its employees, Singh et al. (2010, p. 1665) stated that:

IEQ can negatively affect occupants' physical health (e.g., asthma exacerbation and respiratory allergies) through poor air quality, extreme temperatures, excess humidity, and insufficient ventilation and psychological health (e.g., depression and stress) through inadequate lighting, acoustics, and ergonomic design.

Taking the contradicting relationship between energy-efficiency measures and IEQ into account, it is important to stimulate the renovation of office buildings towards EPC class C without neglecting the IEQ. This is also emphasised in the revised Energy Performance of Buildings Directive (EPBD, 2018/844, Annex I): "Member States should support energy performance upgrades of existing buildings that contribute to achieving a healthy indoor environment" (European Parliament and the Council of the European Union, 2018; Dorizas et al., 2019). Since there are large numbers of offices badly or not classified, it is likely that a lot of energy-efficiency renovations of offices need to be carried out in the near future. The initiators of these renovations should be encouraged to renovate their office buildings in order to reach higher levels of energy efficiency while simultaneously improving the IEQ and therefore the productivity of the employees of their organisation. The Netherlands Enterprise Agency (2018) published a four step approach focused on reaching EPC class C by 2023; (1) request a customised advice, (2) explore financial arrangements, (3) carry out the measures, and (4) have a new energy label drawn up. This approach neglects the effects of the renovation on the IEQ and possible future obligations regarding the energy performance of existing utility buildings. The Netherlands Enterprise Agency (2018) advises to consider a more extensive renovation towards CO₂ neutral since this is an obligation by 2050. This eventually prevents another renovation in the near future to comply with new energy performance standards.

1.2 Building certification systems

When it comes to retrofitting energy saving measures, the preferred outcome equates to a building with a low carbon or an energy-efficient operation of the building (World Green Building Council, 2014). This is often referred to as green buildings. Globally, there are several certification systems to assess the extent to which a building can be considered 'green'; in terms of energy efficiency, for instance. One of these certification systems is called BREEAM, which measures, among others, energy efficiency and health and well-being of occupants in one assessment. The certification system WELL focuses on the enhancement of health and productivity of occupants of buildings. This certification system focuses on eleven themes that contribute to health-related themes in buildings: air, water, nutrition, lighting, movement, thermic comfort, noise, materials, mental health, social health, and innovation (DGMR, 2023). The main difference between the WELL certification system and BREEAM, is that the WELL certification systems solely focuses on occupant's health, and BREEAM mainly focuses on sustainability and considers health as a smaller part of the certification system (Dutch Green Building Council, 2018). A case study of Jin and Wallbaum (2020) showed that a newly renovated and BREEAM certified building did not meet the designed high-performance levels of IEQ which resulted in occupant dissatisfaction and a decrease in occupants' well-being. This shows that there is a gap between the design and the actual condition and occupant satisfaction (Jin & Wallbaum, 2020, p. 2). Green buildings, certified with BREEAM, LEED, Green Star, or similar, do not always support a high level of comfort and satisfaction of its occupants and therefore do not always encourage the productivity of its occupants (Kwon et al., 2019; World Green Building Council, 2014). Jin and Wallbaum (2020) emphasise that, despite the presence of green certifications for buildings, a legislation perspective is still lacking observation and involvement of occupant perceptions related to IEQ. They suggest that future guidelines, standards and building certification schemes should take this into account as well. This idea is endorsed by Mujeebu (2019, p. 1): "IEQ should be given specific focus while designing new buildings as well as in building retrofit plans". Additionally, a better IEQ positively impacts the learning and working performances of occupants in office buildings. In most cases of retrofitting energy saving measures, the IEQ is not taken into account which produces, for instance, a renovated building with insufficient ventilation causing overheating or increased indoor air pollutants (Fabbri & Dorizas, 2019). This emphasises the importance of office renovations that "does not harm IEQ and does not compromise comfort, health and wellbeing" (Fabbri & Dorizas, 2019, p. 4). This is also considered by the Dutch Green Building Council (2018), mentioning that it would be optimal to combine certification systems that focus on sustainability and health, for instance BREEAM and WELL, in order to focus on the upgrade in sustainability of the built environment while also enhancing the health of and in buildings more extensively.

1.3 Office renovation decision-making process

Renovation is considered to be a process of fixing and replacing existing parts of the building to improve its performance (Ástmarsson et al., 2013). For the renovation of office buildings, several decision-making processes are considered by different stakeholders. Decision-making can be seen as a process where one decides upon a "preferred option or a course of actions from among a set of alternatives" (Wang & Ruhe, 2007, p. 73). Ribeiro and Videira (2008, p. 113) state that "building renovation decision-making is a complex process that involves many stakeholders and relies on multi-dimensional information". The initiators of office renovations are the owners of the office buildings, as they are the ones that should obey the obligation of EPC class C (Netherlands Enterprise Agency, 2018). These initiators have different decision-making processes prior to renovation; to be motivated to carry out the renovation, decide upon the desired outcome, and, related to this research, to be encouraged to include an upgrade of IEQ with this renovation. Jensen and Maslesa (2015) mention that the motivation for building renovations is mostly concerned with

a decrease in energy efficiency, or problems with indoor climate. Additionally, Dorizas et al. (2019) mention that the most important drivers for renovation are increased thermal comfort and air quality, higher levels of natural lighting and improved health of occupants. Nevertheless, these aspects are not covered by EPCs and they suggest that evidence-based IEQ aspects should be included in renovation roadmaps as well. This leaves room for improvement when it comes to encouraging the initiators of office renovations to include an upgrade of IEQ in their energy-efficiency renovation towards obtaining a new EPC. As found by Konstantinou et al. (2021), the most mentioned barriers in the renovation decision-making processes are, among others, lack of information, unclear definitions, and coordination and communication. Additionally, when it comes to the renovation of office buildings, the office owners are unexperienced in this field. This is especially the case for business owners that are also the owner of their office building; the owner-occupied office buildings. Magic (2023) states that business owners of organisations with an owner-occupied office property mostly do not have the time, manpower, or knowledge to coordinate the office renovation themselves. The owners of other property types can experience a similar inexperience in relation to renovation of their property as well, for instance, individual home-owners, owners of smaller private schools, and owners of other business related properties. Because of their inexperience, these owners have to rely on external parties for advice and guidance during their renovation decision-making and execution processes. This shows that there is room for improvement in the field of information provision and help defining the outcome, as well as help guiding the process with clear coordination and communication among all stakeholders. Therefore, this research should provide in the establishment of a guideline or decision-making tool which involves necessary information and considerations for the renovation decision-making process, with the encouragement of renovating the office buildings beyond EPC class C, focused on increasing the IEQ.

1.4 Research purpose

The purpose of this research is to create a decision-making model which functions as a tool to assist the initiators of office renovations in their decision-making processes prior to renovation. The decision-making model is supplemented with an advice report which also addresses other important stakeholders in the decision-making process prior to office renovation. The tool focuses on achieving an energy-efficiency office renovation, together with a strong focus on IEQ. As Blaikie and Priest (2019) describe several types of research purposes in their book *Designing social research*, this research purpose corresponds with the type of research purpose change. Blaikie and Priest (2019, p. 80) describe this type of research purpose as one “to intervene in a social situation by manipulating some aspects of it, or to assist the participants to do so, preferably on the basis of established understanding or explanation”. The aim of this research is to guide the renovation of Dutch owner-occupied office buildings towards energy-efficient offices with increased IEQ to eventually increase employee productivity and satisfaction. The importance of developing such a guideline is emphasised by Roumi et al. (2023) who states that it is necessary “to help plan and implement sustainable building upgrades aiming for both energy efficiency and desirable IEQ” (p. 2). Besides, Kwon (2020) states there will be less demand for renovated office buildings if they do not focus on enhanced user satisfaction post-renovation.

1.5 Scope justification

The following paragraphs examine recent research of Kadaster (2022) to determine which owner and office type should be focused on with this research. Kadaster (2022) studied the total Dutch office building stock to concretise exact numbers of buildings that are in need of renovation and to show the allocated owner types and regional differences. The target group is selected based on the relatively biggest renovation task still to be completed.

The research of Kadaster (2022) showed that market parties own the largest amount of office buildings when it comes to the floor surface. But, compared to other owner types, the market parties already have a large share of their office portfolio classified with EPC class C or better (Kadaster, 2022). This is shown in figure 4 (adapted from Kadaster, 2022). Relatively, the housing associations and private owners have the biggest renovation task to comply with the target of reaching EPC class C.

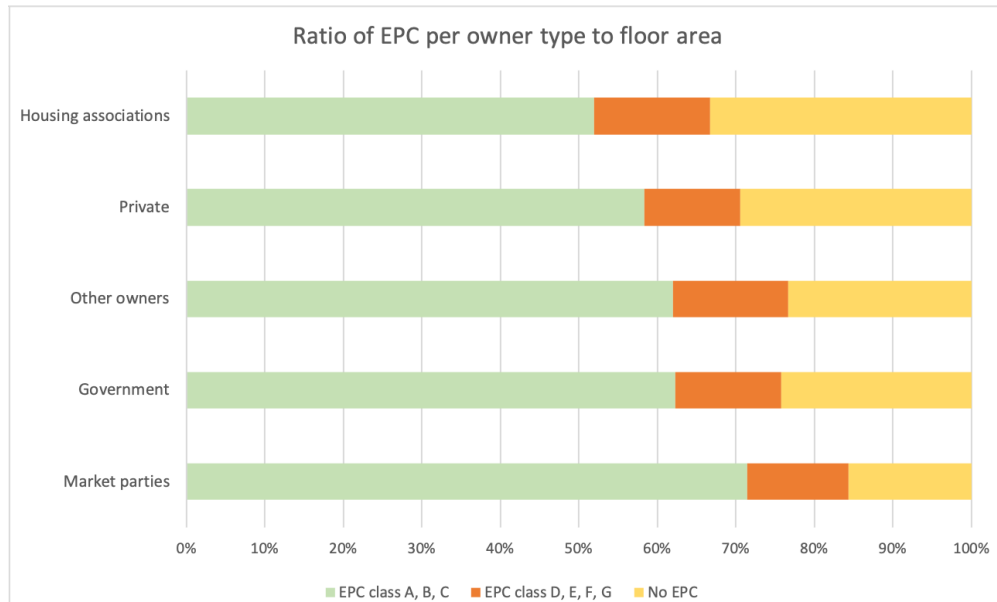


Figure 4. Ratio of EPCs per owner type, related to floor area. (Adapted from Kadaster, 2022).

When considering the private owners and housing associations, Kadaster (2022) showed that the biggest renovation challenge for the private owners and housing associations lies with the smaller offices (smaller than 1,000 square metres). This is illustrated in figure 5 (adapted from Kadaster, 2022).

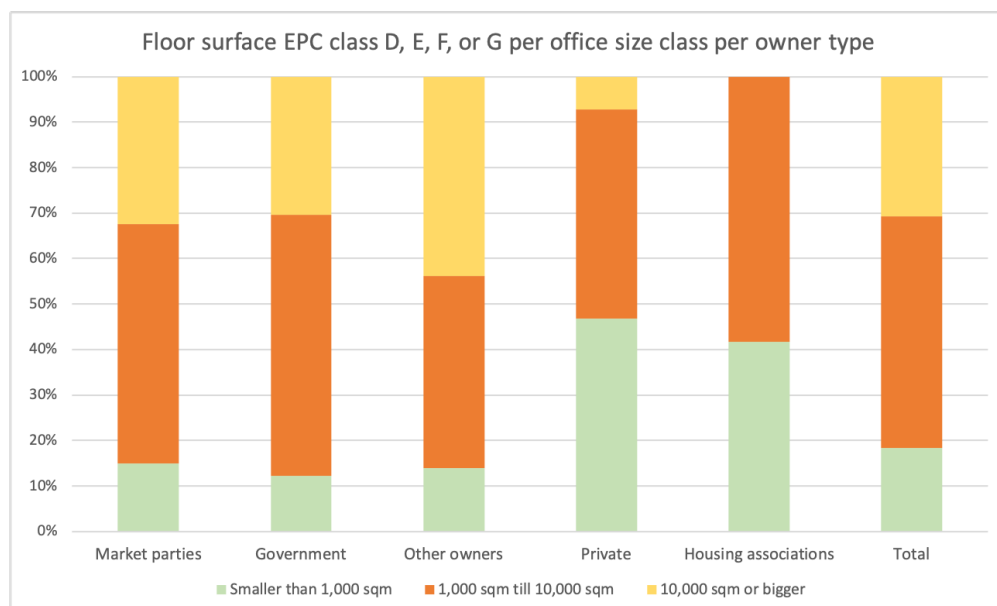


Figure 5. Floor surface classified with EPC class D, E, F, or G per office size class per owner type. (Adapted from Kadaster, 2022).

Relatively, the biggest challenge is concerned with the smallest office size class (< 1,000 sqm) for the private owner-occupied office buildings, according to the research of Kadaster (2022). Jensen and Maslesa (2015) found that the main barrier in the decision-making process of this target group is the lack of knowledge and information, and funding. This shows that there is an information deficit and knowledge gap for this target group which should be covered with this research. However, this information deficit and knowledge gap is not specifically for owners of small Dutch owner-occupied offices, but also for the other office size classes. Therefore, the scope of this research is limited to owner-occupied office buildings in The Netherlands that are still in need of an energy-efficiency renovation in order to reach EPC class C, to obey the set targets of the national government. Additionally, office owners of private owner-occupied offices who are willing to renovate their office building for other reasons can benefit from the results of this research as well.

1.6 Research questions

The main research question is: *“How can the renovation decision-making process, prior to renovation, of private owners of Dutch owner-occupied office buildings be guided with a focus on improving energy efficiency and Indoor Environmental Quality (IEQ)?”*. This research question is divided into the following sub questions to be answered:

1. What does the decision-making process prior to renovations entail for private owners of Dutch owner-occupied office buildings?
2. What are the motivations and barriers of private office owners to carry out energy-efficiency renovations in Dutch owner-occupied offices?
3. To what extent are private owners of Dutch owner-occupied offices aware of the impacts post-renovation, based on IEQ and occupant’s productivity?
4. What are the motivations and barriers of private office owners to consider IEQ during the renovation process of Dutch owner-occupied offices?
5. What are specific elements and critical moments in relation to the different identified phases of the decision-making process prior to renovation of private owners of Dutch owner-occupied office buildings?

This chapter is followed by a literature review study, examining a broad range of existing literature on the concepts of this research. Afterwards, the research method is elaborated. The research findings are presented in the fourth chapter. These findings are discussed and limitations of these findings are elaborated in Chapter 5. Subsequently, the research questions are answered in Chapter 6 as a conclusion of this research. Additionally, the personal reflection report associated with this thesis and its results can be found in Appendix G. The main deliverable of this research, the advice report, is uploaded as a separate document.

Literature review study & Theoretical framework

This chapter provides a comprehensive review of existing literature related to this research topic. It aims to explore the current state of knowledge, identify gaps, and highlight key findings and theories. By examining different literature sources, this chapter offers valuable insight and a solid theoretical framework to support the further research. Chapter 2.7 elaborates on the theoretical framework which connects all concepts of the discussed literature. This theoretical framework is used to define the case selection criteria in the next chapter.



2.1 Dutch office market

The Dutch office market refers to, amongst others, the economic aspects that are associated with the Dutch office spaces. As of October 1st 2022, the total Dutch office stock consisted of 137,500 addresses with a (partly) office function, adding up to 144 million square metres of total floor surface (Kadaster, 2022). Still, due to the aftermath of the Covid-19 pandemic, the supply of office spaces is decreasing since 2021 (Preesman & Dekker, 2023). Most of the withdrawals of office buildings from the total office stock are allocated to obsolete buildings which were old, located at less attractive or less central places, and not future-proof. Preesman and Dekker (2023) found with their research that the locations of office buildings that are accessible and multimodal, are still attractive for occupiers and investors. This results in a growing demand for high quality and well-located office spaces. The growing demand eventually translates itself into an increased median rent per square metre and a polarisation of the location of office spaces; most of the high quality office spaces are located in the four biggest cities of The Netherlands; Amsterdam, The Hague, Rotterdam, and Utrecht. The median rent increased by 4% in 2022 to roughly €130 per square metre, compared to 2021 (roughly €125 per square metre) (Preesman & Dekker, 2023). The rent shows even further growth on prime locations in the first quarter of 2023: the rent in Amsterdam grew till €555 per square metre per year, followed by Utrecht (€305 per square metre per year), Rotterdam (€300 per square metre per year), and Eindhoven (€240 per square metre per year) (Hesselink, 2023).

Not only is the demand for well-located offices growing, also the needs of occupiers are changing when it comes to office functions and its quality (Savills Research, 2022). This is also a result of the aftermath of the Covid-19 pandemic, as many office workers have worked from home. As the pandemic gradually recedes into the background of one's day-to-day life, the Dutch office users are expecting to work at home and at the office in a more structured way (Savills Research, 2022). With the rise of remote work, there is a growing emphasis on the role of the office, leading to an increasing desire to identify its unique strengths and differentiate it from the at home workplace. The unique strengths of office spaces are listed by Savills Research (2022), mentioning that the office spaces primarily add value "as a breeding ground for interaction and innovation". They also emphasise that the well-being of employees is increasingly becoming more prominent. Recently, the quality of offices is also acknowledged in terms of their energy classification, according to Van Nimwegen (2023). The increase in energy costs, due to the war in Ukraine, and the increase in interest rates led to a decrease in property value for investors. Nowadays, office buildings with EPC class A or better are more attractive for occupiers because it will eventually result in lower energy bills, even if the initial rent might be higher upfront (Van Nimwegen, 2023). Besides, the energy label C obligation increases the awareness of occupiers when it comes to the importance of a sustainable office building (Savills Research, 2022). This also leads to a growing demand for sustainable high-quality offices. Office owners should renovate their buildings to comply with the requirement, or should figure out alternative options (Van Nimwegen, 2023). Chapter 2.3 discusses the concept of energy labels more thoroughly and examines what it means for office buildings, in terms of energy consumption, to obtain EPC class C.

This section showed that the Dutch office market is shifting in terms of demand for location and demand for quality standards. Occupiers are interested in well-located offices that provide high-quality office spaces in terms of office functions and sustainability. Besides, there is a growing awareness for the well-being of office users.

2.2 Involved stakeholders in office renovations

As mentioned in the previous section, the decision-making process of building renovation involves many stakeholders (Ribeiro & Videira, 2008). Wijntjes (2023) considers stakeholders as people and groups that are involved in or associated with a construction project. When people or groups are directly involved or associated with the project, one must consider them as internal stakeholders. And vice versa, people or groups that are indirectly involved or associated with the project, one must consider them as external stakeholders (Wijntjes, 2023). Aapaoja and Haapasalo (2014) defined different types of stakeholders; primary team members, key supporting participants, tertiary stakeholders, and extended stakeholders. The primary team members and key supporting participants are considered as internal stakeholders, whereas the tertiary stakeholders and extended stakeholders are considered as external stakeholders. Besides, they analysed different construction projects in terms of the concerned stakeholders. Figure 6 (Aapaoja & Haapasalo, 2014) shows the stakeholder classification of an analysed renovation project which contained the renovation of 39 offices in a four-story building built in 1971.

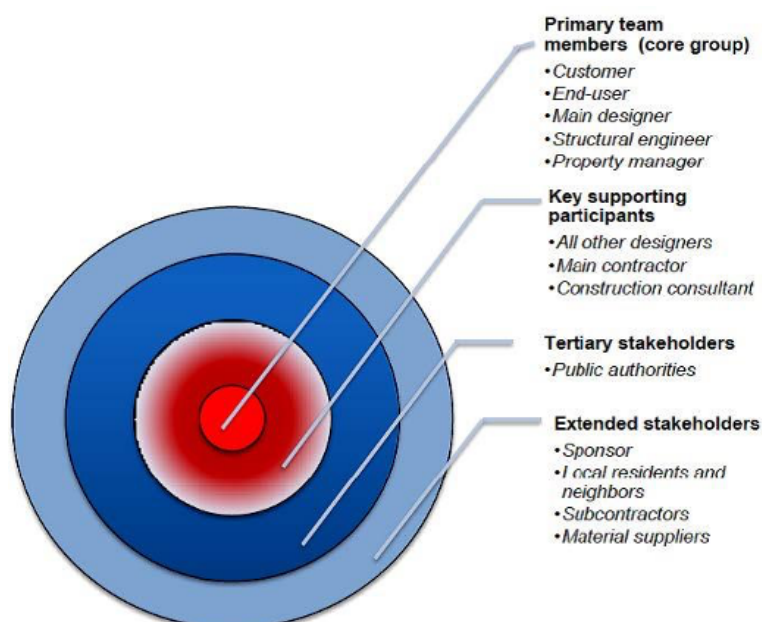


Figure 6. Stakeholder classification in the renovation project. (Aapaoja & Haapasalo, 2014).

An analysis of a general renovation process phases and tasks of Kostantinou et al. (2021) showed the different leading stakeholders of each renovation phase. Their study focused on general building renovation processes for all building types. The involved stakeholders that were mentioned in their article are: client team, design team, specialist consultants, construction team, specialist subcontractors, and facility management. On the following page, table 2 provides an overview of the renovation process phases and tasks, supplemented with leading stakeholders during each phase (adapted from Kostantinou et al, 2021). However, in the case of renovations of private Dutch owner-occupied offices, the identified renovation process phases of Kostantinou et al. (2021) might not be present in such a clear way. This is further examined through the research and data collection for answering sub question 1.

Phase	Pre-project	Concept design	Final design	Execution and hand-over	Post-construction
<i>Description</i>	Defines the need for the project, the problems, the ambition. Setup the design team	Identification and comparison of strategy, interventions, design principles	Tender, specification of products, engineering of components	Manufacturing, assembly off-site and on site, hand-over	Post-occupancy evaluation/ optimisation loops
<i>Core tasks included</i>	Setting objective and criteria Diagnosis of existing condition Definition of client requirements Cost initial estimate Selection design team	Identification of renovation measures Decision on industrialised components design concept Assessment and optimisation Preparation of permit applications	Detailed design for industrialised renovation Survey of existing building Engineering of the components Tender and products specification	Manufacturing Transport Mounting Site Construction Construction quality control Hand-over	Building operation optimisation Monitoring Post occupancy
<i>Phase outcome</i>	Project brief approved by the client, and confirmed feasibility	Renovation strategy approved by the client	All design information required to manufacture and construct the project completed	Manufacturing, construction, commissioning completed and hand-over	Building used, operated, ad maintained efficiently
<i>Leading stakeholder</i>	Client team	Design team Specialist consultants Client team	Design team Construction team Specialist subcontractors	Construction team Specialist subcontractors	Client Facility management Specialist consultants

Table 2. Overview of renovation process phases and tasks, including leading stakeholders. (Adapted from Konstantinou et al., 2021).

Above mentioned stakeholders should be identified for this research specifically as above listed figure and table are specific for the examined projects of the studied articles of Aapaoja and Haapasalo (2014) and Konstantinou et al. (2021). Figure 7 on the next page shows the stakeholder classification of Dutch owner-occupied office renovations, based on the different stakeholder types of Aapaoja and Haapasalo (2014). The involved stakeholder groups of Kostantinou et al. (2021) are also classified in this figure. This figure shows that the customer, end-user, and property manager are all covered by the same person, or organisation. This means that the organisation that invests in the renovation also benefits from the consequences of the renovation; decreased energy consumption, lower energy bill, increased productivity, higher work output, higher revenue, and so forth. However, adding an additional advisor to the core group of the project is common practice for office renovations, especially when the core business of the organisation is not related to construction (Hull, 2018). This advisor can act as the project manager, representing the needs and desires of the client, and also bringing relevant knowledge into the project that is normally not held within the organisation. The project manager then acts on behalf of the client to help guide the renovation process from definition to realisation. As illustrated in figure 7, some identified stakeholders of Aapaoja and Haapasalo (2014) and Konstantinou et al. (2021) are left out since they are not relevant for this research in the field of renovations of owner-occupied offices. Additionally, the internal and external classification of stakeholders are illustrated in figure 7, based on the information of Wijntjes (2023). Figure 7 shows that, in the case of office renovations of owner-occupied offices, it is specific that the office owner covers multiple roles as an internal stakeholder: the customer, property manager, and a representative of the end-users.

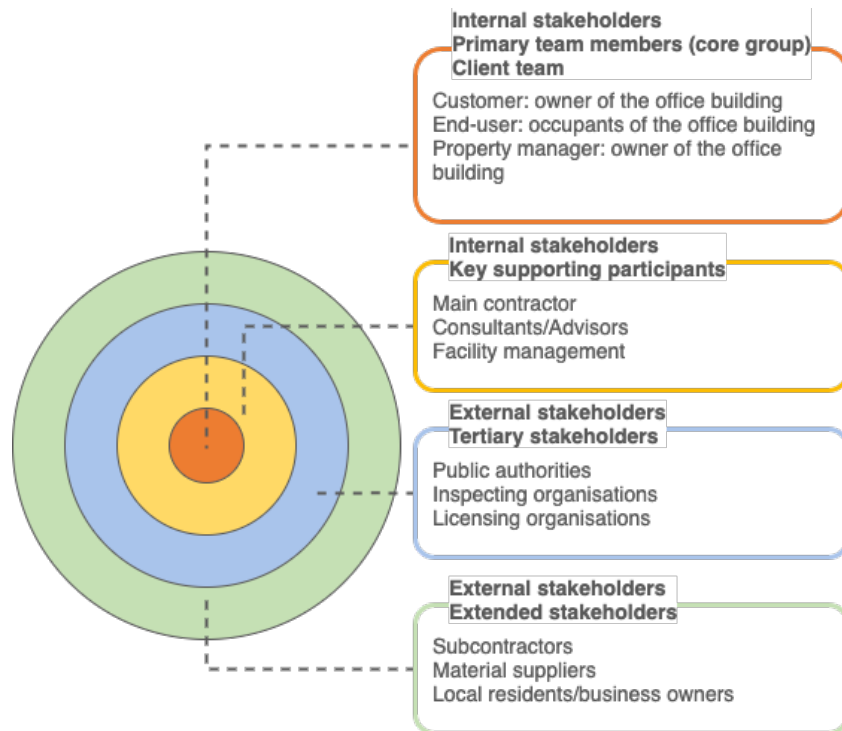


Figure 7. Stakeholder classification for office renovations. Own work.

2.3 Energy Performance Certificates for offices

When considering EPC regulations for Dutch office buildings, a recent amendment of the Dutch Building Decree of 2012 states that office buildings larger than 100 sqm should have an EPC class C by January 1st 2023 (Ministry of the Interior and Kingdom Relations, 2023). This means a primary fossil energy consumption of a maximum of 225 kWh per sqm per year (Netherlands Enterprise Agency, 2018). The EPC was introduced by the European Union in 2002, by the Energy Performance of Buildings Directive (EPBD) 2002/91/EC (Velt et al., 2020). The implementation of EPCs was aimed at making the energy performance of individual buildings more transparent. Besides, EU Member States have implemented national EPC regimes as well. An EPC, or energy label, indicates how energy-efficient a building is, based on the primary fossil energy consumption expressed in kilowatt hour per square metre per year (Netherlands Enterprise Agency, 2017). Additionally, it shows which energy-saving measures are still possible. When implementing energy labels to its full potential, it “could be an effective force that triggers a new wave of renovation activities across the EU” (Zuhaib et al., 2022, p. 2). This can especially be the case when EPCs are used in renovation policy frameworks as a certain minimum standard which has to be met (Sunderland & Santini, 2020). The implementation of minimum energy performance standards through EPCs is already in use by several states of the United States, England, Wales, Scotland, France, and The Netherlands. In the Netherlands, both residential and some non-residential buildings are required to have an EPC when putting up for sale or rent (Ministry of General Affairs, 2022; Bedrijfsenergielabels, 2021). This label is valid for 10 years which does not ensure that the energy label is still applicable for the current condition of the building (Sipma et al., 2017). This shows that there can be a difference between the indicated energy consumption by the EPC and the actual energy consumption of a building. According to INNAX (n.d.), the different classes of energy labels in the Netherlands range from class G (> 300 kWh/sqm year) to class A+++++ (<= 0 kWh/sqm year). Buildings with EPC class A+++++ are buildings that are CO₂ or energy neutral.

The EPC class of a building is determined based on the determination method NTA 8800. The NTA 8800 offers terms, definitions and the method to determine the numerical value of the

energy performance of a building (NEN, 2021). Sipma et al. (2017) describe that the energy label is determined based on the Energy Index (EI) which is calculated using EPA-software for existing buildings and EPG-software for new buildings. The numerical value is then converted into a letter designation, the EPC class. The EPA-software calculates a theoretical consumption of the building; the measured consumption originates from metre readings. It is important to mention that the EPC only takes the energy consumption of the building into account and neglects the energy consumption of the users (Sipma et al., 2017). This means that the EPA-software uses the following energy systems for its calculation: heating, cooling, indoor lightning, warm water, ventilation, pumps, and humidification. Unfortunately, an article of Dubbeling (2014) discusses that offices with EPC class A, B, and C consume more gas and electricity than expected, and offices with EPC class E, F, and G consume less gas but also more electricity than expected. Follow-up inspection of around 47 offices showed that 10 offices received the wrong EPC and 6 of those were classified too good. Besides, renovations and function changes in buildings are possibly not communicated but these aspects also have an impact on the overall energy consumption. When the EPC of a building is calculated and determined, the intensity of use is not taken into consideration which actually has a lot of impact on the energy consumption. For instance, due to higher occupancy than anticipated, there is a greater need for cooling than provided for in the label calculation (Dubbeling, 2014). Higher occupancy also affects the use of, for example, chamber pots and lifts. Several articles suggested that indicators for real energy use as a consequence of occupancy should also be incorporated in the calculation for EPCs (Zuhaib et al., 2022; Dubbeling, 2014; Sipma et al., 2017).

Unfortunately, an article of the Netherlands Enterprise Agency (2018) states that more than half of the Dutch office building is not classified with the EPC class C yet. On July 1st 2023, 10% of the office buildings have an EPC class D or worse, and 31% of the office buildings do not have an EPC yet (Netherlands Enterprise Agency, 2018). This means that there are many existing office buildings in need of renovation. Although, new energy performance standards for utility buildings by 2050 will be published in 2030. The expectation is that utility buildings should be CO₂ neutral by 2050 (Netherlands Enterprise Agency, 2018). The Netherlands Enterprise Agency (2018) advises to consider a more intensive renovation (towards CO₂ neutral) when renovation is already needed in order to comply with current regulations. This avoids further renovation in the future.

2.4 Decision-making process prior to renovations

As this research focuses on guiding the decision-making process of private office owners of Dutch owner-occupied offices, this section discusses several decision-making processes as found in literature. The decision-making processes are not specified in literature for office renovation projects. Therefore, the found theories are compared with the decision-making processes of office owners who participated in this research in Chapter 4.

Nielsen et al. (2016) state that the process of renovation is comparable to the process of designing a new building. The constraints of dealing with an existing building and site, together with its users, are considered as the main difference between these processes. When it comes to decision-making for renovations, several steps in the process are identified in the pre-design and design phase. The pre-design phase focuses on defining criteria for renovation and the related measures and weight criteria (Nielsen et al., 2016). Also, the building diagnosis is made based on registration, existing databases, and possibly by user-surveys. The design phase is dedicated to testing different design alternatives, followed by an estimation of the performance of these alternatives, and an evaluation of the alternatives (Nielsen et al., 2016). This eventually leads to a choice of design alternative. The chosen design alternative can then be designed in detail in

order to construct, operate, and renovate. Besides, Nielsen et al. (2016) identified six areas where decision-making methods can be used to support the process of renovation: goal setting, criteria weighting, building diagnosis, design alternatives generation, performance estimation, and design alternatives evaluation (Nielsen et al., 2016). The relation between these six areas or modules is illustrated in figure 8 (Nielsen et al., 2016). This figure also shows the related actions which are needed to draw up decision support tools for sustainable renovation processes.

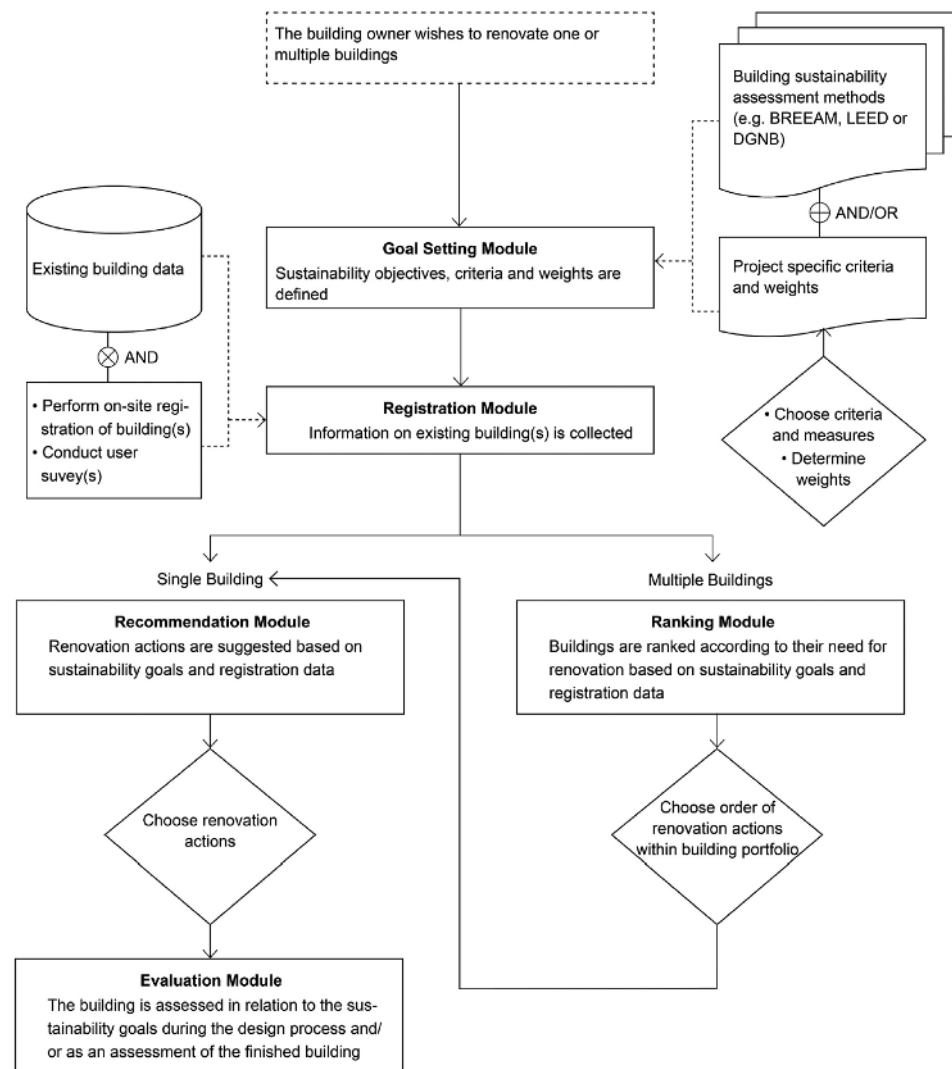


Figure 8. Suggestions of modules, their interrelations and related actions for future decision support tools for sustainable renovation of one or multiple buildings. (Nielsen et al., 2016).

Another framework for the decision-making process for the implementation of Energy Renovation Measures (ERM) is drawn up by Broers et al. (2019). Although, this framework is based on decisions which have to be made by Dutch private homeowners but it is meant as “a holistic perspective on the stages of the decision-making process of ERM, the many factors homeowners must consider, and the many factors influencing the process” (Broers et al., 2019, p. 2). Therefore, it is an interesting approach to consider when discussing decision-making processes of (office) renovations. The six stages which are considered by Broers et al. (2019) are: getting interested, gaining knowledge, forming an opinion, making a decision, implementing ERM, experiencing ERM. The six stages of Broers et al. (2019) are similar to the different steps of the decision-making process of private homeowners when deciding on investing in energy saving measures. These different steps are documented by the Association of Dutch Municipalities (Dutch: Vereniging van Nederlandse Gemeenten, VNG) to identify the customer journey of Dutch homeowners related to

investing in energy saving measures. This customer journey can also be applied to private office owners since the investment for the energy saving measures results in a direct benefit for the owner-occupier. With this customer journey, the different steps in the decision-making process are identified. It starts with 'becoming aware' and 'gaining interest' and eventually leads to the installation of energy saving measures, 'sharing experiences' and 'wanting more' (VNG, 2015). Interestingly, the framework of VNG (2015) shows a lot of overlap with the framework of Broers et al. (2019).

The customer journey and the related heatmap in figure 9 (VNG, 2015) shows the experiences of homeowners within their customer journey; the red marked blocks illustrate negative aspects (barriers) and the green marked blocks illustrate positive aspects (drivers). The drivers in the early stages of the customer journey are: aware of the importance of energy saving, aware of the advantages of energy saving for their property, opportunities to participate in joint approaches, ability to pay for measures, and accessible information gathering about measures. Figure 9 (VNG, 2015) also illustrates that the most barriers are experienced by the homeowners in the first phases of their decision-making process. These barriers are related to not receiving information at the right time, nor by trustworthy organisations, nor by their surroundings, and not related to clarifying the financial benefits. Besides, the customers are not aware of the urgency of energy-efficiency upgrades and therefore are not triggered to invest in it. Other barriers are related to the unavailability of an advisor to advise on the right investment to make and to explain the different options available, and the hesitancy related to the expected rendement.

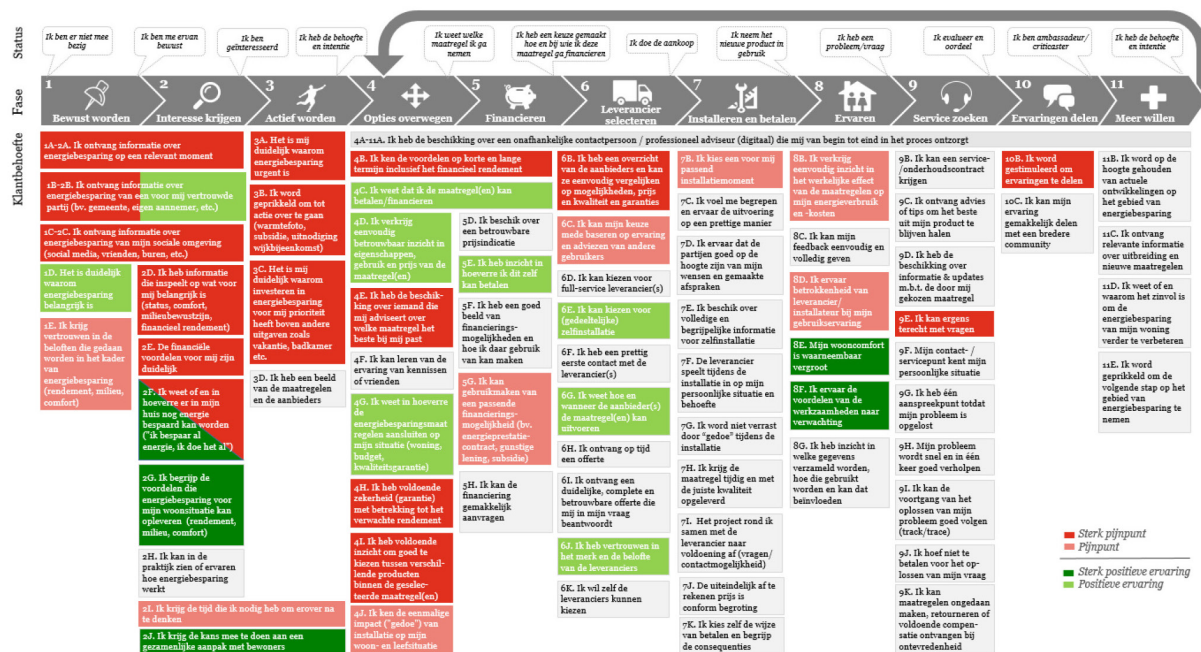


Figure 9. Customer journey and heatmap. (VNG, 2015).

A similar outcome related to the barriers in the renovation decision-making process is emphasised by Ebrahimigharehbaghi et al. (2020). Their questionnaire survey showed that the barriers in the decision-making process of individual home-owners were most present in the consideration, decision, and executing phases of renovations. The main identified barriers related to the decision-making process prior to renovations are determining costs for interior renovations and finding ways to increase the energy efficiency of renovations (Ebrahimigharehbaghi et al., 2020). Another important outcome of their research is the fact that potential renovators experience most of their identified barriers in the early stages of the decision-making processes and renovators at later stages of the decision-making processes. Jensen and Maslesa (2015) also identified different

barriers in the decision-making for building renovations. The barriers range “from market and policy failures, through professionals’ inadequate knowledge and understanding, to the behaviour of building users” (Jensen & Maslesa, 2015, p. 2). When looking at owner-occupiers, the main barriers are the lack of knowledge and information, and funding. Other barriers mentioned by Jensen and Maslesa (2015) are: “too little political consciousness about the value creation by renovation, weak economic incentive structures . . . , lack of life cycle cost perspective, lack of standard solutions/concepts, . . . lack of demand causing lack of development causing lack of demand, overview and common direction is lacking among the actors, no overview of potential and priority, and renovation has an image problem compared to new building activities” (p. 3).

Figure 10 combines the customer journey of VNG (2015) with the different modules of Nielsen et al. (2016) and adds the project phases of planning, implementation, and post-renovation in order to provide a holistic overview of the decision-making process of sustainable building renovations. This framework is used in Chapter 4 to analyse the decision-making processes of the participants. This research focuses on the planning phase of the decision-making process of Dutch owners of owner-occupied offices.

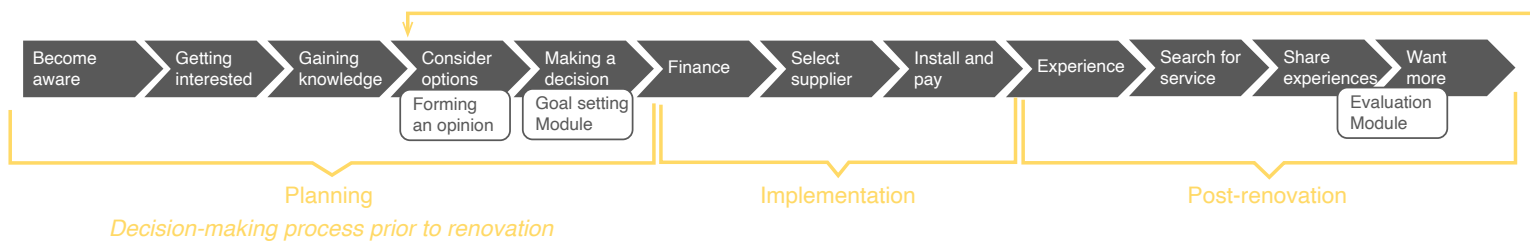


Figure 10. Decision-making process of sustainability renovations. Own work (based on VNG, 2015; Nielsen et al., 2016).

2.5 Office renovation practices focused on energy efficiency or Indoor Environmental Quality

The focus of this research lies with enhancing IEQ during the process of an energy-efficiency renovation in Dutch offices. Therefore, it is important to illustrate differences and overlaps in the renovation aspects of both renovation practices in offices. Both renovations can lead to an improved indoor environment, but the objectives of the renovation differ. The aim of energy-efficiency office renovations is to reduce energy consumption and enhance building performance through measures such as insulation upgrades, HVAC system optimisation (Heating, Ventilation, and Air Conditioning), energy-efficient lighting installation, and the utilisation of renewable energy sources (European Commission, 2020; Kwon, 2020). On the other hand, IEQ office renovations prioritise creating a healthy and comfortable indoor environment for occupants by improving air quality, thermal comfort, acoustics, lighting quality, and ergonomic factors (Dorizas et al., 2018; Mujeebu, 2019).

Some aspects of the office renovation decisions overlap between energy-efficiency and IEQ improvements (Fabbri & Dorizas, 2019). For instance, lighting upgrades using energy-efficient technologies to enhance both energy efficiency and lighting quality, or adjustment of the building facade to reduce the energy consumption of the building while simultaneously improving thermal comfort (Kwon, 2020). Or, the optimisation of HVAC systems not only to reduce energy consumption but also to improve IAQ and thermal comfort (Juan et al., 2010). The aspects that are implemented in IEQ office renovations but do not contribute to better energy-efficiency are mostly concerned with acoustics and ergonomic factors, such as swapping out furniture, or the addition of acoustic panels. On the following page, table 3 summarises the given examples

of office renovation practices and its related results in terms of energy-efficiency and IEQ. The information in this table is based on the above mentioned literature used for this section.

Renovation practice	Focus: Energy-Efficiency	Focus: Indoor Environmental Quality
Upgrade/addition of insulation	Higher insulation coefficient (less heating loss, lower energy bill)	Improved thermal comfort, higher user satisfaction, less health related issues, higher productivity
Upgrade/Install HVAC systems	Decrease in energy consumption by systems, lower energy bill	Improved air quality, improved thermal comfort, higher user satisfaction, higher productivity
Install LED lighting	Decrease in energy consumption by systems, lower energy bill	Improved lighting quality, higher productivity
Installation of renewable energy sources	Decrease in energy consumption by systems, lower energy demand, lower energy bill	
Swap out furniture		Improved ergonomics, improved comfort, higher productivity
Add acoustic panels		Improved acoustics, higher user satisfaction, higher productivity
Create more windows		Improved lighting quality, higher cognitive function, higher productivity
Upgrade window type (insulated windows)	Higher insulation coefficient (less heating loss, lower energy bill)	
Addition of more 'green' in the office (plants, etc.)		Improved air quality, higher user satisfaction, higher productivity

Table 3. Renovation practices and its consequences. Own work.

The table shows that there are some office renovation practices that cover both energy-efficiency and IEQ aspects. Nevertheless, to ensure certain levels of comfort and indoor quality, measurable limits or ranges of values should be specified during the design stage of renovations (Dorizas et al., 2019). These criteria are defined in several European and ISO standards, as shown in table 4 (adapted from Dorizas et al., 2019). By measuring the different indoor environmental criteria, one is able to assess the IEQ.

Categories of the indoor environment	Design criteria/guidelines
Thermal criteria	EN ISO 7730, ASHRAE Standard 55-2013, ISO 7726:2001; EN 15251:2007
Air quality and ventilation criteria	EN 15251:2007, EN 16000-1:2006, EN 13779, EN ISO 16814:2008, EN 16798-7, EN 15242:2007
Lighting criteria	EN 12464-1, EN 12193, EN 15193-1, EN 17037
Acoustic criteria	EN 15251:2007

Table 4. Indoor environmental categories and relevant guidelines. (Adapted from Dorizas et al., 2019).

When it comes to Dutch standards for indoor environmental criteria, Roelofsen (2012) stated that the current Bouwbesluit 2012 does not consider comfort. Only aspects such as usability, safety, health, and energy efficiency are considered. Air quality is measured by air pollution caused by occupants of buildings, the minimum ventilation rate, and the presence of air currents (Roelofsen, 2012; Klimaatbeheer, 2020). However, aspects such as interior, installations, the building itself, and outside air also influence the indoor air quality, but are not considered in the Bouwbesluit

2012 (Roelofsen, 2012). Additionally, Klimaatbeheer (2020) stated that other matters such as the presence of cooling, relative humidity limits, temperature fluctuations and/or the comfort in the room are not further specified. When it comes to office buildings, the employer should meet regulations of the Arbowet and the related Arbo Regeling. The matters that are laid down in these laws and regulations are focused on ergonomic comfort, temperature, and ventilation (Klimaatbeheer, 2020). Nevertheless, these regulations do not contain information about threshold values for temperature, but only a statement that “there must be a comfortable temperature in relation to the work to be performed and the climate must not lead to damage to health” (Klimaatbeheer, 2020).

This section showed that there are many similarities between renovation practices focused on energy efficiency and renovation practices focused on increased IEQ. For this research, it is important to consider the design criteria that are defined in European and ISO standards related to IEQ during energy-efficiency renovations in order to create energy-efficient and ‘healthy’ offices. Additionally, the Dutch regulations for indoor environments in office buildings, as regulated by the Bouwbesluit, Arbowet, and the related Arbo Regeling should be considered. Unfortunately, the Dutch regulations still lack specification and threshold values.

2.6 The impact of Indoor Environmental Quality on office users

The four main components of IEQ are indoor air quality, thermal and acoustic comfort and adequate levels of lighting (Dorizas et al., 2019; Fabbri & Dorizas, 2019; Zhang et al., 2022). Additionally, Mujeebu (2019) adds other IEQ components to this list, such as water quality, ergonomics, sound quality, micro-organisms, odour, hygiene, electromagnetic radiation, and vibration. Each of these aspects contains significant exposures affecting the health of occupants, according to Mitchell et al. (2007). The building structure, building systems, furnishings, the outdoor environment, and the occupants and their activities all interact in a complex way which results in those significant exposures. Besides occupants’ health, the satisfaction, comfort and well-being, the cognitive function and productivity of the building users is also affected by the IEQ (Zhang et al., 2022). Jin and Wallbaum (2020) state that the consequences of bad indoor environments are especially significant in the office environment, affecting employees’ performance and productivity. This leads to low work productivity and more sick leaves (Fabbri & Dorizas, 2019; Jin & Wallbaum, 2020). On the other hand, a workplace with a high scoring quality of the indoor environment improves the health and mood of its workers and thereby increases their productivity (Mujeebu, 2019). Their increased productivity pays back by the generation of additional monetary returns for the company and it eventually evens out the additional costs of maintaining high IEQ levels. This section discusses some identified aspects which are affected by the indoor quality in office environments.

2.6.1 Occupants’ health

Jin and Wallbaum (2020) studied different factors affecting the satisfaction of occupants in a newly renovated office. This study also showed that the factors of air quality, relative humidity, and noise are associated with symptoms of fatigue. Besides, there are several factors identified by Jin and Wallbaum (2020, p. 7) which caused perceived stress by the occupants. These factors are concerned with “air quality, acoustic and thermal environment including unpleasant odour, stuffy air, dust, room temperature, air draught and relative humidity”. A study of Choi et al. (2012) concluded that the dissatisfaction of office workers with their environment eventually leads to lower work productivity which adversely affects their health. Newsham et al. (2009) complement this statement by discussing that there is a correlation between job stress, physical

symptoms, and job satisfaction. Better indoor environments therefore play a role in increasing the job satisfaction of office workers, and other organisational productivity. The World Green Building Council (2014) listed occupant health outcomes that are a result of bad physical office environment factors, such as headaches, skin irritation, infections, fatigue, asthma & breathing disorders, stress & depression, and so forth.

2.6.2 User satisfaction

A study of Frontczak et al. (2011) examined the relationship between IEQ and occupant satisfaction. They found that five studies focused on the impact of IEQ showed that thermal, visual, and acoustic environment and air quality has an impact on occupants' satisfaction. Jin and Wallbaum (2020) studied a newly renovated office building which is labelled with a BREEAM certification. This means that the building is assessed by a third party based on "the level of compliance of built environment projects with a set of clear and scientifically robust sustainability goals" (Zakir, 2022). Even in new green buildings, or newly green renovated buildings, occupants complain about the conditions of the indoor environment. Jin and Wallbaum (2020) therefore conducted a post-occupant survey to examine the perceived IEQ conditions and the actual satisfaction of the occupants, revealing the existing problems and occupant demand. This study showed that the condition of room temperature and noise were pointed out as dissatisfying conditions. Moreover, cold room temperature and too much room noise were addressed as the main causes for perceived stress at least once a week.

However, Kim and de Dear (2012) state that individual IEQ items differ in the strength of impact on occupant satisfaction. This illustrates that there is a nonlinear or asymmetric relationship between the overall satisfaction of office workers and the performance of IEQ factors. Therefore, Kim and de Dear (2012) identified basic, bonus, and proportional factors to classify IEQ factors. When basic factors are performing adequately and according to the expectations of the building users, the occupants do not notice them and it does not influence their overall satisfaction. If these basic factors are not meeting the expectations, the overall satisfaction levels are deteriorated (Kim & de Dear, 2012). Bonus factors have a high impact on the satisfaction of occupants when the performance of these factors is high. Their impact is much lower when the performance of these factors is lacking. Proportional factors have a linear effect on the overall satisfaction levels of the occupants. The relation between occupant satisfaction and the performance of IEQ factors is illustrated in Kano's satisfaction model, as shown in figure 11 (adapted from Kim & de Dear, 2012).

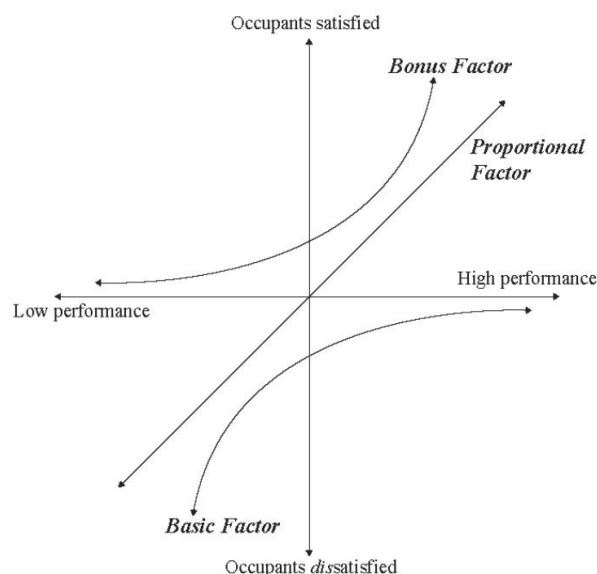


Figure 11. Kano's satisfaction model. (Adapted from Kim and de Dear, 2012).

In the analysis of Kim and de Dear (2012), no bonus factors related to IEQ were identified. IEQ items which are considered as basic factors are: temperature, noise level, amount of space, visual privacy, adjustability of furniture, colours & textures, and workspace cleanliness. These items do have an impact on the overall satisfaction but foremost when these are identified as poorly performing. The proportional factors that are identified by Kim and de Dear (2012) are: air quality, amount of light, visual comfort, sound privacy, ease of interaction, comfort of furnishing, building cleanliness, and building maintenance. Kwon (2020) concluded a study on the relationship between user satisfaction and design factor for office renovations by stating that the increase of user satisfaction eventually results in the improvement of productivity and less absenteeism in workspaces. Besides, the users' satisfaction levels can be increased by giving them more personal control when it comes to the users' interaction with building services and systems (Kwon, 2020). For example, occupants who possess greater autonomy in regulating their thermal and visual comfort tend to show higher levels of satisfaction with their working environment.

2.6.3 Cognitive function and productivity

Bad indoor environment influences the productivity of employees because of a decrease in user satisfaction, as mentioned above. Contradictory, by investing in a healthy and comfortable indoor environment the absenteeism and productivity loss can be reduced (Boerstra & Te Kulve, 2021). Additionally, Mahbob et al. (2011) indicated with his study that IEQ impacts the physical and psychological health of office occupants. These health aspects are related to feelings of satisfaction and comfort. Figure 12 (Mahbob et al., 2011) shows that these feelings of satisfaction and comfort influences the work performance, and thus, the productivity of employees.

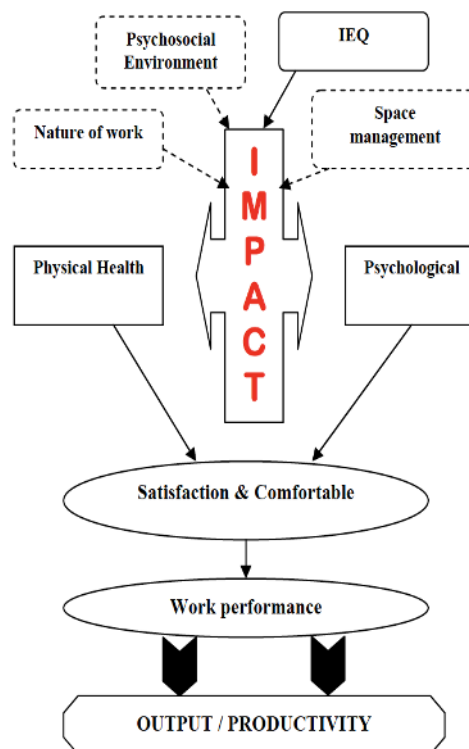


Figure 12. Relationship of productivity with IEQ. (Mahbob et al., 2011).

A study of Jin and Wallbaum (2020) indicates that the IEQ factors concerned with noise, relative humidity, and air movement show an association with difficulty concentrating. This illustrates

that there might be a direct effect of IEQ factors on the productivity and cognitive functions of office workers as well. Additionally, factors of quality of light, acoustic and air quality are mostly regarded with self-reported work productivity (Jin & Wallbaum, 2020). Zhang et al. (2022) emphasise the effect of lighting on occupants' performance and productivity as well as these are influenced by light entering their eyes. Boerstra and Te Kulve (2021) summarised research on the impact of indoor environment aspects on the productivity of office users into an understandable figure. This figure illustrates the potential productivity loss per indoor environmental aspect when considering a suboptimal situation. An adapted version of this figure is illustrated in figure 13 (adapted from Boerstra & Te Kulve, 2021). The figure shows the indoor environmental aspects of temperature, air quality, noise, and lighting. According to this figure, noise-related aspects show the biggest impact on the productivity of office users.

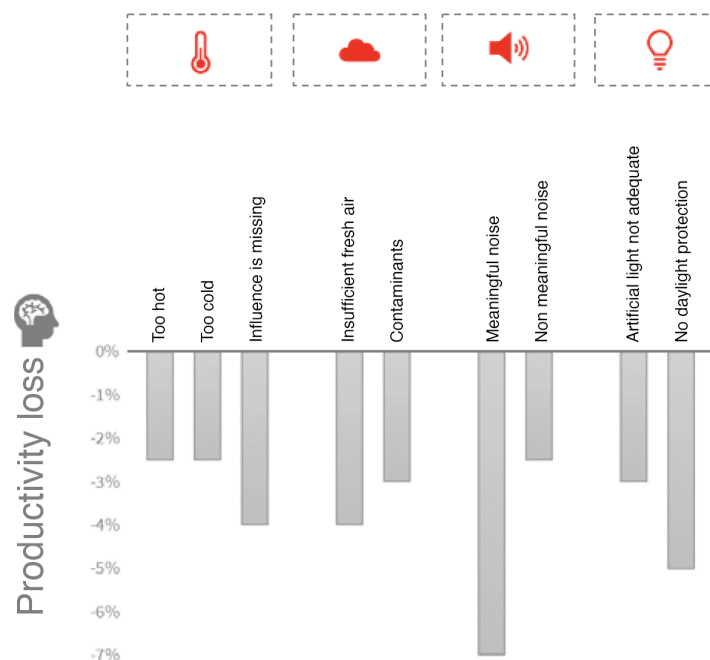


Figure 13. Potential productivity loss per indoor environmental aspect in case of a suboptimal situation. (Adapted from Boerstra & Te Kulve, 2021).

When considering the impact of decreased occupant productivity, one should consider factors such as absenteeism/presenteeism, revenue, task efficiency, medical costs, and so forth. (World Green Building Council, 2014). These factors all affect the business operating costs, of which 90% is estimated to be dedicated to staff costs and only 10% is dedicated to the energy costs of the building. Staff costs include costs of ill-health, costs related to absenteeism and additional costs of recruitment (World Green Building Council, 2014). This shows that the lack of productivity of the staff has a much higher impact on the business operating costs than the energy performance of their office building. Fabbri and Dorizas (2019) mentioned that increased IEQ can reduce illnesses, which results in fewer absenteeism.

This section discussed several aspects that are related to IEQ in office spaces, such as the health of occupants, user satisfaction, cognitive function, and productivity. Each of these aspects affect the work output of office users. By enhancing a good quality of the indoor environment in office spaces, the occupants are less likely to discover health related issues, are more satisfied, and their cognitive function is positively enhanced. The resulting increased work output and occupants' productivity is beneficial for the organisation as it results in, among others, less sick leaves caused by job stress or poor IAQ, decrease in organisational costs, greater organisational productivity and organisational work output, and so forth.

2.7 Theoretical framework

Figure 14 (refer to Appendix A for full size) shows the theoretical framework of this research. This theoretical framework is a result of the literature that has been studied and applied to this research. It shows the connections between the different concepts from the literature and illustrates the purpose of this research with the red lined boxes and dotted lines; with a new standardised approach which guides the decision-making process prior to renovation, the renovation practices are focused on energy efficiency and IEQ. This eventually leads to the positive outcomes that are related to IEQ renovations and energy-efficiency renovations, as illustrated in figure 14.

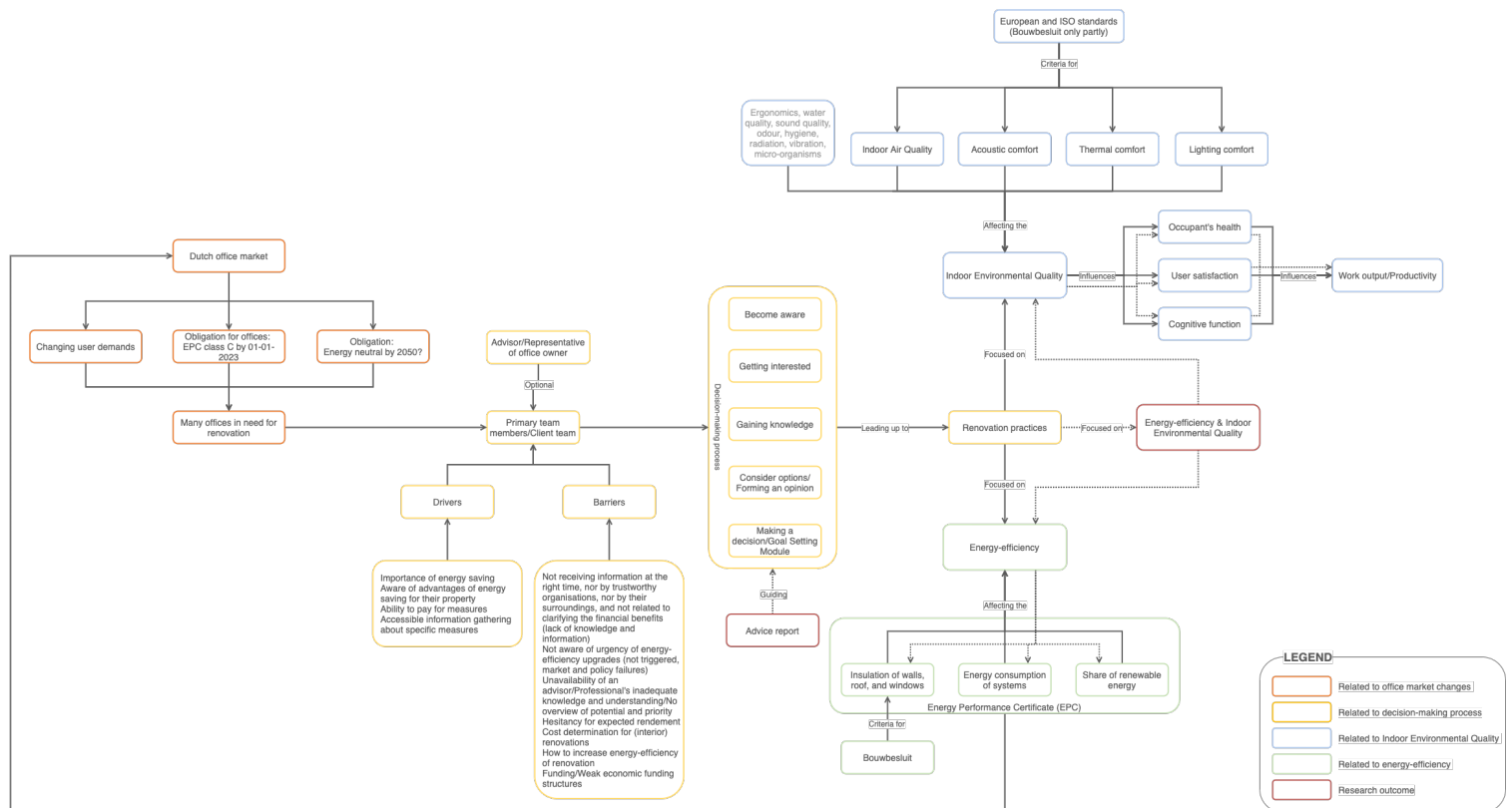


Figure 14. Theoretical framework. Own work.

Research method

This chapter elaborates on the used research method for this research by discussing its research design, the selection of case studies, and the data collection and analysis. The discussion of the research data management plan and an elaboration on ethical considerations can be found in Appendix B.



3.1 Research design

This research is a qualitative study which means that the data collection and analysis is non-numerical. This research design is used to understand concepts, opinions, or experiences, and to gain in-depth insights into a specific problem or to generate new ideas for research (Bhandari, 2022a). During this research, the qualitative research method of semi-structured in-depth interviews is used. The interviews are conducted as part of a case study. According to Stake (2005), a case study does not necessarily cover a methodological choice of research but it covers a choice of what is studied. Flyvbjerg (2011) discusses the intensity of case studies since it entails “more detail, richness, completeness, and variance” (p. 301). The target group for this research are the owners of Dutch owner-occupied offices that have made the decision to renovate their offices because of the EPC class C obligation that has to be met, or have other motivations for an office renovation. The cases are selected based on a non-probability, self-selection sampling. This means that the case projects are selected based on certain criteria and their availability or willingness to participate (McCombes, 2022). The selected cases are owner-occupied office buildings that are already renovated or are going to be renovated in the near future. By using these cases, one is able to analyse the decision-making processes prior to renovation of the associated office owners in the case of energy-efficiency renovations and IEQ renovations. This allows to find missing aspects in this decision-making process and helps to determine the contents of the advice report to guide the decision-making process prior to renovation for future initiators of office renovations. Prior to the conduction of interviews for the case study, the literature review study is used to determine case selection criteria for the case projects. This is illustrated in figure 15, which shows the systematic design of this research.

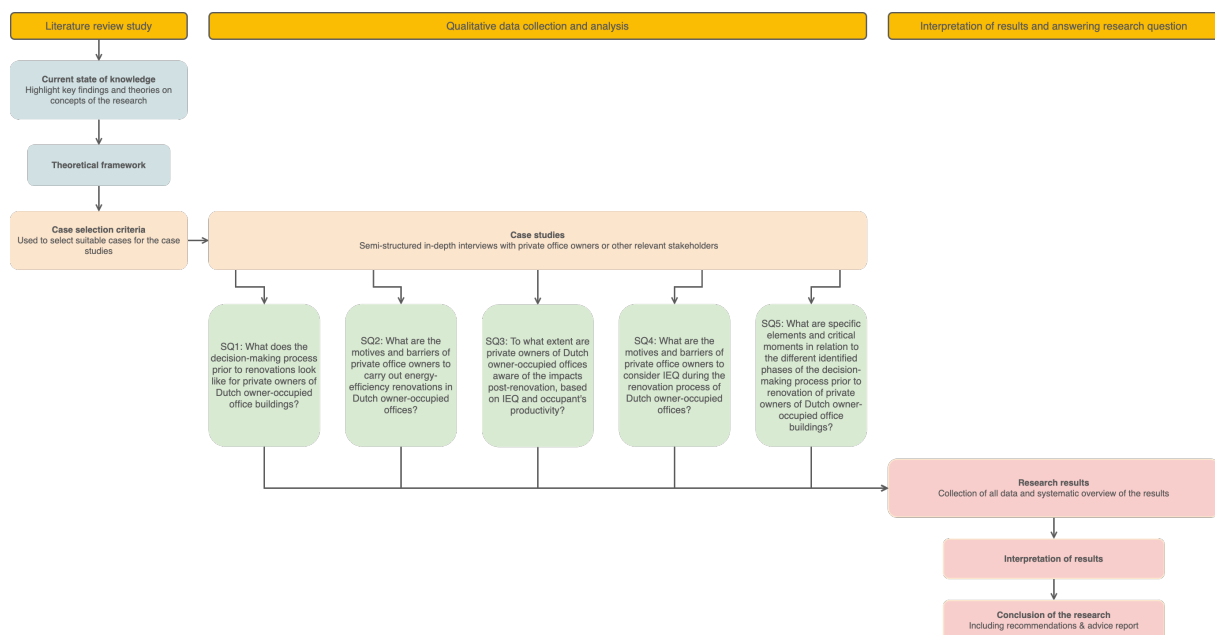


Figure 15. Research design. Own work.

3.2 Data collection and analysis

The data collection for the different cases is done by conducting interviews with the office owners, or other relevant associated stakeholders, of the renovated and to-be renovated offices. Each of the sub questions are answered with the help of the collected data from the literature and the interviews with stakeholders of the different case studies. Data collection by means of interviews is considered as primary data by Blaikie and Priest (2019) since it is generated and analysed by the researcher. For this research, in-depth semi-structured interviews are conducted. The base

interview questions for the case studies can be found in the interview protocol, as listed in Appendix C. Appendix D contains the informed consent form which is sent to and signed by the participants in advance of the interviews. As the conducted interviews are semi-structured interviews, any additional questions that have been asked are left out. The base interview questions are listed in Dutch, as the interviews are also conducted in Dutch.

Blaikie and Priest (2019) discuss several settings for data collection in their book *Designing social research*. The data gathering for this research is focused on natural social and semi-natural settings. In natural social settings the researcher is located in “an area of social activity and study people going about their everyday lives” (Blaikie & Priest, 2019, p. 159). Especially meso-social phenomena are interesting to study for this research because it covers, among others, organisations. However, the cases cover office buildings for the organisations that are housed there but not the entire organisation is studied. Therefore, semi-natural settings are also used for this research. In semi-natural settings individuals are considered as representatives of their own and other people’s activities, attitudes and motivations in order to generalise their input for the organisations they represent. In this study, the representatives are stakeholders of the studied renovation projects.

The main research question should be answered by analysing all the data that is gathered by means of the interviews related to the several sub-questions. Blaikie and Priest (2019) suggest an analytic induction method for the analysis of a case study method. This means that an initial investigation leads to a formulation of a hypothesis which is tested and revised through the examination of the cases. Eventually, this results in a universal relationship between the cases and a substantiated conclusion to answer the research questions. This method is similar to the deductive logic but its main differences are concerned with the fact that the deductive logic is based on theories derived from existing theories and analytic induction relies on a logic stemming from an initial investigation of the cases (Blaikie & Priest, 2019; Bhandari, 2022b). The analytic induction method for data analysis leads to a formation of hypotheses which can be used to define concepts. These concepts are assigned to the answers given in interviews as well to find relationships between the concepts. The analysis of the interviews based on these concepts is carried out using the Atlas TI software. This software is an accessible tool to easily organise and analyse the interviews, and illustrate the relationships between the concepts (or codes) by visualising the results in charts, networks, and diagrams (Riopelle, 2022).

3.3 Case studies

The main focus of this research are Dutch owner-occupied offices that are in need of renovation because of the EPC class C obligation, or owners who are willing to renovate their office building for other reasons. The cases that are selected are Dutch owner-occupied offices that have already finished their renovation because of the EPC class C obligation, or are still in the design or construction phase and therefore received a postponement from the obligation. The Netherlands Enterprise Agency (2018) has developed an online GIS-viewer to map Dutch offices and indicate which offices have to measure up to EPC class C. This GIS-viewer is used to select suitable cases for this research as it also provides an overview of the characteristics of the office building in terms of EPC class, construction year, floor area, and other matters.

In order to come up with an advice report which is suitable for the entire domain of owner-occupied offices, it is important to list case selection criteria to ensure that each aspect of the research is covered by the case studies. To ensure this, the theoretical framework is used as a starting point to list the case selection criteria. Therefore, the selection criteria correlate with the different themes

and colours of the theoretical framework. Besides, some general selection criteria are added as well, such as, construction year and building type. The construction year is related to the EPC class prior to renovation and the designated 'jump' in EPC class as a result of the renovation practices. The decision-making process prior to renovation, as listed in the theoretical framework, is divided into two project phases for the case selection criteria; planning and implementation. The project phase 'post-renovation' is added to the criteria to allow the selection of case projects which are already finished. The 'building type' theme is also added, as office owners of mixed-use buildings are dependent on the other owners of the units in the building when it comes to the decision for the implementation of certain renovation measures. Additionally, the number of employees of the organisation is also listed as a case criterion, as this might influence the organisational structure and the way an office renovation is tackled within an organisation. It should be noted that all criteria of each theme are ultimately covered by the totality of cases. Table 5 shows the different case selection criteria for the different themes.

Theme	Criteria 1	Criteria 2	Criteria 3
Construction year	< 1900	1900 - 2000	> 2000
EPC class "jump" (in relation to construction year)	Unknown / G or F → C (relative "big jump")	Unknown / F - D → C or > C (relative "big jump" or "small jump")	Unknown / D - A → > C (relative "small jump")
Decision-making phase (Project phase)	Planning (Become aware, Getting interested, Gaining knowledge, Consider options/Forming an opinion)	Implementation (Making a decision/Goal Setting Module)	Post-renovation
Stakeholders (Advisor)	External advisor	Advisor in-house	
Stakeholders (Project team)	Presence of project team	Absence of project team	
Renovation practices focused on Indoor Environmental Quality	Yes	No	
Renovation practices focused on energy-efficiency	Yes		
Building type	Mixed-use	Individual	
Number of employees	0 - 20	20 - 60	60 - 100

Table 5. Case selection criteria. Own work.

Based on above mentioned case selection criteria, five cases have been selected for this research to cover each theme and the assigned criteria. Table 6 presents an overview of the case selection criteria and how these are covered with the five cases of this research. For these five cases, several participants are selected for the interviews. Table 7 on the following page shows the profiles of the interviewees and how the interviewees are related to the different cases.

	Case project 1 Krimpen aan den IJssel 1	Case project 2 Gouda	Case project 3 Moordrecht	Case project 4 Rijen	Case project 5 Krimpen aan den IJssel 2
Construction year					
< 1900			x		
1900 - 2000	x			x	x
> 2000		x			
EPC class "jump"					
"Big jump"	Unknown / G or F → C		x		
"Big jump" or "small jump"	Unknown / F - D → C or > C	x		x	x
"Small jump"	Unknown / D - A → > C	x			
Project phase					
Planning					x
Implementation	x				
Post-renovation		x	x	x	
Advisor					
External advisor	x		x		x
Advisor in-house		x		x	
Project team					
Presence of project team				x	
Absence of project team	x	x	x		x
Renovation practice (IEQ)					
Yes				x	
No	x	x	x		x
Renovation practice (energy-efficiency)					
Yes	x	x	x	x	x
Building type					
Mixed-use			x		
Individual	x	x		x	x

Table 6. Case characteristics. Own work.

		Business profile of organisation	Function in organisation	Function during renovation
Case 1 Office building Krimpen aan den IJssel 1	<i>Interviewee 1</i>	Financial services	Co-partner	Initiator
Case 2 Office building Gouda	<i>Interviewee 2</i>	Supply of raw materials and products for the construction sector	Sustainability manager	Advisor
Case 3 Office building Moordrecht	<i>Interviewee 3</i>	Financial services	Owner	Initiator
Case 4 Office building Rijen	<i>Interviewee 4</i>	Social housing association	Project developer	Project manager of project team
Case 5 Office building Krimpen aan den IJssel 2	<i>Interviewee 5</i>	Accountancy	Owner	Initiator

Table 7. Profiles of interviewees. Own work.

Research findings

In this chapter, the research findings are examined which resulted from the carried out case studies, by means of the conducted interviews with relevant stakeholders. Chapter 4.1 first elaborates the different cases that have been studied based on general characteristics of the project and the building itself. This section is followed by an extensive discussion of the findings, divided by subchapters related to the different sub questions of this research. The codes that are used to analyse the interviews are categorised by different code groups related to the steps in the decision-making process, barriers, motivations, IEQ, renovation strategy, and renovation measures. Appendix E contains the different code groups and the assigned codes that are used with the analysis of the interviews by using AtlasTI software.



4.1 Case studies

The following paragraphs provide a short explanation of the different case projects that have been studied during this research in relation to the associated property characteristics and the renovation practices of the case project.

4.1.1 Case 1: Office building Krimpen aan den IJssel 1

The first case study contains the renovation of an office building located in Krimpen aan den IJssel. According to Interviewee 1, this office building underwent renovation in 2022 because of their tripled energy bill. Figure 16 illustrates the office building in its state after renovation. The renovation consisted mostly of updating their installations for heating and cooling by applying infrared panels and new aircon units, and installing LED lighting. As of 2023, the building owner also decided to install so-called windwokkels, vertical wind turbines. The vertical wind turbines are shown in figure 17 (De Reuver-Tellier, 2023). According to De Reuver-Tellier (2023), their goal is to generate their own energy from sunlight and wind in order to control their energy consumption and to make a contribution to the national climate targets. According to the GIS viewer, the registered EPC indicated a class F rating (Netherlands Enterprise Agency, 2022a). Constructed in 1955, the building predominantly serves as an office space, with a floor area of 611 sqm. Additionally, the building owner utilises the property for their organisation.



Figure 16. Case 1, office building Krimpen aan den IJssel. (Reklatekst B.V., n.d.).



Figure 17. Vertical wind turbines. (De Reuver-Tellier, 2023).

Interviewee 1 mentioned that the main goal of the organisation was to lower the energy bill by installing vertical wind turbines and making adjustments in their heating and cooling systems. Another aspect was reaching EPC class C because of the set regulations by the government. However, this was not their intrinsic motivation. Unfortunately, the renovation measures did not lead to reaching EPC class C. The organisation is planning on carrying out another renovation to ensure reaching EPC class C, at least.

4.1.2 Case 2: Office building Gouda

The second case study contains an office building which is located in Gouda. This office building serves as the headquarter for the organisation. On the following page, figure 18 (Google, 2022) illustrates the office building in its current state. Interviewee 2 mentioned that the building was constructed in 2002, initiated and financed by the organisation itself. The building has a usable floor surface of 1,967 sqm and it is predominantly used as office space (Netherlands Enterprise Agency, 2022a). Over the past 1,5 years, the organisation aimed to address sustainability issues

within the organisation more thoroughly. Therefore, they hired a sustainability manager 1,5 years ago to focus on the sustainability of the business operation and its properties. According to Interviewee 2, the starting point for their renovation were the energy saving duty and EED-audit duty of the government which they have to comply with. This has led to, among others, the replacement of their climate installations with heat recovery pumps, replacement of their central heating boiler for a heat pump, replacement of TL lighting for LED lighting, and the addition of motion sensors for lighting.



Figure 18. Case 2, office building Gouda. (Google, 2022).

This office building was also listed in the GIS viewer of an office building that has to comply with the EPC class C obligation (Netherlands Enterprise Agency, 2022a). As the building did not have a registered energy label, the organisation applied for the establishment of an EPC class which resulted in a classification of EPC class A+. Interviewee 2 mentioned that the organisation aims to be a forerunner when it comes to sustainability in its business operation and their properties. The organisation uses the sustainability of their head quarter as an image towards their customers as well.

4.1.3 Case 3: Office building Moordrecht

The third case study focuses on the renovation of an office building located in Moordrecht. Based on the information provided by the online GIS viewer, this property was constructed in 1839 and has an EPC class A rating (Netherlands Enterprise Agency, 2022a). The usable floor space of the office is 151 sqm. A photograph of the office building is illustrated in figure 19 on the next page. Interviewee 3 disclosed that the building had an initial EPC class G classification before its renovation, which occurred approximately two and a half years ago. The motivation for obtaining an energy label was to facilitate the sale of the building from the previous to the current owner, as the organisation was still renting the office space. After buying the office building, the current office owner was aware of the impending EPC class C obligation, scheduled for 2023. Consequently, they undertook renovation activities to prepare for this obligation and to allow sufficient time for more extensive renovations, if needed. To achieve at least an EPC class C

rating, several renovation measures were implemented over the past few years. According to Interviewee 3, these actions included installing double glazed windows on the front and back sides of the building, incorporating LED lighting, adding acoustic panels between workplaces, and employing air conditioning units for heating and cooling, as opposed to using a central heating boiler. Surprisingly, as mentioned by Interviewee 3, these seemingly small adjustments ultimately resulted in an EPC class A rating after renovation.



Figure 19. Case 3, office building Moordrecht. Own work.

4.1.4 Case 4: Office building Rijen

The fourth case contains the renovation of an office building located in Rijen. According to the GIS viewer, the property was built in 1991 and has a usable floor space of 3,655 sqm (Netherlands Enterprise Agency, 2022a). Currently, the building is registered with EPC class A and is listed as a building with an office function (KadastraleKaart, 2023). Figure 20 (Leystromen, 2018), on the following page, shows a part of the total property. Almost ten years ago, the organisation set up a project team within their own organisation to guide the interior renovation of their office space. The previous office lay-out was not sufficient for the future plans of the organisation; the organisation was merging with other organisations and all employees were supposed to be working in the headquarter in Rijen. Besides, two smaller locations of the organisation were closed in the future in order to facilitate the entire business operation from one location. Previously, the office lay-out was based on closed workplaces and the goal of the organisation was an open workplace concept. Besides, Interviewee 4 mentioned that the organisation was aware of the EPC class C obligation that was set for the 1st of January 2023. Before the renovation, the property was labelled with energy label E, so this has led to an integral renovation of both the interior and the installations of the property; the entire roof is filled with solar panels, heating is facilitated by air heated pumps, and ventilation is mechanically adjusted. Because the measures were quite extensive, the project

team needed to set up a business case which should ensure the financial feasibility of the project, as mentioned by Interviewee 4. This eventually led to a multi-year investment plan for the overall renovation. Interviewee 4 acknowledges the evolving character of the organisation, as they are planning to upgrade their workplace with more possibilities for hybrid working.



Figure 20. Case 4, office building Rijen. (Leystromen, 2018).

4.1.5 Case 5: Office building Krimpen aan den IJssel 2

The fifth case is another office building located in Krimpen aan den IJssel. This office building was built in 1989 and is registered with energy label E (Netherlands Enterprise Agency, 2022a). The usable floor space of this office is 313 sqm. Interviewee 5 mentioned that last year, the office owner decided to ask a third party for advice upon sustainability measures to reach EPC class C. The office owner was not aware that the property of the organisation also had to comply with the EPC class C obligation. This means that they are still in the process of renovating and finding ways to obtain energy label C. The installation of LED lighting was the first and only intervention that was carried out based on the advice report. The advice report also suggested the installation of solar panels and adjustment to the front entrance doors, to decrease heat loss. Currently, they are planning on carrying out roof insulation and the renewal of their roofing material, followed by the installation of solar panels. Unfortunately, receiving offers from third parties for these activities is taking a long time. According to Interviewee 5, electric heating possibilities are still investigated, such as heating with their air conditioning system, or heating with infrared panels, in order to reach a gas-free building operation. Figure 21 illustrates a photograph of the building in its current state.



Figure 21. Case 5, office building Krimpen aan den IJssel 2. Own work.

4.2 Decision-making processes prior to the renovation

Chapter 2.4 discussed the decision-making processes of sustainable or energy-efficiency renovations for general building types and housing, based on existing literature. Figure 22 is also presented in that section as a holistic overview of the decision-making processes discussed in Chapter 2.4. This framework is used to analyse the decision-making processes of the participants, specifically during the planning phase. It should be noted that the decision-making processes, as elaborated in Chapter 2.4, are not specified for office renovation practices. Still, this framework is used to determine whether this framework is also applicable for the decision-making processes related to the case projects, in order to answer the first sub question of this research: “*What does the decision-making process prior to renovations entail for private owners of Dutch owner-occupied office buildings?*”. This section provides an analysis of the decision-making processes of the interviewees, prior to the execution of the actual renovation implementations, based on the different distinguished steps during the planning phase. Chapter 4.6 delves more into specific elements and critical junctures during the different identified phases of the decision-making process prior to renovation of Dutch owner-occupied offices.

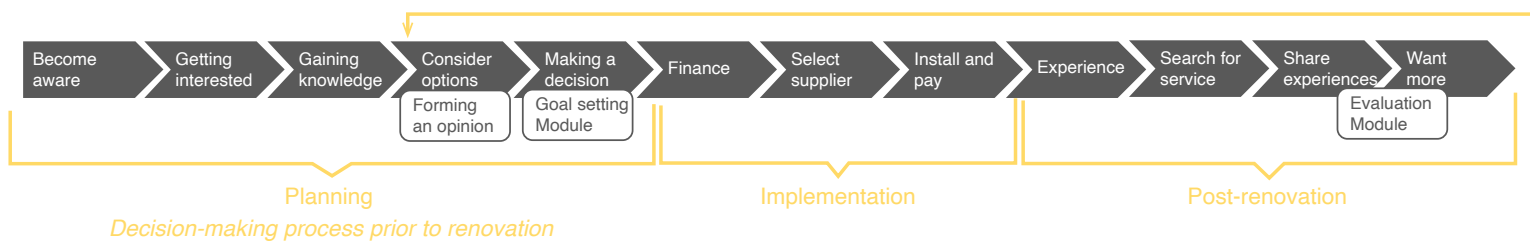


Figure 22. Decision-making process of sustainability renovations. Own work (based on VNG, 2015; Nielsen et al., 2016).

4.2.1 Become aware

When it comes to becoming aware that the property was in need of renovation, or the organisation itself was in need of an updated or renovated property, there are several motives mentioned by the participants. For Interviewee 1, 3, and 5, the participants became aware because of the governmental obligation of EPC class C for office buildings by January 1st 2023. The focus of their renovations therefore lay on an upgrade in the energy efficiency of their property in order to obey the set governmental regulation. Interviewee 2 mentioned that their organisation wants to focus on the sustainability of their entire business operation. This means that the awareness on the sustainability of their office building grew as being part of an integral sustainability assignment for the organisation. Contradictory, the awareness of Interviewee's 4 organisation for an office renovation grew because of several merging organisations that needed to be housed at one location. This renovation was mainly focused on an update of the functional layout of the building and its work spaces. However, as the organisation was aware of the, at that time, future EPC class C obligation, they decided to upgrade the energy efficiency of the property simultaneously.

4.2.2 Getting interested

As the first awareness of the majority of the participants is related to a governmental obligation, Interviewee 1, 3, and 5, did not necessarily show a growth in interest in relation to sustainability matters or energy-efficiency renovations in their answers after becoming aware. Moreover, the governmental obligation was one of the only reasons for them to renovate their properties. The same is noted with the answers of Interviewee 4. The organisation of Interviewee 4 only integrated an energy-efficiency upgrade in their renovation plans because the organisation

already planned a renovation to optimise the functional layout of their work spaces. This was also due to the governmental obligation that was already foreseen at that time. As for Interviewee 2, the interest for an energy-efficiency renovation of their office building grew because it is part of the integral sustainability assignment of the organisation, as previously mentioned. Becoming aware and getting interested can be seen as a joint step in the decision-making process prior to their renovation.

4.2.3 Gaining knowledge

Interviewee 1, 3, and 5, again show similarities in the decision-making process when it comes to gaining knowledge. In order to gain relevant knowledge for the renovation and its options, they all hired an external advisor to advise them upon possible measures to implement to obtain EPC class C. As Interviewee 3 stated: “So then I immediately had someone come over here and say, well, how are we going to do that? And then they gave me those suggestions. Based on that, it turned out like this.”. This quote translates the trust of the participant towards the advisor; the advisor has the knowledge that the organisation needs for the renovation. Interviewee 1 stated the same: “Yes, we rely on the advisor and we do that work [being an advisor] ourselves. And yes, those are the specialists.”. Besides an advisor, Interviewee 1 also talked with the municipality to inform them about large wind turbines. The vertical wind turbines that are placed, was an idea that Interviewee 1 occurred during the visitation of one of the clients of the organisation. It was a formal business meeting, but the associated company recently installed their vertical wind turbines on their property. Interviewee 1 mentioned: “And when I parked my car there, I suddenly saw it [the vertical wind turbines] turning and then I thought, hey. And that was actually the first question I asked there and I did not come for that. And that is why I took that back with me: “Hey, that might be something for us as well”. After gaining knowledge, Interviewee 1 showed a growth in interest.

Interviewee 4 discussed that the organisation established a project team for the office renovation; to approach it as a project as the organisation is used to as a housing association. In this project team, several roles are represented and a lot of relevant knowledge is already in-house, especially as the organisation already practises energy-efficiency renovations for their housing portfolio. The organisation of Interviewee 2 also has relevant knowledge in-house available, as the participant was hired as a sustainability manager for the integral sustainability assignment of the organisation. However, Interviewee 2 did mention: “At the moment that we do lack knowledge, we will hire a partner, or an advice company, or we approach an installer.”. Additionally, the examination of the building to assess the EPC class is always done by an external advisor. This applies to all cases. Interviewee 4 stated, in relation to this: “Of course, the determination of an energy label, we always have that done by an advisor. We cannot and should not do that ourselves.”.

4.2.4 Consider options (Forming an opinion)

The involved advisors presented several renovation measures to Interviewee 1, 3, and 5. As Interviewees 3 and 5 elaborated, those were also the only measures that were taken into consideration. Apart from Interviewee 1, these participants did not gather any additional information for possibilities elsewhere. Interviewee 5 expressed: “They did give some tips, a few aspects, so to say. So, indeed, the installation of solar panels was suggested as an option. The adjustment of the front facade (...) to do something with that. And LED lighting. Those were actually the three aspects that stood out for me.”. Interviewee 3 took the advice to heart, as the participant stated: “Well, he [the advisor] said: If you do this, you will obtain EPC class A. I said: Well, then I will not do anything more, I think it is alright, then.”.

Interviewee 1 did mention that the main motivation for their renovation was their tripled energy bill. Because of this, the organisation aimed at a renovation measure that would pay back the investment by a considerable decrease in their energy bill. Therefore, the investment that the organisation made was not the cheapest option, but it was the investment that should have the most impact on their energy bill. Interviewee 2 and 4 both mentioned that the consideration of their options consisted of the establishment of a multi-year approach for the renovation of their office buildings. This allowed the organisations to ensure the financial feasibility of the plans and also allowed them to determine the sequence of several interventions that are necessary and/or desired. Interviewee 2 expressed: “We are now working on mapping those strategic issues. So, what themes are important for our sector and in general? And energy is one of them. And how are we going to approach this and what spot do we want to put on the horizon?”. This shows that the organisations of Interviewee 2 and 4 approached the office renovations differently, but this is also related to the fact that their motivations for the office renovations differ compared to those of the other participants. This is further elaborated in Chapter 4.3.

4.2.5 Making a decision (Goal setting Module)

In all case projects, the final decisions for the implementation of renovation measures are made by the initiator of the renovation, the office owner. In relation to the role of the participants during the renovation, this means that Interviewee 4 and 5 did not make the renovation decisions or investments for the renovation themselves. Their role was to advise the office owner and initiator upon possible measures. As mentioned in the previous section, Interviewee 3 and 5 considered the options that were proposed by the advisors as the only suitable solution to obtain EPC class C and therefore the final decision for the implementation of renovation measures is based on the advice that is provided to them with the supplied advice reports. Interviewee 1 made a final decision based on the option with the foreseen biggest impact on the reduction of their energy bill costs. The organisation hopes that these measures subsequently lead to obtaining EPC class C after implementation.

Table 8 provides an overview of above mentioned results, based on the conducted interviews with the participants. This table is divided by phases in the decision-making process prior to renovation. This table is further developed in the following sections of this chapter, to eventually provide a holistic overview of the research results with all information, motivations, barriers, and other matters, allocated to the different phases in the decision-making process.

Decision-making aspects prior to renovation	Planning phase				
	Become aware	Getting interested	Gaining knowledge	Consider options	Making a decision
Case 1	Tripled energy bill in a short period of time. Focus on lowering energy bill and aiming to consequently obtain EPC class C.	Not specifically mentioned after becoming aware.	Consult an advisor. Inspiration from vertical wind turbines of a client. Conversation with the municipality about wind turbines. Growth in interest after inspiration.	Aiming for the option with the biggest foreseen impact on a decrease of their energy bill costs. Not opt for the cheapest option.	Interviewee is initiator and office owner, makes final decision based on highest reward in terms of a decrease in energy bill costs.
Case 2	Organisation wants to focus on sustainability as an integral part of their total business operation, including their properties.	Interest for improved energy-efficiency in their office grew because it is part of the integral sustainability assignment.	Knowledge in-house because of hiring a sustainability manager. Consult additional advisors when necessary.	Establishment of a multi-year renovation strategy to ensure financial feasibility of different interventions.	Interviewee is sustainability manager; advises the initiator/office owner upon possible interventions.
Case 3	Because of EPC class C obligation. The office building does not comply yet and is in need of an energy-efficiency upgrade.	Not specifically mentioned after becoming aware.	Consult an advisor.	Only consider options presented in advice report.	Interviewee is initiator and office owners, makes final decision based on advice report.
Case 4	Several merging organisations needed to be housed at one location. Major office renovation needed for improved functional layout, consequently aiming for improving energy-efficiency to obtain EPC class C in time.	Not specifically mentioned after becoming aware.	Establishment of a project team with several bodies of knowledge in-house. Consult additional advisors when necessary.	Establishment of a multi-year renovation strategy to ensure financial feasibility of different interventions.	Interviewee is project leader of the renovation; advises the initiator/office owner upon possible interventions.
Case 5	Because of EPC class C obligation. The office building does not comply yet and is in need of an energy-efficiency upgrade.	Not specifically mentioned after becoming aware.	Consult an advisor.	Only consider options presented in advice report.	Interviewee is initiator and office owners, makes final decision based on advice report.

Table 8. Decision-making aspects, allocated to different decision-making phases. Own work.

4.3 Motivations and barriers to carry out energy-efficiency renovations

The second sub question of this research is: “What are the motivations and barriers of private office owners to carry out energy-efficiency renovations in Dutch owner-occupied offices?”. The following sections discuss the motivations and barriers which are mentioned by the interviewees, in relation to the different phases of the decision-making process. Firstly, table 9 presents a comprehensive overview which resulted from the analysis of the interviews with AtlasTI. This figure shows the different barriers and motivations in a co-occurrence table, related to the different decision-making phases. With the help of this diagram, it can be noted that most motivations are linked to the decision-making phases of becoming aware and considering options/forming an opinion. The mentioned barriers mostly occur during these phases as well. The following sections discuss the motivations and barriers, as mentioned by the participants, more extensively.

	Decision-making process: becoming aware	Decision-making process: consider options/forming an opinion	Decision-making process: gaining knowledge	Decision-making process: getting interested	Decision-making process: making a decision/Goal setting module
Barrier: availability of resources and people	0	6	0	0	1
Barrier: building not sufficient for measures	0	7	1	0	0
Barrier: delivery time	0	1	0	0	0
Barrier: execution too extensive	2	10	1	1	1
Barrier: ISO not considered by advisor/third party	1	2	3	0	0
Barrier: investment too expensive	4	10	1	2	0
Barrier: lack of knowledge	3	10	4	0	0
Barrier: not taking initiative	9	3	1	1	0
Barrier: uncertainty of future of organisation	1	5	1	2	0
Motivation: being a leader in sustainability	0	0	0	3	0
Motivation: EPC class C obligation	7	4	2	0	0
Motivation: image of organisation	2	2	0	3	2
Motivation: other governmental obligations	2	3	0	1	0
Motivation: preparing for the future	6	4	0	3	1
Motivation: reduce energy bill costs	2	6	1	1	3
Motivation: sustainability as part of the organisation	1	1	0	1	0

Table 9. Co-occurrence table of motivations and barriers in relation to decision-making phases. Own work with AtlasTI.

4.3.1 Motivations

During the interviews with the office owners of the case study projects, several motivations for their renovations have been mentioned. The office building of Interviewee 2 did not have a registered energy label prior to their renovations, but it was classified with EPC class A+ afterwards. However, their motivation was to prepare for the future and therefore avoid new renovations when the obligations in terms of EPC class become stricter in the future. Besides, their organisation already had to comply with other regulations that were set by the government in earlier years; “The basis was actually the energy saving obligation from a few years ago and the Energy audit duty from the European Union, we took up that list of points [from the Energy audit duty]”. Nevertheless, Interviewee 3 wanted to update their entire interior because it was outdated and their property was labelled with EPC class G. Interviewee 3 carried out renovations and applied for a new EPC registration afterwards. Interestingly, the renovation of Interviewee 3 was not necessarily aimed at reaching EPC class C in the first place, but it also came as a favourable side-effect, as also seen with Interviewee 1. The building eventually reached EPC class A after renovations. An outdated interior was also mentioned as a motivation by Interviewee 4 as their organisation needed to house more employees in their office as a result of merging organisations and the desire to close smaller offices which were located in their working regions. This raised the question for an updated office lay-out while simultaneously adjusting the office place to respond to the concept of hybrid and flexible workplaces.

Another motivation that is mentioned by Interviewee 1 and 2 is the fact that the renovation enhances the image of their organisation. In case of Interviewee 1, the placement of the vertical wind turbines resulted in many positive responses from their clients and other people visiting or passing their building. Interviewee 1 mentioned: “We have people visiting or passing by on a weekly basis now . . . they are supporting us and telling us we are doing a good job”. When it comes to the image of the organisation for Interviewee 2, the renovation of their office is part of a larger goal; “Sustainability should become a strategic element of the entire company”. This

means that their entire business operation is changed into a more sustainable business operation over the coming years and the upgrade of their office is only a part of the multi-year strategic sustainability plan they are currently setting up. By implementing their multi-year strategic sustainability plan for their entire business operation, including their properties, they are trying to be a leader in sustainability in their sector and be an example for other organisations. Interviewee 2 mentioned: “If we do so in our business operation, why not do exactly the same for our fabrics and offices that are just standing somewhere in a random industrial area?”. A similar point of view is acknowledged by Interviewee 4 as their renovation resulted in an EPC upgrade from class E to class A. The organisation of Interviewee 4 has to comply with sustainability standards given by national regulations because they provide social housing. Interviewee 4 mentioned that their office should comply with the same regulations and show their capability in energy-efficiency renovations. This relates to the motivations of contributing to the image of the organisation and sustainability as a part of the organisation. On the other hand, Interviewee 3 and 5 mentioned that, eventually, their main priority was to comply with the governmental obligation of EPC class C and that there was no motivation to invest more money in their property than needed. Interviewee 3 mentioned: “On the one hand you wish to heat more economically and efficiently, but I did not feel like investing ten thousand of euros to eventually save a couple of tens per month. I do not think I would ever earn that back.”

4.3.2 Barriers

Besides motivations to carry out energy-efficiency renovations, there were also experienced barriers when it came to deciding upon carrying out the energy-efficiency renovation. The barrier that is encountered by almost all interviewees is the lack of knowledge of the participants. In their cases, the renovation of their own property does not belong to the core activities of their organisation. Therefore, Interviewee 1, 3, and 5 all engaged a consultant to advise them upon possible measures to comply with the governmental obligation of EPC class C. Nevertheless, when Interviewee 1 was questioned about the information provision in the advice report that the organisation received concerning possible sustainability measures, the participant declared: “Well, I am a layman at that”. In the case of Interviewee 4, their organisation is familiar with carrying out energy-efficiency renovations for their housing portfolio. Interestingly, all participants decided to hire an advisor to advise them upon possibilities for their property and their renovation. This is also due to the fact that none of these organisations is allowed to draw up energy labels, so a third-party was involved to criticise their properties in order to register a new EPC class after renovation. The lack of knowledge of the interviewees also resulted in them not taking initiative for energy-efficiency renovations or investigating the possibilities. When asked whether the renovations would have occurred in the absence of their energy bill tripling, Interviewee 1 provided a concise and impactful response: “I don’t believe so.” The barrier which considers the lack of knowledge of the interviewees is also related to the barrier of not taking initiative in most cases. Interviewee 1 and 5 both did not comply with the EPC class C obligation by 1st of January 2023. Interviewee 5 even declared: “We have done very little, too little” and “We actually slept a bit before then, of course we should have done it sooner”.

Interviewee 1, 3, and 5 mostly experienced that certain renovation measures would be too extensive and too expensive for them. Their organisations are smaller, in terms of employees and business operation, compared to the organisations of the other case studies. Any investment they would make, is associated with the financial future of their organisation. Interviewee 3 even mentioned that his retirement is in the back of his mind when deciding upon investments for energy-efficiency renovations. Consequently, these organisations are withholding additional investments aimed at preparing themselves for potential future obligations as it is uncertain for them whether

the investments will be earned back in time. Their incentive primarily revolves around adhering to existing regulations, and these organisations intend to react and contemplate future investments solely when such future obligations become mandatory. When it comes to obtaining EPC class C, Interviewee 1 stated that their organisation would consider the least expensive options to comply with the regulation. Still, as their energy bill tripled in a short period of time, they opted for more expensive measures to “kill two birds with one stone”; lower their energy bill costs and obtain energy label C simultaneously. The extensiveness of renovation measures that were mentioned were mostly concerning the installation of solar panels or mechanical ventilation systems. For the installation of solar panels, Interviewee 5 stated: “You should only install solar panels when the roofing is inspected in terms of the right condition. We were told that we should replace our roofing material first”. Interviewee 1 received the same advice when considering the installation of new solar panels. However, the extensiveness of replacing the roofing material set him back to decide upon this measure. Interviewee 3 also mentioned extensiveness of measures as a barrier in his decision-making as his property is rather old and leaves many measures impossible, or seemingly impossible, to implement. For example, the installation of a mechanical ventilation system for Interviewee 3 was named as a “never-ending story” as Interviewee 3 eventually stated: “Yes, undoubtedly, you should be able to realise some sort of mechanical ventilation, I guess, but it would probably cost a lot because, of course, the property is not built for it and it would require rather many adjustments”. This quote also shows the lack of knowledge and reluctance to invest more than needed.

To deal with the expensiveness of investments, Interviewee 2 and 4 decided to come up with a multi-year strategy for the implementation of their renovation measures to ensure the financial feasibility of their plans. Interviewee 4 even mentioned that this multi-year strategy was presented as a business case. When Interviewee 1, 3, and 5 were asked about a possible multi-year strategy, their answers were likewise: their organisations are considered as too small to capture a renovation strategy in a multi-year plan.

When it comes to the actual execution of the renovation practices, the most mentioned barrier was the delivery time of materials and the lack of availability of resources and people. This is mentioned by Interviewee 1, 2, and 5, who were the case studies with the most recent renovations or are still planning on carrying out renovation measures. The unavailability of resources and people led to a delay in the planning of their renovation process.

4.4 Awareness of impact of Indoor Environmental Quality post-renovation

During the interviews, the first part focused on the decision-making processes of the participants, related to the renovation of the case project. The second part focused on the concept of IEQ. To introduce this second part, the first question to be asked was: “*Are you familiar with the concept ‘Indoor Environmental Quality’, in other words, the quality of the indoor environment, and what kind of influence this has on the employees/occupants of office buildings?*”. The answering of this question by the interviewees leads up to the data collection needed to answer the third sub question of this research: “*To what extent are private owners of Dutch owner-occupied offices aware of the impacts post-renovation, based on IEQ and occupant’s productivity?*”.

It is important to highlight that none of the interviewees were familiar with the IEQ concept when questioned in the interview. Therefore, all participants were informed about the concept of IEQ, the associated aspects, and consequences of an inadequate IEQ through a pre-written introduction, as listed in the interview protocol. Since the interview protocol is written in Dutch, the following paragraph contains the introduction that was elaborated to the participants in English. This introduction is based on information on the concept of IEQ which derived from the literature review study.

“The four domains/aspects of IEQ are air quality, thermal comfort, acoustic comfort, and lighting comfort. These aspects all have a certain influence on the health of occupants of offices. In addition, this can influence the satisfaction, comfort, well-being, cognitive function, and productivity of office users. Air quality includes air humidity, level of ventilation, odour dispersion, dust, air dryness, etc. When office users are dissatisfied with the quality of one of the four aspects or domains, they may become tired more quickly, be dissatisfied with their workplace, or get health related problems. This significantly reduces the productivity of the employees. For example, many studies show that most complaints from office users are associated with the temperature of their workplace or noise pollution. This causes a lot of stress and a drop in productivity. Light quality also has a major influence on the cognitive productivity of office users. Poor light quality is more likely to lead to health problems such as headaches, fatigue, etc.”

After discussing the above mentioned introduction, all interviewees indicated with their answers that there was a profound understanding of the consequences and it was logical to them, especially consequences in terms of productivity and job satisfaction. For instance, Interviewee 1 stated that the temperature in their office building is a daily issue, especially during summer time. Consequently, Interviewee 1 praised: “I get that your productivity decreases then, yes, you just doze off [in Dutch: dan kak je gewoon in]”. Interviewee 3 also discusses the indoor temperature of their office building and states that each employee can adjust the temperature to their own desire. When considering the indoor temperature, Interviewee 3 gave a similar understanding as Interviewee 1: “But I do think it contributes to your comfort, just to your work, yes, your enjoyment of work, how you feel about it”. Additionally, after the implementation of double glazed windows in the office building of Interviewee 3, their acoustic and thermal comfort increased because of a reduction in noise pollution and heat loss. Unfortunately, Interviewee 5 was the only participant to state that the quality of the indoor environment did not play any role at all in their organisation. The other interviewees were unwittingly already paying attention through the implementation of their renovation measures. However, this does not imply that those systems were integrated based on a motivation to upgrade their IEQ.

When it comes to job satisfaction, Interviewee 1, 2, and 3 stated that they are curious about the user satisfaction and overall workplace satisfaction after the implementation of the renovation measures. Yet, these participants mentioned that it is not measured or questioned. Interviewee 1, 2, and 3 stated that the employees can express themselves upon this subject in an informal way and mention shortcomings whenever they would like. The same applies to the answer given by Interviewee 5. Consequently, Interviewee 4 was the only participant to mention a resonance group and an employee satisfaction survey as part of their renovation strategy. The resonance group is used to gather information about the preferred workplace lay-out and to create a support base for the renovation measures and avoid any resistance. The employee satisfaction survey is used post-renovation by the organisation to see how the employees experience their workplace and to find aspects that should be focused on, or improved with additional renovation practices. This shows that the organisation of Interviewee 4 is consciously taking the opinion of their employees into consideration when it comes to workplace satisfaction. However, the other participants also take this into consideration, but they do not use an employee satisfaction survey. Interviewee 2 stated that there is a possibility that such a survey will be implemented. The other participants stated that their organisation is too small to do so and it is more likely to gather such information more informally in the workplace.

When reviewing the awareness of the participants in relation to the impacts of certain renovation measures on the IEQ and occupants' productivity post-renovation, it can be noted that none of the participants paid attention to possible impacts prior to renovation, nor did they act on it to mitigate the possible impacts. This is related to the fact that the participants were not familiar with the concept and the consequences of a bad IEQ. However, after elaborating this, the participants showed understanding and willingness to consider it more specifically. The next chapter contains motivations and barriers of the participants when it comes to the consideration of IEQ during renovation processes.

4.5 Motivations and barriers to consider Indoor Environmental Quality during renovation

The fourth research sub question inquires: *“What are the motivations and barriers of private office owners to consider IEQ during the renovation process of Dutch owner-occupied offices?”*. As previously mentioned in chapter 4.4, none of the participants were familiar with the IEQ. After discussing the characteristics of the different IEQ aspects briefly, Interviewee 1, 2, and 4 all recognised that certain renovation measures undertaken did indeed lead to an enhancement in the quality of their indoor environment, but it was not their intrinsic motivation during the renovation process. The subsequent paragraphs explore the motivations and barriers related to the consideration of implementing IEQ aspects during the renovation process as cited by the interviewees.

4.5.1 Motivations

When it comes to the implementation of IEQ measures during renovation, none of the interviewees were considering the consequences of their renovation measures in a conscious way. Still, some renovation processes of the studied cases did incorporate measures that are beneficial for the quality of the indoor office workplace. The most common implementations were: adjustments in ventilation systems, ergonomic comfort of workplaces, personal control over workplace temperature and ventilation, or possibility to open windows, and acoustic adjustments. Interviewee 1 even mentioned the installation of air quality monitors, despite the fact that they are still unaware of the meaning of the digits on such monitors.

After asking whether the participants would make certain renovation choices differently if one was aware of the IEQ aspects prior to their renovation process, the recurring answer was referring to the importance of the health and wellbeing of their employees. Related to health issues, Interviewee 1 stated: “Well, I think the health of yourself and of your employees is the most important thing, so that comes first”. Besides, this participant mentioned that the occupants of the office spent more of their time at the office than at home. This emphasised the importance to ensure job satisfaction and happiness at work through renovation measures for Interviewee 1. Interviewee 4 showed more thoughtful thinking when mentioning that sustainability and IEQ should “probably have a fifty-fifty rating”; the participant stated: “You should just have both”. When considering workplace satisfaction of the office occupants, Interviewee 2 suggested the implementation of an employee satisfaction survey: “I think the ‘human’ side of sustainability is also important. In itself, I would find it interesting to know whether the colleagues are satisfied with the office space”. An employee satisfaction survey was already implemented in the renovation process of Interviewee 4. Their organisation even uses the outcome of the survey to plan future adjustment to the office. However, Interviewee 4 was also the only participant to mention active end-user involvement through resonance groups during the renovation process, which shows their involvement with their occupants. Interviewee 1, 3, and 5 stated that their organisation is too small for the implementation of an employee satisfaction survey and that they are open to discuss any issues in an understated way in the workplace. For instance, Interviewee 3 expressed: “So, it is kind of an ‘like knows like’ office, so I always tell them: if there is anything, if you miss anything at all, do not feel encumbered, just call. The threshold is low, for that matter”.

4.5.2 Barriers

When discussing the concept of IEQ during a renovation process, several barriers were mentioned by the participants. The most prevalent barrier was a difference in personal preferences in relation to aspects such as temperature, ventilation, and lighting. This barrier is connected with the desire for personal control, which appeared to relate closely to user satisfaction, based on information provided in the literature study. The participants correlated an upgrade in their IEQ with automated and standardised ventilation rates and temperatures in the workplace. This is supported by Interviewee 3, as the participant communicated the desire to upgrade the IEQ of the office workplace by installing a mechanical ventilation system. However, the interviewee emphasised that the property was too old and did not leave the organisation with the possibility for the implementation of this measure. This also relates to another barrier, lack of knowledge, which is also a barrier in the case of energy-efficiency renovations. The lack of knowledge barrier is found by all participants. As mentioned earlier, Interviewee 1, 3, and 5 hired an advisor to advise them upon possible renovation measures to comply with the EPC class C obligation. This third party only advised the organisations involved about the energy-efficiency upgrades and did not include the IEQ aspect in their reports. Interestingly, when these participants were asked who should advise them on IEQ aspects in relation to their renovations, they all stated that it was the role of the advisor in these cases. For instance, Interviewee 1 stated: “They just make a report on how you can become more sustainable compared to the energy and financial savings, but not in terms of living or working comfort, absolutely not”. Interviewee 2 acknowledged that other third parties, that are involved during the implementation of renovation measures, would not advise about the consequences of certain measures in terms of IEQ either: “Look, if we call an installer for example, to get rid of the last central heating boiler that is left . . . yes, then you go to the installer and they will not mention: well, your comfort will be different then, or better, or less. They are not taking that into consideration either”.

Lastly, the barrier that was commonly found throughout the interviews is not taking initiative. However, as there is a lack of knowledge and the advisory third parties do not consider the consequences of a renovation for IEQ aspects, it is somewhat logical that the participants do not act towards a better indoor quality. Not only are the participants not motivated, or even informed about IEQ aspects and the consequences of their renovations for their occupants, most of them are also unwilling to invest more than needed. As mentioned in chapter 4.3, some of the participants articulated that their renovation was mainly focused on reaching EPC class C. All the investments they are willing to make should be focused on their main goal. Interviewee 5 even stated that the organisation is only willing to invest in an improvement of their IEQ when there are governmental obligations involved: “We would only do so, I guess, when it becomes mandatory”. A similar way of thinking is found by Interviewee 1 and 3, as they are both focused on their return on the investment, in other words, if the investment will eventually pay back in time.

4.6 Specific elements and critical moments in relation to decision-making phases

The fifth sub question is: “*What are specific elements and critical moments in relation to the different identified phases of the decision-making process prior to renovation of private owners of Dutch owner-occupied office buildings?*”. In order to answer this sub question, all research results are summarised in a systematic way, related to the different decision-making phases, as identified during the interviews. Table 10 illustrates the summary of the research results and also lists the key take-aways in the right column. Table 10 continues on the following page.

	Case 1	Case 2	Case 3	Case 4	Case 5	Key take-aways
Become aware	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - Reduction of energy bill costs, as their energy bill costs had tripled. - Becoming an owner of their building 3 years ago raised the awareness that they should determine a strategy and a vision for their property. - The participant is aware that there were approaching governmental obligations in terms of sustainability. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The organisation aims to integrate sustainability in the entire business operation. This included a sustainability upgrade of their property. - Governmental obligations related to their business operations raised their awareness (energy audit duty, energy saving duty). 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant bought the office building 4 years ago and it had a registered EPC class G. The initial office renovation was focused on upgrading the interior and functional layout of the workplaces. - The participant found out that the office building had to comply to the EPC class C obligation in 2 years time at that time. - In terms of IEQ, the participant only was aware of Dutch ARBO regulations. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The organisation had to merge with other organisations and therefore more people had to work in the office building. - The functional layout of the office had to change. - In terms of IEQ, the participant mentioned Dutch ARBO regulations as boundary conditions. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The office owner received a letter which mentioned that office building did not comply with the EPC class C obligation in time. 	<p>Key take-aways</p> <ul style="list-style-type: none"> - The EPC class C obligation raised the awareness of the majority of the office owners. - The office owners were aware that being or becoming an office owner also means that one has to decide upon a strategy for their office building in terms of maintenance and adjustments to the changes in their organisations.
	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - If the energy bill costs had not tripled over the past period of time, the renovation would not have taken place the same way as it did now. The participant stated that they would have opted for cheaper measures to only obtain EPC class C. - The participant was not aware of post-renovation IEQ impacts and therefore did not experience a raised awareness to consider this during the renovation process. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant focuses on reaching governmental standards and current standards do not raise awareness related to IEQ and office renovations. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant focuses on reaching EPC class C and did not want to be aware of post-renovation IEQ impacts and did not become aware to consider this as well. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The organisation understands that sustainability is important to carry out towards their clients by means of their office building, but the investments for the office building can also be used for the renovations of their housing stock. - Only ARBO regulations are used as a guideline for IEQ aspects. The concept of IEQ was not familiar for the participant. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant stated that the office renovation was initiated too late because he was not aware that the obligation counted for his office building and only started the process when a letter was sent that the office building did not comply yet. - IEQ aspects are never considered by the participant. The organisation functions as is and that did not raise a need for any updates in relation to their IEQ, only to comply with governmental standards, the office renovation is going to be carried out. 	<p>Key take-aways</p> <ul style="list-style-type: none"> - Focus lies on complying with governmental obligations related to sustainability and energy-efficiency. - If other dysfunctions of the office building would not have been present, the renovation would not have been initiated.
Getting interested	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - When looking for renovation measures to reduce their energy bill costs, the EPC class C obligation approached. This gained their interest to invest in measures which would simultaneously decrease their energy bill costs and obtain EPC class C. - The interest grew when the interviewee saw vertical wind turbines at the property of one of their clients. The interviewee acknowledged that this investment was also meant to make a statement towards their clients as being a sustainable organisation. - Air monitors were installed because a client of them introduced them. - The participant understands the effects of a bad IEQ, after explaining them during the interview. The participant stated that the organisation is always interested in the way the employees experience their working environment. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - When sustainability becomes an integral part of the business operation, the organisation becomes more attractive for their clients. A sustainable head quarter can function as a 'signboard' for their sustainable business operation. - The participant is interested in the 'human' side of renovations and is willing to gather information by the employees and users of the building concerning the IEQ because the participants acknowledged that a bad IEQ can impact a user's productivity and overall workplace satisfaction. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant was willing to make small adjustments to comply with EPC class C. - The participant understands the effects of IEQ, after explaining them during the interview. The participant stated that the threshold is low for employees to express dissatisfaction and discomfortability. - The employees have different rooms with separate workplaces. The temperature can be adjusted separately in each room. Each employee can adjust this to their own desires. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - After the first workplace renovation, the office owner became aware of the EPC class C obligation and the office building needed another renovation. - The organisation uses employee satisfaction surveys to gather information about workplace satisfaction and possible future needs for workplace updates/renovations. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant tried LED lighting in one of the workplaces to test the lighting quality. After deciding upon the installation of LED lighting for all workplaces, the energy bill costs decreased. This raised the interest of the office owner for the installation of more sustainability measures as well. 	<p>Key take-aways</p> <ul style="list-style-type: none"> - Sometimes, sustainability plays a big role in the organisation and the office owner wants to use their building as a part of their sustainable image towards their clients. - After information about IEQ concepts, the majority of the participants were interested and also expressed the importance of the health and wellbeing of their employees.
	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant does not understand the values that are stated on the air monitors nor does the participant act on a change in value for these monitors. - Different personal preferences are stated as a barrier, as the participant does not consider smart systems as useful. This requires standardisation and the personal control will be decreased. - The workplace satisfaction of employees is not asked about and employees should mention it as it occurs. The participant thinks that the threshold is low for them to open up about it. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant stated that different personal preferences are very common in terms of the indoor climate of a workplace. This leaves them uninterested for standard temperatures or ventilation rates. - Standardisation in terms of motion sensors is implemented, but the employees are annoyed with the systems when they are working without moving. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant mentions the complexity of the office building multiple times, being a mixed-use building with different owners. The office is located at the ground floor with housing above. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The organisation might not become interested when renovations are focused on improving the IEQ, because the investment is not balanced or cannot be balanced with the investments in their housing stock. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The office owner mentions that all employees are used to the office buildings and they do not mention any dissatisfaction. The office owner also does not ask about it. - The participant stated that governmental obligations are needed for small offices when they want to reach something in terms of sustainability and a healthy indoor climate. Those office owners will not initiate something like that themselves, to avoid additional investments and ensure the business operation of their organisation. 	<p>Key take-aways</p> <ul style="list-style-type: none"> - Governmental obligations related to IEQ aspects can help to become aware/get interested. - Mixed-use buildings ask for a different approach than individual buildings, especially in the case of multiple owners. Certain measures cannot be implemented, or are harder to realise. - Workplace satisfaction among employees in smaller organisations is not asked (regularly). Office owners have a passive attitude towards this and expect employees to approach them if needed. - The organisations value the atmosphere among employees more than focussing on the implementation of IEQ aspects. If the organisation functions as is and there is no sense of dissatisfaction among employees, no additional investments on IEQ aspects are considered.
Gaining knowledge	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - An advisor set up a report for them to set out different renovation possibilities for sustainability measures. - To reach EPC class C, they are expecting to hire another advisor to list possibilities. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - To gain knowledge on the topic of sustainability for their business operation, the organisation hired a sustainability manager. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - An advisor was hired to set up a report with possibilities to reach EPC class C. - The advisor mentioned that the office building did not need additional renovation measures to reach EPC class C, only the heating and cooling should be carried out by the airco units and the central heating system should be shut down. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - A project team was set up to cover different fields of knowledge. - Additional advisors were hired during the process when needed, especially for drawing up a new energy label. - To create a support base among employees, the project team made use of a resonance group for input on the overall layout of the workplaces. 	<p>Motivations for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - An advisor was hired to set out different scenarios to implement in order to reach EPC class C. 	<p>Key take-aways</p> <ul style="list-style-type: none"> - Office owners of smaller organisations hire an advisor when it comes to the implementation of measures to reach EPC class C. These advisors have an important role because the report of them is the only thing that is taken into consideration. - Larger organisations have in-house knowledge and approach renovation processes as a multi-year plan. Resonance groups can be used for input and to create a support base for the project plans.
	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - They considered their property as one with limited possibilities for sustainability measures because it has a lot of windows on all facades. - The interviewee considered oneself as a layman when it comes to the renovation of the office building. - The advisor did not advise upon IEQ consequences and if it can have an impact on occupants of a building, the participant thinks the advisor should elaborate that. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The sustainability manager that was interviewed is not familiar with the concept of IEQ and does not gather information to learn about it. The focus of his job lies with sustainability. - The participant stated that the government should provide more information regarding the IEQ consequences in office buildings and workplaces. Each office-owner should have the possibility to gather the same information, without needing an advisor, as the participant mentioned. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant knew that the building did not have a lot of opportunities when it comes to the implementation of renovation measures, because the office building is part of a mixed-use building with multiple owners. - The office owner was scared that there was a need to insulate the facades or the roof. This would be too costly and extensive for the organisation. - It is not the profession of the participant to be concerned with renovations, the participant considered oneself as a layman. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The investment for their office building should be balanced out by the revenues that the organisation has because of renting out their housing stock. Any additional investments can be used for their housing stock to also increase their rental prices (to a certain level, because it is a social rental sector). - The participant mentioned that it is a constant consideration to balance the investment. It should be functional and of good quality, but not too much. 	<p>Barriers for energy-efficiency and IEQ renovations</p> <ul style="list-style-type: none"> - The participant mentioned that he is a layman in the field of sustainability and office renovations. The advisor did only mention energy-efficiency measures. 	<p>Key take-aways</p> <ul style="list-style-type: none"> - Office owners can consider the possibilities of their properties limited in terms of the implementation of renovation measures. This can scare them in terms of large investments and the intensity of the implementation of a renovation measure. The advice report can show them scenarios that they did not consider as possible beforehand and should be clear about the process and financial investment. - Office owners of smaller organisations consider themselves as laymen, therefore the advisor has an important and prominent role in their renovation process. - IEQ aspects are not considered by the advisors as they are not asked out by the participants. This is because the participants are were not aware of IEQ aspects and their consequences post-renovation.

Making a decision	Consider options		Making a decision
	Motivations for energy-efficiency and IEQ renovations	Barriers for energy-efficiency and IEQ renovations	Motivations for energy-efficiency and IEQ renovations
	<ul style="list-style-type: none"> - When considering their options to lower their energy bill costs, they tried to incorporate measures that would also help to reach EPC class C. - The renovation measure is always related to the financial investment and the expected revenue. 	<ul style="list-style-type: none"> - The renovation measures for the office building are set out in a multi-year plan to ensure financial feasibility. - The renovation measure is related to the financial investment and the expected revenue. 	<ul style="list-style-type: none"> - The renovation measures should focus on reaching EPC class C with the least expensive measures. - Investments to increase the IEQ will only be considered when it becomes an obligation by the government, as mentioned by the participant.
	<ul style="list-style-type: none"> - Some measures would be too extensive as it required the removal and renewal of their roof construction, the vertical wind turbines were considered as a 'safe' options as it did not require any adjustments to the property itself. - The considerations were based on the advice that was provided by the external advisor as the interviewee did not carry out individual research. - It is considered more important to comply with governmental standards than to invest more in IEQ aspects, as they are not always tangible or obligated by the government. 	<ul style="list-style-type: none"> - The financial investment is based on the motivations of the organisation to carry out renovations. Investments based on improving IEQ have to go hand in hand with energy-efficiency measures. - The office building houses over 100 employees so it was hard to consider everyone's wishes and desires during the process. 	<ul style="list-style-type: none"> - The building is a mixed-use building with multiple owners which resulted in certain measures not being able to carry out. - No additional options were considered, only the advice report was considered and directly implemented. - The office owner was not willing to do large additional investments, so they were not considered. - The office owner kept his retirement in the back of his mind when considering options and related the needed investments to this uncertainty of the organisation.
	<ul style="list-style-type: none"> - Decisions are made based on the possibility to lower their energy bill costs. - Decisions are made by one of the office owners that is held responsible for the office renovation. 	<ul style="list-style-type: none"> - Their intrinsic motivation is to become a leader in sustainability in their field. The decisions are made based on visualising the sustainability of their organisation towards their clients. - The sustainability manager provides advice upon possible renovation measures to the office owner who makes a final decision based on the financial investment. - Final decisions on possible investments are always based on the availability of subsidies and financial feasibility. 	<ul style="list-style-type: none"> - Any needed investments to reach EPC class C should not require large investments. - Because the renovation was carried out during the COVID-19 pandemic, the availability of people was not an issue and also resources were available on time. The implementation phase was not delayed because of this and decisions could be made straight forward. - The office owner initiated the renovation and makes all the decisions in the process.
	<ul style="list-style-type: none"> - The availability of resources and people, and an expected delay in delivery time was considered as a barrier when making a decision. They considered other options which would not depend on this availability or delay. - The renovation that is already carried out did require a large financial investment and any additional financial investments are only made when they are related to complying with governmental standards or obligations. This is related to the uncertainty of the organisation and that any financial investment would influence the operational safety of the organisation. 	<ul style="list-style-type: none"> - The availability of resources and people led to a delay in the renovation process. - The participant stated that it is hard to make a decision for more than 100 employees. 	<ul style="list-style-type: none"> - The renovation concerning the functional layout and upgrade of the workplaces did require a large financial investment. Any additional financial investments are only made when they are related to complying with governmental standards or obligations. The participant wants to ensure that the organisation is able to pay back the investment before his retirement.
	<ul style="list-style-type: none"> - The participant considered the renovation as a step-by-step approach; decisions upon additional investments are made after the implementation of other measures. However, this is not laid down in a multi-year plan. - The office owner stated that 'gezelligheid' is considered more important than the indoor climate of the office building. - Any additional investments will only be made when it becomes obligated by the government in terms of energy-efficiency and IEQ aspects. 	<ul style="list-style-type: none"> - Final decisions are always based on the intrinsic motivation at the initiation of the renovation process. - Final decisions are made by the office owner, either advised by advisors in-house or external. - Smaller organisations make decisions to only comply with governmental standards, larger organisations also focus on reaching a future proof office building to avoid further future renovations because of new obligations or a shift in the organisational structure. - Final decisions on investments are based on financial feasibility, either supported by a multi-year plan (large organisations), business case (large organisations), or expected revenues and payback period in a short period of time (smaller organisations). 	<ul style="list-style-type: none"> - The unavailability of resources and people influences the final decision in relation to expected delays. - The smaller organisations already invested a lot of money in order to obtain EPC class C. Decisions upon IEQ aspects are only related to possible future governmental standards.

Table 10. Summary of research results with key take-aways, divided by decision-making phases. Own work.

Based on the key take-aways of the research results and the establishment of the analytical framework, it was possible to generalise the decision-making process of the participants. This decision-making scheme is illustrated in figure 23 (refer to Appendix F for full size). This figure also lists the main barriers in relation to the different phases in the decision-making process leading up to the renovation. Aspects in the decision-making process that only applies to either the larger or smaller organisation are marked respectively with an 'L' and an 'S'. The organisations with over 60 employees are considered as larger organisations within this research and the smaller organisations are the organisations with less than 60 organisations.

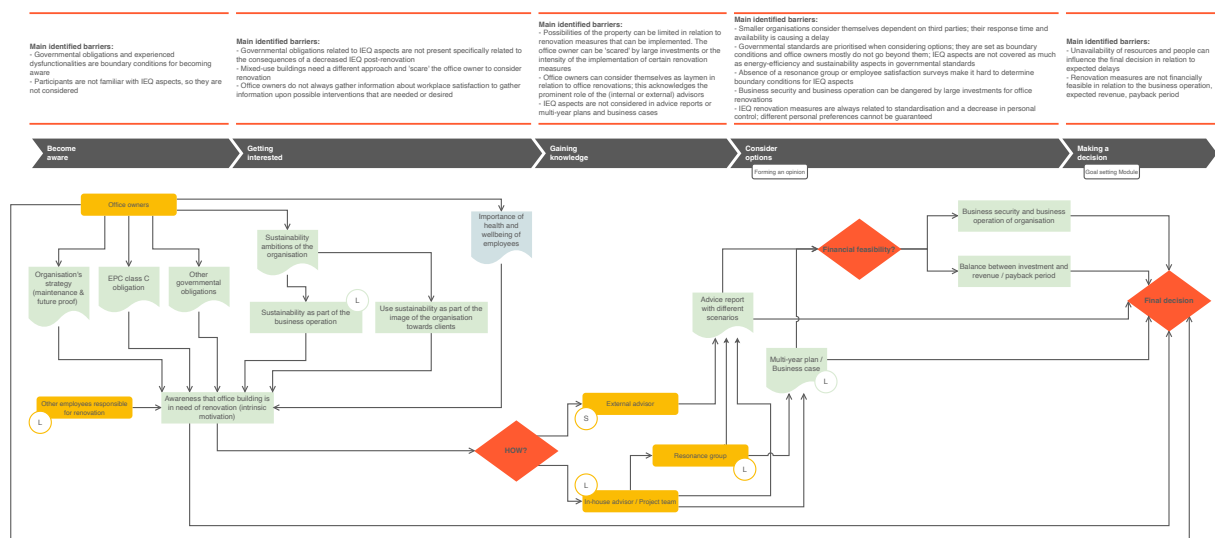


Figure 23. Decision-making scheme based on research results. Own work.

The decision-making scheme features red diamonds that highlight critical moments in the pre-renovation decision-making process. These important moments were identified based on insights gathered through the interviews with stakeholders from the case study projects. These benchmark moments serve as focal points within the decision-making process, exerting significant influence. Consequently, these benchmark moments are elaborated in the next chapter to enhance the interpretation of the results.

4.7 Analytical framework

In order to guide the interpretation of the results in the next chapter, an analytical framework is created. This analytical framework illustrates the different identified decision-making phases and summarises the contents of table 10 in a concise manner. The green boxes illustrate the motivations or motives, the orange boxes illustrate barriers or missing aspects in the decision-making processes of the participants. The analytical framework is shown in figure 24. Together with figure 23, these figures are subject to the interpretation of the results in the next chapter.

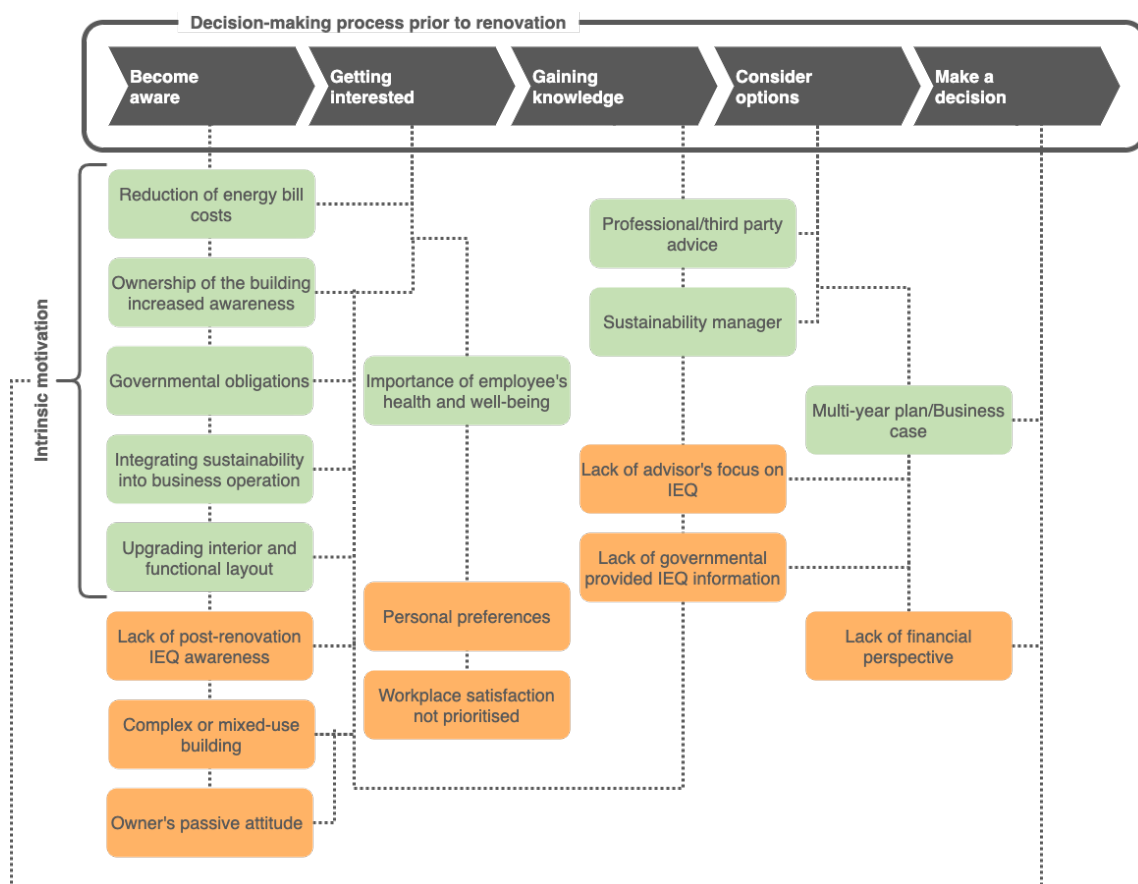
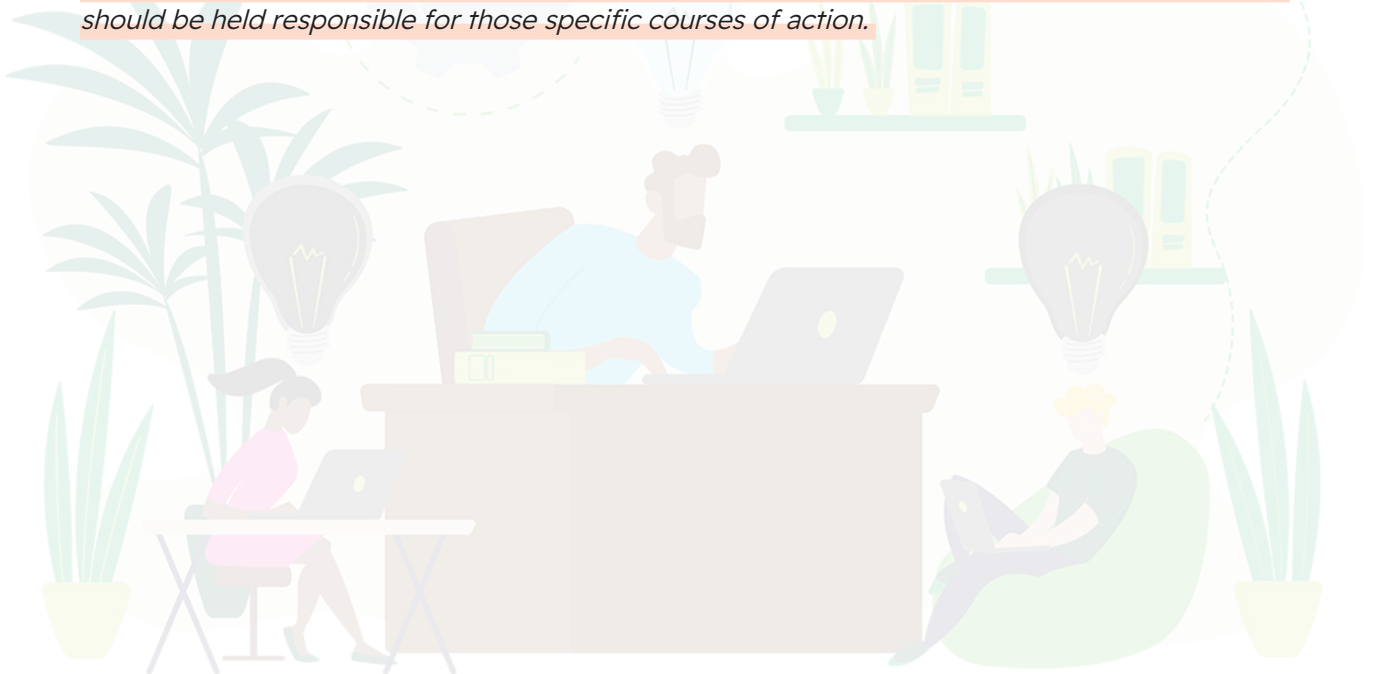


Figure 24. Analytical framework. Own work.

Discussion

In this chapter, an extensive discussion of the research findings is presented, also in relation to the theoretical background of this research. Initially, the results are interpreted and evaluated, based on a generalisation of the findings and focussing on the benchmark moments identified within the decision-making process. The decision-making scheme outlines three pivotal moments, as depicted in figure 23: 'HOW?', 'Financial feasibility?', and 'Final decision'. Each of these benchmark moments is individually elaborated in this chapter to establish a holistic interpretation of the research outcomes. Additionally, the IEQ concept in relation to the case study projects is discussed extensively, because the consideration of this aspect during the renovation process was lacking in all interviews with the stakeholders. Chapter 5.2 provides a summary of the interpretation of the results as a preparation for the final conclusion of this research. This summary provides an overview of possible solutions to overcome barriers in the decision-making process and who should be held responsible for those specific courses of action.



5.1 Interpreting results

Before delving into the various benchmark moments within the decision-making scheme as thematic elements in this section, it is essential to consider the extent to which the research findings can be applied to the intended target group of this research. In order to enhance the possibility of generalisation of research findings from case studies, Gomm et al. (2000, p. 105) stated that researchers often use a systematic selection of cases for their research, in order to avoid a case selection based on convenience. During this carried out research, the case study projects have been selected based on predetermined case selection criteria; construction year, EPC class “jump”, decision-making phase, stakeholders, renovation practices, building type, and number of employees. By using these criteria, the target group of this research and the concepts that derived from the literature review study are aimed to be covered. As written in the book of Gomm et al. (2000), it is essential to underscore that when the target group exhibits significant heterogeneity, no individual case within the target population encompasses all the characteristics of the entire population. Therefore, multiple cases have been selected to cover the case selection criteria collectively. The selected case study projects are all allocated to the target group of Dutch private owner-occupied office buildings, but there are differing aspects in terms of the implementation of renovation measures, the intrinsic motivations for renovation, the decision-making processes, and so forth. However, the decision-making process stages for sustainability renovations, which was found and established with the literature review study, turned out to be largely applicable to the decision-making process of office renovations as well. This helped to understand the different phases in the decision-making and its related motivations and barriers. Eventually, this has led to the establishment of a general decision-making scheme, combining all gathered information from the different case study projects. Within this scheme, the different benchmark moments are highlighted. These moments are discussed in the following paragraphs.

5.1.1 HOW?

During the interviews, the participants related to the smaller organisations mentioned a like-wise reaction to the EPC class C obligation that was approaching for them: *“How are we going to do that and where do I start?”*. There was a sense of fearfulness for large investments and the office owners started the renovation process with hesitance. In the literature review study, an article of Ebrahimigharehbaghi et al. (2020) is discussed which mentioned the lack of knowledge to find ways to increase the energy efficiency of renovations and the determination of costs as barriers in the decision-making phase prior to renovations of individual home-owners. This strongly correlates to the findings of this research. To overcome this lack of knowledge, the office owners hired an advisor that would eventually provide them with an advice report with several scenarios for the office renovation. This shows that the advisor has a prominent role in their decision-making processes, as the advice report is considered as the only possible option. In the literature review study, the involved stakeholders in office renovations are examined, based on the stakeholder classification in renovation projects of Aapoja and Haapasalo (2014) and identified leading stakeholders during different renovation phases by Konstantinou et al. (2021). Additionally, the prominent role of the advisor was also emphasised by Hull (2018). In the literature review study, the addition of an advisor to the core group of the project, or client team, was mentioned as common practice for office renovations.

When it comes to the decision-making process prior to renovation of the studied case projects, the primary team members, or client team were present in all case projects. This is similar to the research findings of Konstantinou et al. (2021), who mentioned that the client team is the leading stakeholder in the pre-project phase. The advisor is added to the client team as a supporting stakeholder in the decision-making phase of *getting interested* and *gaining knowledge*.

Nevertheless, differences in client teams were identified when it comes to the smaller and larger organisations. The client team of the smaller organisations merely consisted of the office owner and the external advisor, whereas the owner is the only stakeholder making the decisions for the renovation, based on the advice of the external advisor. The client team of the larger organisations consisted of the office owner together with internal advisors, sometimes in the form of a project team. The end-users were represented by a resonance group as part of the client team with one of the case projects as well. This shows that the larger organisations, consisting of more employees and housed in a relatively bigger office building, showed a better decision-making process in terms of representation and consideration of end-users, and setting up a project team or hiring an internal advisor. Additionally, key supporting participants were also present in the decision-making process of the larger organisations, being additional external advisors. Because the stakeholder groups for the larger organisations had more members compared to the smaller organisations, the renovation process was carried out on a more professional level in terms of the establishment of a multi-year plan, or a business case. This is elaborated further in the next paragraph.

5.1.2 Financial feasibility?

The issue of financial feasibility emerged as a benchmark moment in the decision-making phase where office owners and other responsible stakeholders deliberated over renovation implementation options. As previously highlighted, owners of smaller organisations expressed apprehension regarding the potential need for substantial financial investment and the prospect of engaging in an extensive renovation process, which would demand considerable time and necessitate adjustments to the organisation's business operation. This apprehension is rooted in the fact that smaller organisations, characterised by fewer employees and lower annual revenue, perceive large investments as a threat to their business security. Furthermore, office owners harboured uncertainty and fear regarding the timely return on their investment. In the context of the studied case projects involving smaller organisations, a timely return is intricately linked to the fact that office owners are already contemplating their retirement, and there exists uncertainty concerning potential successors for the organisation. This is also elaborated in the literature review study, based on the article of Jensen and Maslesa (2015), where the identified barriers of owner-occupiers were related to the lack of life cycle cost perspective and no overview of potential and priority in terms of the implementation of renovation measures. The financial investment decisions of the interviewed stakeholders are always weighed against factors such as the expected payback period and expected revenues, particularly in terms of reducing other operational costs. However, due to the nationwide increase in energy costs, participants noted that the payback period would likely shorten. Smaller organisations demonstrated a willingness to assume less financial risk and did not develop investment plans, such as multi-year strategies, or similar plans.

When analysing the larger organisations, financial feasibility is assured through the establishment of a business case or a multi-year plan. This practice is closely tied to the fact that these organisations conduct renovations with the assistance of internal advisors, and, in one case, these internal advisors collaborate as a project team. The internal advisors are required to present their multi-year plan to the office owners to obtain authorisation and secure financial resources for the renovation endeavours. Similar to the smaller organisations, the financial investments for these renovation projects are also assessed in relation to operational costs. However, in one of the examined case projects, the decision to invest in their office building must be weighed against potential investments in their housing stock, as the organisation functions as a social housing association. Such associations generate revenue from rental income derived from their own housing stock. This rental income is allocated to support the entire spectrum of business operations, including housing renovations, new construction, and maintenance of the housing

stock. Consequently, committing significant resources to office renovation could potentially deplete the available equity earmarked for maintaining and enhancing the residences of their clients.

Drawing from the aforementioned discussions regarding the financial feasibility of office renovation projects, the presence of a multi-year strategy can be a strategic choice to guarantee the viability of such renovations. In the case of smaller organisations, adopting the practice of formulating a multi-year plan can facilitate the execution of more substantial investments. This proactive approach enables them to surpass governmental standards, ensuring that their office building remains future-proof, thereby pre-empting the need for costly future renovations and subsequent investments.

5.1.3 Final decision

The last indicated benchmark moment in the decision-making process phases leading up to the office renovation is the final decision moment. As presented in the decision-making scheme in figure 23, the final decision is made by the office owners, influenced by the awareness that the office building is in need of renovation. This awareness is triggered by an organisation's strategy for the office building, governmental obligation, and sustainability ambitions of the organisation. The importance of health and wellbeing of employees could also trigger the awareness that the office building is in need of renovation, but this did not come forward during the interviews. This is elaborated in the next section. Additionally, the advice report and the multi-year plan or business case are influencing the final decision, as well as the financial feasibility of the prospected renovation measures.

The literature review study examined the decision support tools of Nielsen et al. (2016) and the customer journey of private homeowners when deciding on investing in energy saving measures, as mapped by VNG (2015). During the literature review study, these frameworks are combined to provide an overview of the decision-making phases prior to renovation. The Goal setting Module, as presented by Nielsen et al. (2016), defines sustainability objectives, criteria and weights, based on the desire of the building owner to renovate a building. This strongly relates to the aspects in the decision-making scheme resulting from this research, as sustainability ambitions of the organisation, if present, are triggering the awareness and desire of office-owners to renovate their buildings. When looking at the customer journey of VNG (2015), the barriers that are found in the decision-making phases leading up to the decision of individual home-owners for renovation measures are similar to the ones that are found during this research. Table 11 on the next page compares the barriers that are listed by VNG (2015) with the barriers that are found by means of the conducted interviews with the stakeholders of the case study projects.

<i>Decision-making phase</i>	<i>Identified barriers</i>	<i>Literature</i>	<i>Cases</i>
Become aware	Not receiving information about energy saving (or IEQ consequences) at a relevant moment	x	x
	Not receiving information about energy saving (or IEQ consequences) from a trustworthy party	x	x
	Not receiving information about energy saving (or IEQ consequences) from social contacts	x	x
	Absence of governmental obligations concerning IEQ aspects		x
Getting interested	Not receiving information about energy saving (or IEQ consequences) at a relevant moment	x	x
	Not receiving information about energy saving (or IEQ consequences) from social contacts	x	x
	Not having information that responds to what is important for an individual homeowner (or office owner)	x	x
	Financial benefits are unclear	x	x
	Not sure about possible energy saving measures (or IEQ measures)	x	x
	Not familiar with the urgency of energy saving	x	
	Not being triggered to take action upon energy saving (or IEQ measures)	x	x
	Absence of governmental obligations concerning IEQ aspects		x
	Lack of knowledge concerning the availability or implementation of renovation measures	x	x
	Lack of knowledge concerning IEQ aspects and its consequences post-renovation		x
Gaining knowledge	Not clear that investing in energy saving should have priority over other expenses	x	x
Consider options	Not familiar with the benefits in the short and long term, including financial rendement	x	x
	Unavailability of advisor to advise upon possible measures	x	
	Absence of security of expected rendement and payback period	x	x
	Absence of insight to consider different selected possible measures	x	x
Making a decision	Not familiar with the benefits in the short and long term, including financial rendement	x	x
	Absence of security of expected rendement and payback period	x	x
	Absence of insight to consider different selected possible measures	x	x

Table 11. Comparison of barriers in relation to decision-making phases from VNG (2015) and case study projects. Own work.

Table 11 shows that there are a lot of overlapping barriers when it comes to the decision-making processes of individual home-owners and the office owners related to the case study projects. Barriers in relation to IEQ aspects are not identified by VNG (2015), as that was not the topic of their study. The results of this research in relation to IEQ aspects are discussed in the next section.

5.1.4 Consideration of IEQ aspects in relation to case study projects

Throughout this research, the concept of Indoor Environmental Quality (IEQ) has been examined in the context of office renovations. As discussed in the preceding section, the significance of employee health and well-being can serve as a catalyst for office owners to recognise the need for renovation. In the literature review study, numerous sources were explored to illustrate the repercussions of IEQ concerning its impacts on office occupants. The primary focus of this research centres on four key facets of IEQ, namely Indoor Air Quality (IAQ), thermal and acoustic comfort, and adequate levels of lighting (Dorizas et al., 2019; Fabbri & Dorizas, 2019; Zhang et al., 2022). Additionally, one component of IEQ introduced by Mujeebu (2019) was also considered during the interviews, namely, ergonomics. Given that IEQ elements can exert significant influence on the

health, satisfaction, comfort, well-being, cognitive function, and productivity of office occupants, it becomes imperative to account for these factors throughout the renovation process of office buildings.

Chapter 2.5 delved into various renovation measures and their correlation with IEQ aspects, drawing upon the literature of Fabbri and Dorizas (2019), Kwon (2020), and Juan et al. (2010). As elaborated in that chapter, enhancements in indoor air quality can be achieved through the upgrading or installation of HVAC systems or the incorporation of more ‘green’ elements within office buildings. Thermal comfort can be heightened by improving insulation or upgrading HVAC systems. Acoustic comfort can be enhanced through the introduction of acoustic panels, while lighting quality can be optimised by installing LED lighting or increasing the number of windows. Ergonomics can be improved by replacing furniture. It is noteworthy that the different case study projects did implement some of these renovation measures, but the primary objectives were not centred around enhancing the IEQ of the office buildings. Office owners undertook these renovation measures for various reasons outlined in earlier chapters, such as reducing energy costs or achieving compliance with EPC class C obligations. Table 12 provides an overview of the aforementioned renovation measures that impact the IEQ of office buildings, and shows which measures were employed by the various case projects.

Renovation practice	Relation with Indoor Environmental Quality aspects	Case 1	Case 2	Case 3	Case 4	Case 5
Upgrade/addition of insulation	<i>Thermal comfort</i>					x
Upgrade/install HVAC systems	<i>Thermal comfort, Indoor Air Quality (IAQ)</i>	x	x	x	x	
Install LED lighting	<i>Adequate levels of lighting</i>	x	x	x	x	x
Swap out furniture	<i>Ergonomics</i>	x		x	x	
Add acoustic panels	<i>Acoustic comfort</i>			x	x	
Create more windows	<i>Adequate levels of lighting</i>		*		*	
Addition of more ‘green’ in the office	<i>Indoor Air Quality (IAQ)</i>	x	x		x	

Table 12. Renovation practices of case study projects in relation to IEQ aspects. Own work.

**Case study project 2 and 4 did not create more windows, but the organisations changed the functional layout of the office building in order to maximise the use of daylight in workplaces.*

When contemplating the potential for ‘standard’ renovation measures to simultaneously enhance both energy efficiency and IEQ, it becomes imperative to raise awareness among office owners regarding the importance of considering IEQ factors. Table 12 illustrates that many of the employed renovation practices have the potential to improve the IEQ of office buildings when implemented and supervised effectively. For instance, one of the interviewed office owners installed air monitors to assess the air quality within their office premises. However, the participant noted that the organisation’s employees lacked a clear understanding of the numerical values displayed on the monitors and were uncertain about how and when to respond to changes in these values. This underscores the need to not only cultivate awareness regarding the significance of adequate IEQ and improving the indoor environment during office renovations but also to prioritise educating employees about the monitoring techniques employed within the building. While this pertains to HVAC systems, a similar principle can be applied to other renovation measures. This may not necessarily entail instruction on interpreting monitors, but it is crucial to

gauge the overall satisfaction of office occupants to ascertain whether any dissatisfaction is linked to IEQ aspects. One of the examined case projects served as an exemplar in this regard, as they initiated an employee satisfaction survey to gather pertinent information regarding areas that require attention in future renovations or workplace upgrades. This serves as an illustration of how employee satisfaction, both in terms of their workplace environment and overall job satisfaction, can be systematically monitored and assessed.

When aiming at the execution of renovation practices that result in both an enhancement in energy efficiency and IEQ, it is beneficial to list so-called ‘no-regret’ measures. These measures are resulting from table 3 in Chapter 2.5 and table 12. The expensiveness of the financial investment for these renovation measures vary, resulting in different payback periods. However, the payback period of any investment are related to the difference in energy costs of the current and new system, and the investment cost. Table 13 lists the different ‘no-regret’ measures and states its consequences for both energy-efficiency and the quality of the IEQ. The two right columns indicate the relative investment and extensiveness: the financial investment as a ratio between the investment costs of the other renovation measures, and the extensiveness as a ratio between the renovation measures. This is indicated by a scale, ranging from 1 (low investment/not extensive) to 4 (high investment/really extensive).

Renovation measure	Energy-efficiency consequences	IEQ consequences	Relative investment	Relative extensiveness
Upgrade/addition of insulation	Higher insulation coefficient (less heating loss, lower energy bill)	Improved thermal comfort, higher user satisfaction, less health related issues, higher productivity	€€€€	++++
Upgrade/install HVAC systems	Decrease in energy consumption by systems, lower energy bill	Improved air quality, improved thermal comfort, higher user satisfaction, higher productivity	€€€€	++++
Install LED lighting	Decrease in energy consumption by systems, lower energy bill	Improved lighting quality, higher productivity	€€€€	+++
Install smart monitors	Automatised regulation of temperature, or ventilation rates	Improved thermal comfort, improved air quality, higher user satisfaction, less health related issues, higher productivity	€€€€	++++

Table 13. No-regret measures. Own work.

It should be noted that the financial investment of abovementioned renovation measures depend on the size of the office to be renovated. For instance, if the roof insulation of an office building is upgraded or added, the costs of the investment vary based on the total roof surface. The same applies to the upgrading or installation of HVAC systems and the installation of LED lighting. The extensiveness of a renovation measure is determined by an interpretation of the consequences for the daily operation of the office building. Nevertheless, the implementation of no-regret measures still requires consequent implementation and consideration to ensure an enhancement in the quality of IEQ.

5.2 Summary of results interpretation

In Chapter 5.1, several barriers are mentioned in regards to the decision-making process prior to renovations. Besides, some recommendations are given to guide and improve the effectiveness of this decision-making process. As this research focuses on improving the decision-making process prior to renovation in order to stimulate both energy-efficiency and IEQ renovations, it is important to focus on barriers, measures, and relevant stakeholders that are related to the implementation of IEQ considerations during this process. This section therefore provides an overview of possible solutions to overcome barriers in the decision-making process and who could be held responsible for those specific courses of action in order to stimulate office renovations focused on energy efficiency and IEQ consequences simultaneously.

Figure 25 presents the barriers, key stakeholders, and pertinent measures derived from the research and its subsequent interpretation. The dashed lines connecting the barriers illustrate their interconnection and mutual dependencies. Furthermore, the stakeholders and measures are positioned in relation to the barriers to demonstrate how they can be instrumental in surmounting or avoiding these barriers. Figure 23, 24, and 25 serve as valuable tools for addressing the research inquiries in Chapter 6. The next chapter contains more practical examples and implications based on the relevant measures which are illustrated in figure 25.

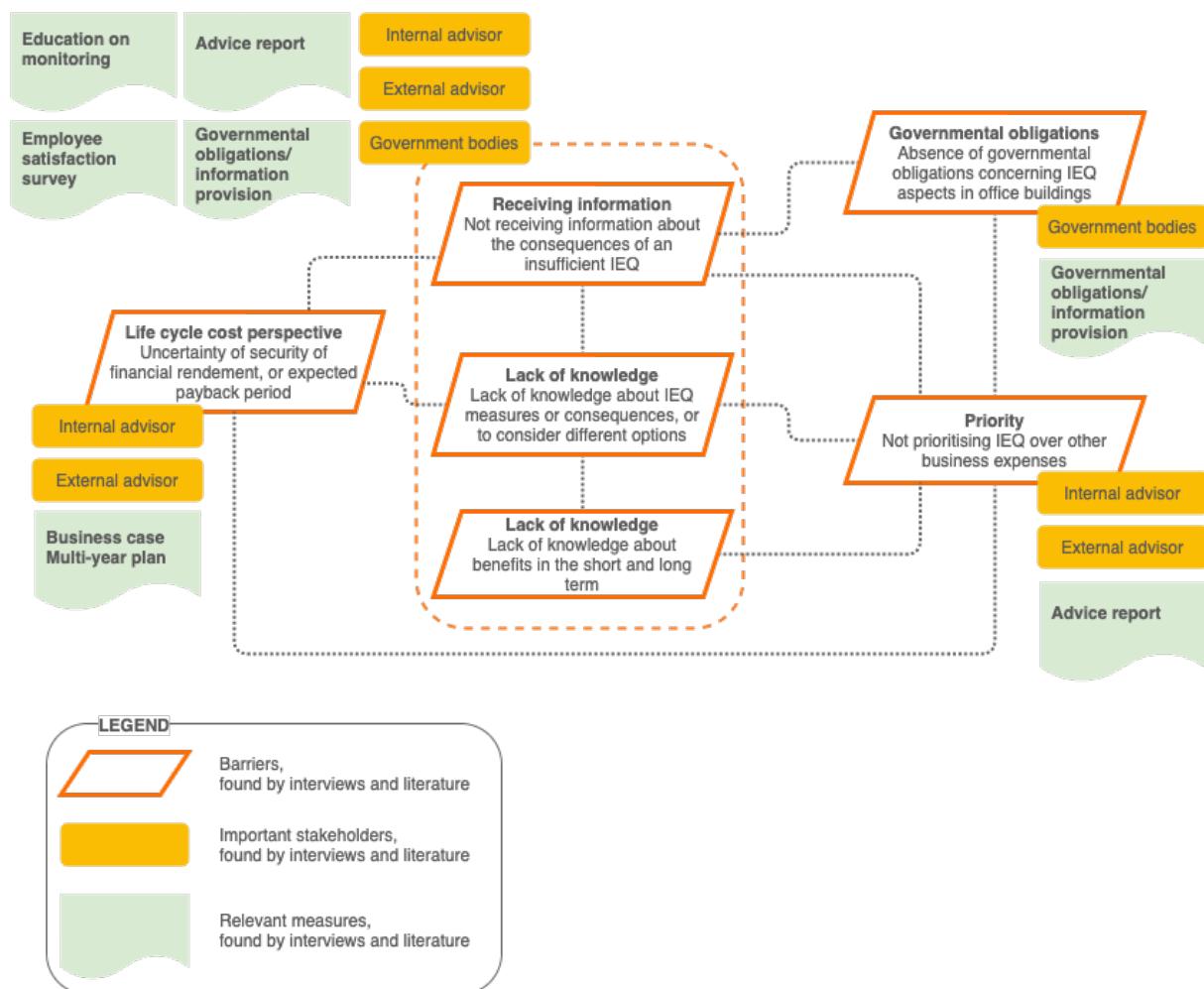


Figure 25. Summary of the interpretation of the results, focused on enhancing IEQ considerations during decision-making processes prior to the office renovations. Own work.

Conclusion

This chapter aims to answer the main research question as a concluding part of this research. The answer to the research question is subject to the research results and the interpretation of these results, as discussed in the previous section. Limitations and recommendations related to this research are presented in Chapter 6.2. The validity of the research results is examined in Chapter 6.3, followed by a section listing recommendations for further research on this topic.



6.1 Answering the main research question

This section addresses the main research question central to this study. The conclusions drawn from the sub questions are utilised to address the primary research question: *“How can the renovation decision-making process, prior to renovation, of private owners of Dutch owner-occupied office buildings be guided with a focus on improving energy-efficiency and IEQ?”*.

Throughout this research, a comprehensive examination was conducted into the decision-making processes undertaken by office owners and other pertinent stakeholders in the context of office renovations. These renovation endeavours were primarily geared towards achieving energy efficiency and compliance with the governmental mandate of EPC class C for office buildings, which took effect on January 1st 2023. In Chapter 4, an extensive delineation is provided of the various motivations and barriers associated with these energy-efficiency renovations. Among the most prevalent barriers identified were issues tied to a lack of knowledge and a limited lifecycle cost perspective with regard to financial feasibility. Notably, as participants were generally unfamiliar with the concept of IEQ, it was imperative to provide a brief introduction to IEQ and elucidate how its various aspects can impact office occupant’s comfort, health, well-being, satisfaction, and productivity. When participants were questioned regarding motivations and barriers concerning the consideration of IEQ in the renovation process of their office buildings, a consistent pattern emerged. The motivations predominantly revolved around the significance of their employees’ health and well-being. Conversely, the barriers were closely associated with insufficient knowledge, financial insecurity, or an uncertainty of a lifecycle cost perspective. Additionally, participants expressed their readiness to contemplate IEQ enhancements if they were mandated by the government or if their interest was piqued by trustworthy information sources at a pertinent moment in their project phase.

As the output of this research also consists of the establishment of an advice report, it is important to list which key strategies and considerations should be taken into account with this advice report. The advice report aims to guide the decision-making process, prior to renovation, of private owners of Dutch owner-occupied office buildings in order to enhance both energy efficiency and IEQ throughout the renovation of their offices.

Other stakeholders can enhance the effectiveness of this decision-making processes as well, such as the advisor and governmental bodies. Therefore, their input is considered as well. This section provides the key strategies and considerations to take into account in this advice report. The final product of the advice report can be downloaded separately in the TU Delft repository. The key strategies and considerations are listed by the different decision-making phases, as used in previous chapters.

6.1.1 Become aware & Getting interested

In the first phase of the decision-making process, it is important to raise the awareness of office owners about the significance of both energy efficiency and IEQ in their office building. Nowadays, the awareness related to the importance of energy efficiency comes from governmental obligations. This can also be helpful for IEQ measures. Governmental obligations regarding IEQ in office buildings can be established by mandating a WELL certification for office buildings, for instance. Besides, listing tangible values for the quality of indoor air in office buildings in the Dutch Bouwbesluit can be beneficial as well. However, as IEQ consequences are less tangible overall, it is more important to provide office owners with sufficient information regarding IEQ aspects and their impacts on the employees of an organisation. The implemented renovation measures that were identified in the different case projects already showed that those implementations can also be used to enhance the IEQ in office buildings.

Education plays a crucial role in ensuring that office owners understand the benefits of these improvements and how they should be implemented correctly to use the renovation process as an integrated approach. Such integrated renovations not only have financial benefits, but also benefits in terms of user and job satisfaction, which will eventually increase financial benefits by increased user productivity. This education should consist of information provision through government bodies, or other organisations, such as labour unions, by means of a regularly magazine or newsletter with contents on IEQ. Additionally, it is beneficial for office owners to conduct an employee satisfaction survey regularly in order to gather information on how employees perceive their workplace and its indoor environment. The outcomes of such surveys can raise an awareness to be triggered to execute renovations or workplace upgrades.

6.1.2 Gaining knowledge

As mentioned, numerous times, the role of the advisor is prominent when it comes to the renovation of private owner-occupied offices. Fortunately, the participants showed that professional guidance is sought during their renovation processes. However, the role of the advisor should shift from only providing information about what is asked out, in terms of energy efficiency, to a more proactive role in also educating the office owners on what certain renovation measures would cause in relation to the indoor quality of their workplaces. This asks for the education of advisors as well. The government can steer this, again, by providing up to date information about IEQ and office users, based on recent studies. A great example of this is the *Programma van Eisen Gezonde Kantoren 2021* (in English: Program of Requirements Healthy Offices 2021) published by Boerstra and Te Kulve (2021), on behalf of *Binnenklimaat Nederland*. This document helps to set strict requirements for the renovation of office buildings in regards to the desired quality of the indoor environment. The publication of Boerstra and Te Kulve (2021, p. 4) aims to “provide guidance to parties who want to create offices that are not only energy-efficient, but above all healthy, comfortable and productivity-enhancing”. Government bodies should consider mandating the use of this program of requirements. The successful implementation of a similar program of requirements can already be found in the school building sector. For this sector, the Netherlands Enterprise Agency published the *Programma van Eisen Frisse Scholen* (in English: Program of Requirements ‘Fresh’ School buildings) (Netherlands Enterprise Agency, 2021). This document helps to guide school boards and municipalities in the process of construction or renovation of school buildings, in terms of defining an ambition profile beforehand and testing the design, execution, and delivery of the school building based on this ambition profile. The municipality of Rotterdam decided to invest additional money in the upgrade of their school buildings and determined that each school building should have ambition profile class B, at least (GGD Rotterdam-Rijnmond, 2019). This example shows that the document of Boerstra and Te Kulve (2021) should be acknowledged and published by the Netherlands Enterprise Agency as well, and that governmental bodies, such as municipalities, should set certain standards for the renovation of the office buildings within their municipality as well.

6.1.3 Consider options

The role of the advisor should be more prominent during the phase where office owners consider their options. The role of the advisor does not stop when an advice report is handed over to the organisation in question. Moreover, maybe that is when it starts. The advisor has relevant knowledge and should help the office owner to choose wisely in terms of an integrated approach to enhance both energy efficiency and IEQ with the renovation. It is important to come up with a life cycle cost analysis during this phase that not only considers the initial investment but also long-term operational and maintenance costs. The article of Ho and Iyer-Raniga (2021) examine a

helpful framework and calculation method to assess the life cycle cost and evaluate sustainability outcomes for the building and construction sector. Besides, it can help to establish a multi-year plan or a business case in collaboration with the advisor to ensure financial feasibility and enhance the financial security of the organisation. If the advisor of the project team does not have this expertise, it is beneficial to conduct a cost expert as well.

6.1.4 Make a decision

As a conclusion, the final decision for renovation measures aiming at an integrated approach that considers energy efficiency and IEQ in tandem rather than as separate goals should be paramount when implementing the above-mentioned key strategies and consideration. The implementation of no-regret measures, as shown in table 13, can be used to enhance both energy-efficiency and IEQ with the office renovation.

6.2 Limitations and recommendations

During the conduction of this research, several limitations affected the research. It is important to list these limitations in order to present that the results of this research are affected by these limitations as well.

As this research consisted of a case study research method, the sample size was rather small and diversity among the case projects is lacking. A larger and more diverse sample can provide a broader perspective on the decision-making processes of private owners of owner-occupied offices and may reveal additional insights. The limited access to case projects is due to time constraints and the execution of case studies during the summer period. It was hard to get in contact with office owners whose office building complied with the case selection criteria and were willing to participate in the given time period. This is also associated with the limitation that for two of the case projects, it was not possible to come in contact with the office owner in time. Therefore, the answers given by the sustainability manager and project leader related to final decisions and the related considerations could not be confirmed or elaborated by the office owners. In order to gather a greater understanding of this topic and to expand this research, it is recommended to conduct longitudinal studies that track the decision-making processes and outcomes over an extended period rather than question the office owners about it afterwards. Their perspective on the decisions might have changed over time and their answers can be less extensive.

As the data collection of the case study projects relies on self-reported information from participants, there is a potential for response bias and inaccuracies in the data. The study revealed a lack of awareness among participants regarding IEQ. This is an important finding of the research, but it also limits the depth of insight into IEQ-related decision-making processes for office renovations. Therefore, it is recommended to also conduct in-depth IEQ-studies to specifically focus on IEQ improvement measures and their effects on office occupants. This can be combined with interdisciplinary research that involves experts in various fields, such as architecture, engineering, psychology, and public health to address the complex and interconnected nature of office renovations that focus on an enhancement of IEQ.

This is also related to another limitation of this research; the limited availability of literature when it comes to office renovations and IEQ. Literature on the decision-making processes specifically for office renovations were hard to find. Therefore, the established decision-making scheme is based on decision-making processes that were identified by renovations of other buildings and related to other owner typologies. Besides, IEQ is a recent topic of interest which meant that there was

not as much literature available than one would like for an extensive literature review study. It is therefore recommended to conduct the in-depth IEQ studies, as mentioned in the previous paragraph.

Lastly, governmental obligations are mentioned in the previous section to raise awareness of office owners when it comes to the consequences of an inadequate IEQ. However, before introducing such obligations, it is important to investigate the effectiveness of governmental policies related to energy efficiency and IEQ in office buildings. It is important to assess whether these policies drive meaningful changes in practice. And, if not, how these policies should be adjusted to reach an intended outcome of the policy measure.

6.3 Research results validation

It is important to consider the validity and reliability of the research method and results at different stages in the research process. Verhoeven (2015) mentions that this helps to assess the quality of the research and determines to which extent one is able to draw well-founded conclusions from research. Validity refers to the soundness or accuracy of the research results (Verhoeven, 2015). This shows to which extent the results represent true findings among similar individuals that have not been participating in the study (Patino & Ferreira, 2018). Additionally, Verhoeven (2015, p. 146) explains that validity is related to “the degree to which they can be applied to other situations, places, and people.”. Nevertheless, reliability is associated with the replicability of a research; if the research is replicated the outcome should consist of similar results to ensure its reliability. To ensure the validity of the research results, several aspects are taken into consideration with this research. This section discusses which courses of action, related to the execution of this research, can ensure the validity of the research results. The following paragraphs make a distinction between internal and external validity.

Internal validity is related to the extent to which the research results represent the truth in the studied population and that the research results are not subject to methodological errors (Patino & Ferreira, 2018). This is important as the results of the research are used to draw conclusions for an entire target group, represented by the participants of this study. In order to increase the internal validity of this research, it was important to adequately plan, control, and implement the used research method. This includes drawing up the interview protocol in advance and using this without any adjustments between the different interviews with stakeholders. This ensures that all participants are asked the same questions and in a similar setting. Additionally, the data management plan is established in early stages of this research process, including a clear explanation of data collection and storage. All interviews are recorded, transcribed, and analysed at the same way. Afterwards, the data is analysed using the AtlasTI software by applying different code groups to the answers of the respondents. Each interview is analysed using the same group of codes to allow the establishment of a pattern in the target group to eventually allow generalisability of the research results.

The generalisability of the research results is also related to the *external validity* of the research results. The external validity of research results assess the extent to which the results apply for an entire population (Verhoeven, 2015). In the case of this research, external validity is ensured by determining case selection criteria that cover a broad range of the population of this research; Dutch owners of owner-occupied offices. Nevertheless, to allow for a higher external validity, it is suggested to conduct validation interviews with additional participants. This is helpful to validate the results and ask for confirmation of the implementation of the research results in the entire population of this research. However, the sample of this research does not ensure the

applicability of the research results to offices with other ownership types, or other building types. The complexity of offices with other ownership types or other building types, for instance the rental sector, lies with a split incentive barrier (Castellazzi et al., 2017). This means that there is a “misplacement of incentives between different actors . . . which discourage energy efficiency improvements to come into effect in reality” (Castellazzi et al., 2017, p. 2). In other words, the owner has to pay for energy efficiency improvements but the tenant experiences the benefits from it, both in terms of financial benefits and comfort benefits. This research does not focus on overcoming this split incentive barrier.

6.4 Further research

This section serves as a part to finalise this research process by listing different suggestions for further research on this topic. Several suggestions are previously mentioned in Chapter 6.2, such as the conduction of longitudinal studies to track the decision-making processes and outcomes over an extended period. Besides, the recommendation to conduct in-depth and interdisciplinary IEQ-studies to address the interconnected nature of office renovations with a focus on an enhancement of IEQ is also mentioned previously. This section elaborates these suggestions more extensively and lists additional further research recommendations.

- 1. Conduct longitudinal studies to track the decision-making processes and outcomes over an extended period.**

As this research examined the decision-making processes prior to the renovation, it was hard to get a detailed understanding of all the different phases and steps that were considered. This is because the decision-making processes of the office owners were questioned after implementing their renovation measures, or during the implementation phase of the renovation process. When conducting longitudinal studies to track the decision-making processes of the office owners as they occur, it is plausible that all steps, phases, and considerations can be documented more properly. The office owners are less likely to leave out important benchmark moments as they are not able to reflect on their decision-making process and therefore will not adjust or relativise the experienced barriers in their steps and considerations.

- 2. Conduct in-depth and interdisciplinary IEQ-studies to address the interconnected nature of office renovations with a focus on an enhancement of IEQ.**

During the data collection period of this research, the lack of awareness among participants regarding IEQ was revealed. This limited the ability to explore the IEQ-related decision-making processes for the office renovations subject to the conducted case studies. Further research into this topic is therefore recommended. As IEQ-related aspects also show overlap with different fields of study, such as psychology, public health, and architecture, it can be beneficial to involve experts from these fields as well. This allows to comprehensively address the complex nature of IEQ aspects in office renovations and its effects of office occupants.

- 3. Conduct case studies on different building and ownership types.**

Chapter 6.3 already mentioned the complex nature of renovation decision-making processes in the rental sector because of the split incentive barrier. This applies to different building types, such as the rental dwellings, commercial office buildings, or rental retail properties. In order to stimulate energy-efficient and IEQ-focused renovations in these fields as well, it is important to conduct case studies for these property and ownership types as well. This allows to assess the sector-

specific motivations, barriers, challenges, and outcomes of energy-efficiency and IEQ renovations in different contexts. Additionally, the same applies for school buildings which can have different ownership types and financing methods. It is important to consider this sector as well in order to overcome the split incentive barrier. This can be supplemented with the following research recommendation, as elaborated under number 4.

4. Research the impact of government regulations and financial incentives in relation to office renovations.

The report of Castellazzi et al. (2017) already mentions different recommendations to overcome the split incentive issue. Their suggestions focus on regulatory solutions, information tools, financial incentives and models, and voluntary approaches, such as green leases. These solutions can also be beneficial for financing and enhancing energy-efficiency and IEQ renovations. However, it is important to research the impact of implementations, for instance, the impact of governmental regulations and financial incentive models. When contemplating the EPC class C obligation, for example, one can suggest that this governmental regulation is not as effective as planned since the renovation rates are still lacking and a lot of office buildings do not comply yet (Stil, 2022; Netherlands Enterprise Agency, 2018). This also leaves room for exploration on the effectiveness of governmental regulations or the availability of financial incentives in order to ensure its effectiveness and correct implementation.

5. Research multi-stakeholder perspectives in relation to office renovations.

This research solely focused on the decision-making process of office owners in relation to the renovation of their office buildings. However, it is recommended to also explore the role of other stakeholders in this decision-making process and the possibility for these stakeholders to steer this process into the desired direction of energy-efficient and IEQ-focused renovations. Additionally, this exploration helps to investigate the perspectives, motivations, and barriers of various stakeholders involved in the renovation process. This can create a fundamental understanding of the collaboration between these stakeholders and allows to streamline the renovation decision-making and execution phases of the renovation process. Possible stakeholders to take into consideration are architects, contractors, facility managers, and advisors in the field of office renovations.

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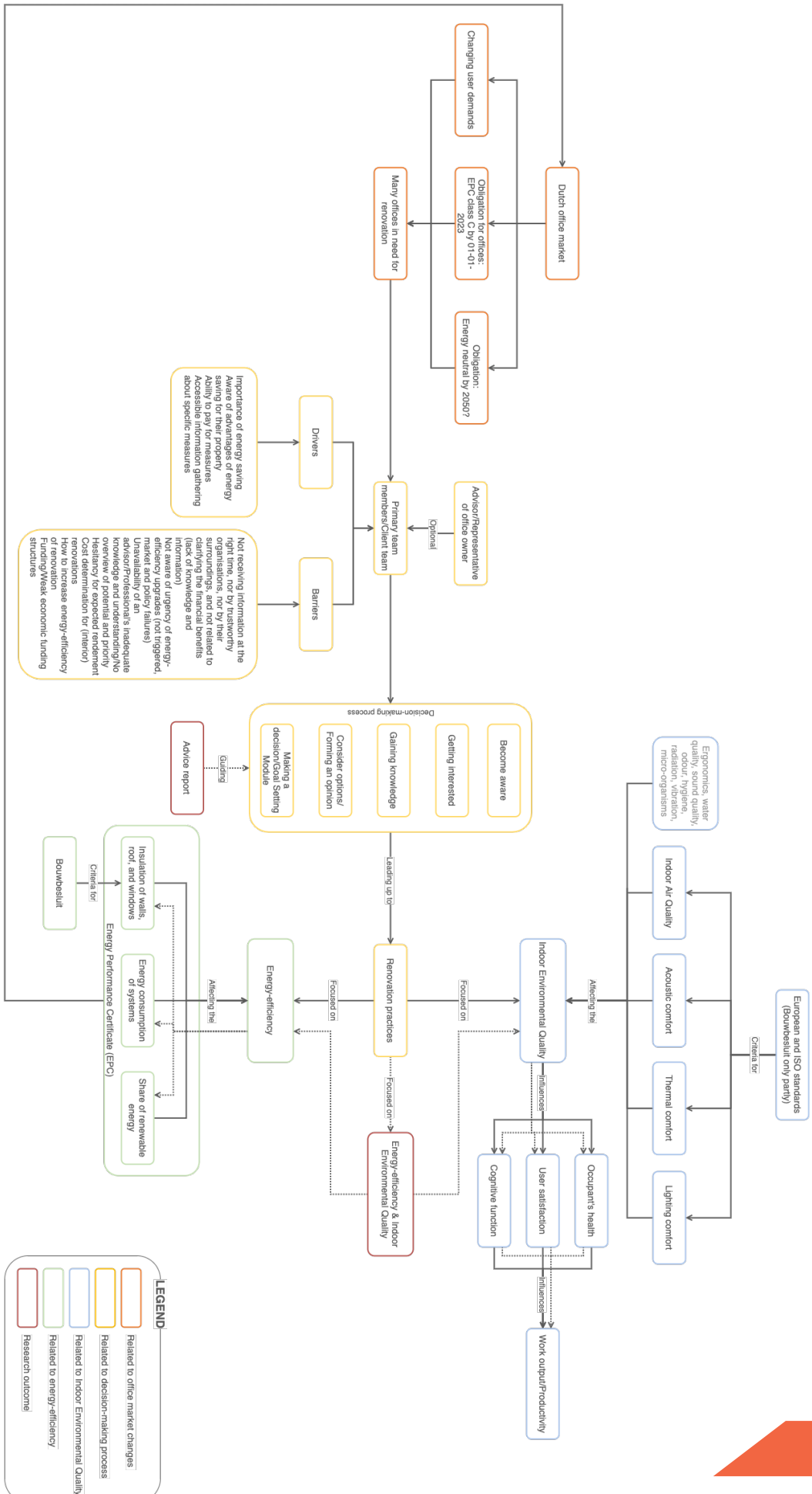
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Appendices



Theoretical framework



Research data management & Ethical considerations

Research data management

It is important to set up a data plan to ensure what happens with the gathered data during and after the project. For this data plan, the FAIR guiding principles of Wilkinson et al. (2016) are used. FAIR stands for Findable, Accessible, Interoperable, and Reusable. The data management plan (DMP) is submitted for feedback to the data steward of the faculty. This section discusses the DMP following the different lifecycle phases of data management.

Various forms of data are gathered for this study, including interview transcripts, recordings, and anonymised analyses of the interviews. These many files are all kept in a personal project storage map on Google Drive. Only project participants, in this case the researcher and supervisors, have access to this map. The data can be backed up by this means and stored in a secure location. When a third party questions the researcher about the validity of the research, it is crucial to preserve a copy of the raw data as proof. Additionally, the anonymised data is available for public use after this research is finalised. This data is accessible through 4TU.ResearchData. The publicly accessible data is accompanied by a README file and methodology document to make the data understandable and easy to reuse. This README file explains how the data is organised and the methodology document explains how the data is collected. These files contain nearly the same content as the previous section 'Data collection and analysis'. Thus, this section can be used to set up the accompanied files. During the project, the data will also be stored in the project storage of Delft University of Technology (TU Delft). The personal data is left out when storing it in the personal Google Drive map, to ensure that confidential data is only stored in the project storage of TU Delft.

The research involves human subjects during the data collection. Besides, personal data is collected during this research. This concerns video materials as recordings of the interviews, the names of the participants, and their email addresses, or other personal communication data. The collection of personal data is necessary to make sure that the data is reliable and it can be used as evidence that the data is not made up. This means that the collected data can be linked to the participants when third parties question the reliability of this research. Personal data is also conducted with signing information forms. The content of these forms is handled in the next section. However, this personal data will not be shared for any other reason than explained. These forms are also stored in the Google Drive for temporary storage and in the project storage of TU Delft for longer storage. When the researcher is no longer a student at the TU Delft, the assigned supervisor has full responsibility for the data and takes ownership of the data. The personal research data is destroyed after the end of the research project and the anonymised data is shared with others on 4TU.ResearchGate for further research. But, after 10 years the stored data is also destroyed, according to the TU Delft Research Data Framework Policy.

The shared data is released under the CC-BY-NC-SA (Attribution-NonCommercial-ShareAlike 4.0 International) licence. As a result, individuals are allowed to share and modify the material, as long as they provide proper credit, do not use it for profit, and distribute their contributions in accordance with the same licence as the original (Creative Commons, n.d.). The anonymised data is made FAIR by being published on 4TU.ResearchGate.

Ethical considerations

During the performance of research, it is important to take research ethics into consideration as well. Polonsky and Waller (2019) discuss five general ethical issues to take into account during research which are discussed in this section.

Voluntary participation

It is important to ensure that participation with all research is voluntary. Therefore, all participants are required to sign an information form prior to their participation. This form consists, among others, information about withdrawing their participation at any point in this process. Their participation is under no obligation of completing the process. The withdrawal of a participant does not have any negative consequences for them and the provided information is not used in relation to this research.

Informed consent

As previously mentioned, an information form is handed to the participants prior to the start of their contribution to the research. This form also describes thoroughly the content of the research and what their information is used for. This ensures that the participants are aware of what they are asked to do and also discusses the consequences of their involvement in this particular research.

Confidentiality and anonymity

The information form also entails the topics of confidentiality and anonymity. By signing this information form, the participants agree that the information they provide is used for this research in a confidential and anonymous way. When it comes to anonymity, the participants should be aware that readers of this research cannot know who the participants are. In relation to confidentiality, the participants agree that the researcher is aware of their identity but will not reveal this in a resulting report. All relevant information of the respondents is left out of the final report and not shared with others.

The potential for harm

Respondents of a research can be harmed in various ways, as mentioned by Polonsky and Waller (2019); physical harm, psychological harm, emotional harm, embarrassment, and so on. Considering the nature of this research, the potential for harm is minimal. Emotional harm and embarrassment of the participants is avoided by ensuring that their input for this research is fully anonymous. If participants expect that any harm could occur because of their involvement, the researcher should ensure that the participation is voluntary and anonymous. This is also covered in the information form.

Communicating the results

Polonsky and Waller (2019) describe three matters to take into account when communicating the results: plagiarism, academic fraud, and misrepresenting results. Plagiarism should be avoided by adequately referring to the work of others in the correct way. This means that someone else's work is not misrepresented as the work of the researcher. Academic fraud concerns intentionally misrepresenting work that has been done. This could mean that data is made up or inaccurate conclusions are put forward purposefully (Polonsky & Waller, 2019). The last topic, misrepresenting the results, relates to drawing conclusions from the research that are inconsistent or incorrect. Any conclusions should be related to and result from the research that is carried out. This means that possible limitations of the research should be mentioned as well, showing that the research could not cover the entire question of the research and that further research is suggested into the topic.

Interview protocol

This appendix contains the interview protocol which is used for all interviews of this research. The interview questions in this interview protocol are used as base questions for the interviews; during the interviews, additional questions are asked based on the answers given by the participants. The interview protocol is listed in Dutch because the interviews were conducted in Dutch.

Opening interview

“Ik zal vanaf nu het gesprek opnemen. Welkom ‘naam participant’, fijn dat u deel kan nemen aan dit interview en mijn onderzoek. Zoals u weet ben ik voor mijn master scriptie een onderzoek aan het uitvoeren naar de besluitvorming voorafgaand aan kantoorrenovaties, specifiek in relatie tot het verbeteren van de kwaliteit van het binnenklimaat ten behoeve van de productiviteit van de gebruikers. Voordat ik begin aan het interview, moet ik u nogmaals toestemming vragen om dit interview op te nemen. De informatie die u tijdens dit interview verstrekt, wordt alleen gebruikt voor het onderzoek, zoals eerder beschreven in het informed consentformulier”

Interview questions

Vraag 1: Zou u uzelf kort voor kunnen stellen met uw achtergrond bij ‘naam bedrijf’ en uw rol bij de renovatie van dit kantoor?

Vraag 2: Wanneer is het proces voor de renovatie gestart? Wat was uw eerste beweegreden?

Vraag 3: In welke fase van de renovatie bevindt u zich momenteel? Of is er sprake van een meerjarig onderhoudsplan om uiteindelijk tot een bepaald doel te komen?

Vraag 4: Heeft u al het onderzoek voor mogelijke ingrepen zelf gedaan, of heeft u hiervoor hulp gezocht bij andere partijen?

Vraag 5: Wie maakt de doorslaggevende beslissing over de renovatie en welke aspecten hierin worden meegenomen?

Vraag 6: Waren er specifieke tegenslagen in uw besluitvorming? Waar liep u tegenaan?

Vraag 7: Bent u bekend met het concept ‘Indoor Environmental Quality’, ofwel de kwaliteit van het binnenklimaat, en wat dit voor invloed heeft op werknemers/gebruikers van kantoorpanden?

Zo ja: Ga door met vraag 8

Zo nee: Verder naar vraag 12

Vraag 8: In hoeverre heeft u de aspecten van IEQ meegenomen in uw afwegingen voor de renovatie van uw kantoor? Welke motivatie had u hiervoor om dit wel of niet mee te nemen?

Vraag 9: Waren er nog specifieke tegenslagen in de afwegingen om IEQ mee te laten wegen in uw besluitvorming voor renovatie?

Vraag 10: Bent u bekend met de effecten van IEQ op het welzijn en de productiviteit van uw kantoorgebruikers?

Vraag 11: Weegt de kwaliteit van het binnenklimaat even zwaar als de energieprestaties van uw gebouw, als u daartussen een keuze zou kunnen maken?

(Niet bekend met IEQ)

“De vier domeinen van IEQ zijn luchtkwaliteit, thermisch comfort, akoestisch comfort en licht comfort. Deze aspecten hebben elk een bepaalde invloed op de gezondheid van gebruikers van kantoren. Daarnaast kan dit invloed hebben op de tevredenheid, comfort, welzijn, hersenfunctie en productiviteit van gebruikers. Bij luchtkwaliteit kunt u denken aan luchtvochtigheid, mate van ventilatie, geurverspreiding, stof, lucht droogte, etc. Wanneer gebruikers ontevreden zijn over de kwaliteit van een van de vier aspecten of domeinen kunnen ze sneller moe raken, ontevreden zijn over hun werkplek, of gezondheidsklachten krijgen. Hierdoor daalt de productiviteit van gebruikers aanzienlijk. In veel onderzoeken komt bijvoorbeeld naar voren dat de meeste klachten van kantoorgebruikers geassocieerd zijn met de temperatuur van hun werkplek, of geluidsoverlast. Dit veroorzaakt veel stress en een daling in productiviteit. Ook lichtkwaliteit heeft een grote invloed op de cognitieve productiviteit van kantoorgebruikers. Slechte lichtkwaliteit leidt sneller tot gezondheidsklachten als hoofdpijn, vermoeidheid, etc.”

Vraag 12: Als u deze informatie hoort over de invloed van de kwaliteit op het binnenklimaat voor uw kantoorgebruikers, had u dan bepaalde renovatiekeuzes anders gemaakt?

Vraag 13: Op welke manier had u meer kunnen weten over de effecten van de kwaliteit van het binnenklimaat? Wie had u erop kunnen/moeten wijzen?

Vraag 14: Zou u bij een volgende renovatie de kwaliteit van het binnenklimaat even zwaar in overweging nemen als de energieprestaties van uw pand?

Closing interview

“Dat was de laatste vraag. Ik wil u hartelijk bedanken voor uw tijd. Dit interview zal mij helpen het onderzoek verder te brengen en duidelijke resultaten te formuleren. Het onderzoek zal uiteindelijk na afstuderen gepubliceerd worden, maar daarvoor stuur ik u eerst het transcript naar u toe ter goedkeuring. Mocht u op dit moment geen verdere vragen hebben, zal ik het interview afsluiten. Mocht u zich later nog bedenken of vragen hebben, mail of bel dan gerust. Dank nogmaals voor uw deelname en we houden contact.”

Informed consent form

Krimpen aan den IJssel, 27 juni 2023

Betreft: Geïnformeerde toestemming deelname onderzoek naar de renovatie van kantoorgebouwen

Geachte heer/mevrouw,

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd 'Energy-efficient and healthy offices'. Dit onderzoek wordt uitgevoerd door Anja van der Ham van de TU Delft.

Het doel van dit onderzoek is om het besluitvormingsproces van eigenaar-gebruikers van kleine Nederlandse kantoren te begeleiden. De uitkomst van het onderzoek zal een adviesrapport zijn dat omschrijft welke mogelijkheden hiervoor gevonden zijn. Hierom zal een interview worden afgenomen om inzicht te krijgen in het besluitvormingsproces van kantooreigenaren voorafgaande aan het renoveren van hun kantoorgebouw. Hierin kunnen verschillende factoren van invloed zijn als het gaat om het afwegen van keuzes ten aanzien van het verduurzamen van het pand. Het interview zal ongeveer 60 minuten in beslag nemen. De data zal gebruikt worden voor het beantwoorden van de verschillende onderzoeksvragen van de masterscriptie van Anja van der Ham. Deze masterscriptie, inclusief de geanonimiseerde resultaten van het onderzoek worden na afloop gepubliceerd in de openbare database van TU Delft. U wordt gevraagd om te participeren aan het interview en na afloop de gegeven antwoorden in te zien en eventueel te herzien ten behoeve van het onderzoek.

Zoals bij elke online activiteit is het risico van een databreuk aanwezig. Wij doen ons best om uw antwoorden vertrouwelijk te houden. We minimaliseren de risico's door de gegeven interviews anoniem te transcriberen. Hierdoor komen de resultaten van het interview geanonimiseerd in het onderzoek terecht. De gemaakte opnames en transcripties worden bewaard in de beveiligde database van TU Delft en worden niet gepubliceerd. De geanonimiseerde transcriptie is enkel op aanvraag in te zien.

Uw deelname aan dit onderzoek is volledig vrijwillig, en **u kunt zich elk moment terugtrekken zonder reden op te geven**. U bent vrij om vragen niet te beantwoorden. Na afloop van het interview krijgt u de mogelijkheid de gemaakte geanonimiseerde transcriptie in te zien en hierop commentaar te geven. Dit geeft u de mogelijkheid uw antwoorden te nuanceren of te herzien. Daarna zal deze informatie gebruikt worden om resultaten voor het onderzoek te beschrijven en de onderzoeksvragen op basis van deze resultaten te beantwoorden.

Als u vragen heeft over dit onderzoek, kunt u contact opnemen met Anja van der Ham (telefoon 06 51 22 13 67, email A.vanderHam@student.tudelft.nl).

Bij instemming met bovenstaande informatie, vraag ik u onderstaand formulier naar waarheid in te vullen en te ondertekenen. Het ondertekende formulier kunt u naar bovenstaand mailadres terugsturen.

KRUIS AAN WAT VAN TOEPASSING IS	Yes
A: ALGEMENE OVEREENKOMST – DOEL VAN HET ONDERZOEK, TAAK VAN DEELNEMER EN VRIJWILLIGE PARTICIPATIE	
1. Ik heb de informatie over het onderzoek gedateerd 27 juni 2023 gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	<input type="checkbox"/>
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	<input type="checkbox"/>
3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent:	<input type="checkbox"/>
<ul style="list-style-type: none"> <i>Het interview wordt opgenomen en daarna anoniem getranscribeerd.</i> <i>Na transcriptie wordt de audio-opname opgeslagen in de beveiligde database, samen met de geanonimiseerde transcriptie.</i> <i>De geanonimiseerde transcriptie wordt opgestuurd naar deelnemer ter controle. Dit geeft de mogelijkheid om antwoorden te herzien en eventueel te nuanceren.</i> <i>Persoonlijke informatie van de deelnemer wordt op geen enkele wijze opgenomen in gepubliceerde stukken.</i> 	
4. Ik begrijp dat het onderzoek eindigt wanneer Anja van der Ham haar complete onderzoek gepubliceerd heeft na het afronden van haar opleiding.	<input type="checkbox"/>
B: MOGELIJKE RISICO'S VAN DEELNAME (INCLUSIEF DATA BEVEILIGING)	
5. Ik begrijp dat mijn deelname de volgende risico's met zich meebrengt: mentale of fysieke ongemakken tijdens het interview, risico voor deelnemer om ongewenste antwoorden te geven. Ik begrijp dat deze risico's worden geminimaliseerd door: mogelijkheid om ten alle tijden het interview te beëindigen, keuze om vragen niet te beantwoorden, mogelijkheid om na deelname aan het onderzoek alsnog terug te trekken uit de studie, zonder opgeven van reden, geanonimiseerd gebruik van vergreken data, mogelijkheid om antwoorden in te zien en te herzien of te nuanceren.	<input type="checkbox"/>
6. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden. Ik begrijp dat deze data en persoonlijk identificeerbare informatie niet gepubliceerd zal worden. (zie punt 8 voor het minimaliseren van het risico op databreuk)	<input type="checkbox"/>
7. Ik begrijp dat binnen de Algemene verordening gegevensbescherming (AVG) een deel van deze persoonlijk identificeerbare onderzoeksdata als gevoelig wordt beschouwd, namelijk [<i>zie onderstaande punten</i>]	<input type="checkbox"/>
<ul style="list-style-type: none"> <i>Regionale of politieke voorkeuren ten aanzien van regelgeving</i> <i>Mogelijk gemaakte investeringskosten voor renovatie</i> <i>Gemaakte keuzes van het wel- of niet naleven van regelgeving</i> 	
8. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk:	<input type="checkbox"/>
<i>Het interview wordt opgenomen en zal na afloop op geanonimiseerde wijze worden getranscribeerd. Daarna krijgt deelnemer de mogelijkheid de transcriptie in te zien en gegeven antwoorden te nuanceren of te wijzigen. De opname en de geanonimiseerde transcriptie</i>	

<i>worden nergens gepubliceerd en enkel beveiligd opgeslagen, waarna enkel de onderzoeker toegang tot deze bestanden heeft. Het is ten alle tijden mogelijk om ten behoeve van het onderzoek de anonieme transcripties in te zien.</i>	
9. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals naam, woonplaats, organisatie, niet gedeeld worden buiten het studieteam.	<input type="checkbox"/>
10. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt na het succesvol afronden van het onderzoek.	<input type="checkbox"/>
C: ONDERZOEKSPUBLICATIE, VERSPREIDING EN TOEPASSING	
11. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor:	<input type="checkbox"/>
<ul style="list-style-type: none"> • <i>Het beantwoorden van de onderzoeksvragen van het onderzoek.</i> • <i>Waarna een adviesrapport opgesteld kan worden.</i> • <i>Het onderzoeksrapport en adviesrapport gepubliceerd worden in de openbare database van TU Delft na afronden van de studie.</i> 	
12. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten.	<input type="checkbox"/>
13. Ik geef toestemming om een afbeelding van het (gerenoveerde pand) in het onderzoeksrapport te gebruiken, inclusief locatie.	<input type="checkbox"/>
D: (LANGDURIGE) DATA OPSLAG, TOEGANG EN HERGEBRUIK	
14. Ik geef toestemming om de geanonimiseerde data (resultaten in het onderzoek) die over mij verzameld worden gearchiveerd worden in de openbare repository van de TU Delft opdat deze gebruikt kunnen worden voor toekomstig onderzoek en onderwijs.	<input type="checkbox"/>
15. Ik begrijp dat de toegang tot deze repository open is voor iedereen.	<input type="checkbox"/>
16. Ik begrijp dat de geanonimiseerde transcripten enkel op aanvraag beschikbaar zijn voor gegadigden.	<input type="checkbox"/>
17. Ik begrijp dat de gemaakte opnames na afronding van het onderzoek vernietigd worden.	<input type="checkbox"/>

Signatures

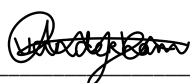
Naam deelnemer

Handtekening

Datum

Ik, **de onderzoeker**, verklaar dat ik de informatie en het instemmingsformulier correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.

Anja van der Ham



27-06-2023

Naam onderzoeker

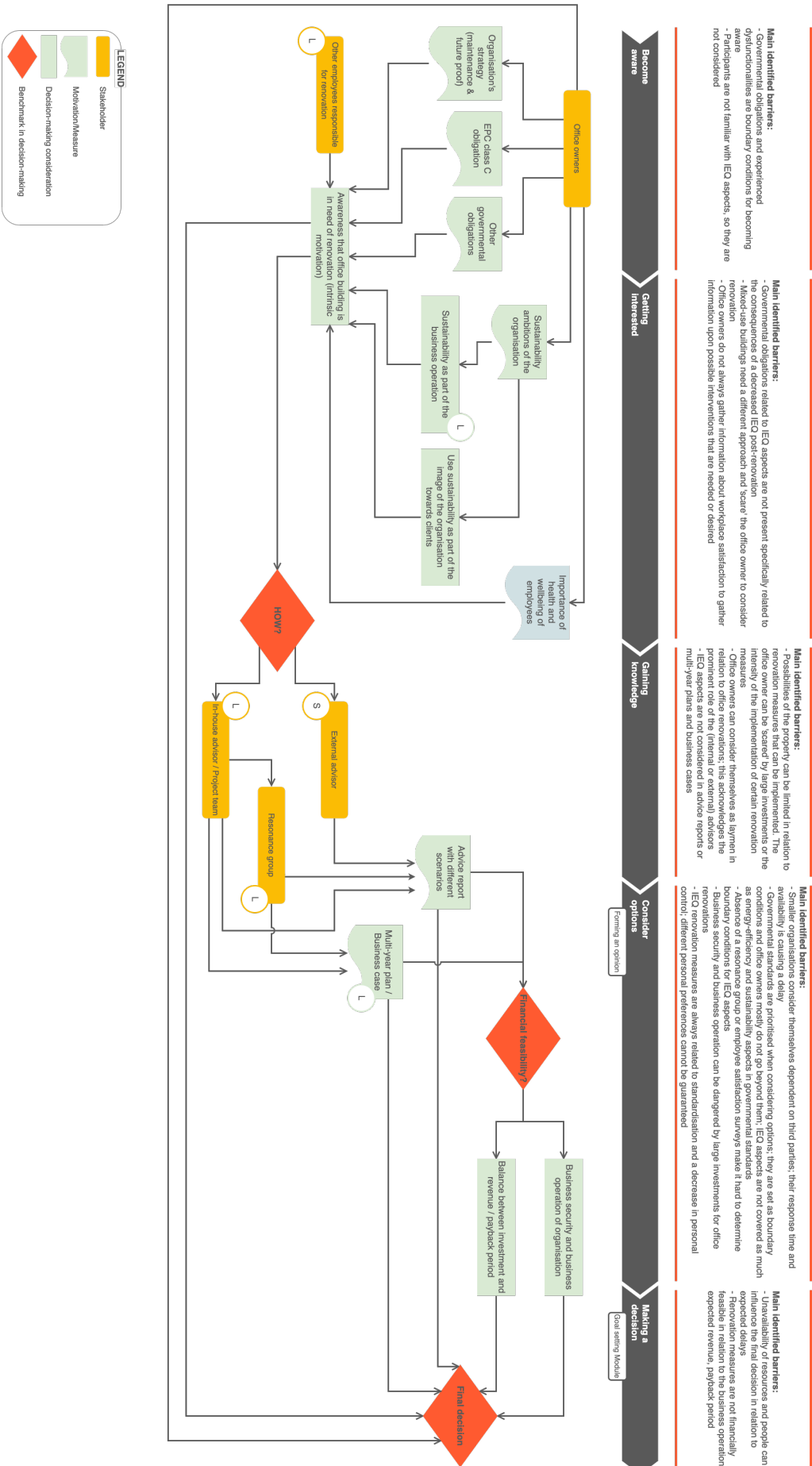
Handtekening

Datum

Contactgegevens van de onderzoeker voor verdere informatie: Anja van der Ham (06 51 22 13 67, A.vanderHam@student.tudelft.nl)



Decision-making scheme based on research results



Reflection

This appendix includes a reflection on this thesis and its process. Firstly, it identifies the relationship of the graduation topic with the master (track), its academic and societal values, ethical aspects, and transferability. Then, the reflection on the research methodology and approach is discussed. At last, a personal reflection on the product, process, and planning of this research is provided.

Graduation topic

At the start of my graduation process, I selected the graduation theme Energy Transition in the Existing Building Stock. My chosen thesis topic is closely aligned with this theme, as it delves into the realm of office renovations prompted by the EPC class C obligation. My research places a significant emphasis on the critical aspect of Indoor Environmental Quality (IEQ). The decision-making processes prior to energy-efficient office renovations are examined during this research in order to understand these and devise strategies to influence them positively. This intervention is crucial to guide stakeholders in the right direction when it comes to managing office renovations to make them both energy-efficient and conducive to a healthy indoor environment. This aligns with my master's track Management in the Built Environment.

The targets concerning sustainability in the built environment become stricter and target dates of European and national obligations are approaching fast. This affects every facet of the master programme; architecture, urbanism, and building sciences. Consequently, new approaches and fresh perspectives are required to tackle these challenges comprehensively. In addition to the growing emphasis on sustainability, the human dimension is also gaining prominence within the built environment. Factors such as user experience, satisfaction, and overall well-being are becoming more important. Therefore, my graduation topic addresses two pertinent issues currently prevalent in the built environment industry: sustainability and the human element. It seeks to harmoniously blend these aspects to create workspaces that not only align with sustainability objectives but also prioritise the health and well-being of their occupants.

Academic and societal value, ethical aspects, and transferability

As previously mentioned, the entire built environment industry is facing sustainability challenges and there is a need to accelerate renovation rates to reach the set targets in time. This graduation project focuses on the drivers and motivations of the stakeholders in relation to the office renovations. The advice report, that is a product of this research as well, helps to guide office renovations. Since this graduation project also emphasises the importance of a healthy workplace, it seeks to guide stakeholders towards an integral renovation process in terms of energy efficiency and Indoor Environmental Quality (IEQ). These aspects all contribute to the academic and societal value of this research; this graduation project adds to the body of knowledge when it comes to office renovation decision-making processes and ways to approach an office renovation in a standardised way.

The start of this year, January 1st 2023, marked an important national target date; the EPC class C obligation for office buildings larger than 100 sqm and used as an office building primarily. As more and more news articles were published about the office buildings that did not comply yet, the value of this graduation project and the associated research scope grew. There are many office buildings still in need of renovation to reach the governmental obligation of EPC class C and these and other future office renovations should not only focus on energy efficiency and the consequences for IEQ should not be neglected. This underscores the necessity to steer renovation efforts toward a direction where IEQ is an integral aspect of the renovation process. This research

was limited to private owner-occupied offices. However, the results of this research do not have to be limited to only this office type. The results and approach can be applicable to other office types and office owners as well. Investors or landlords of office buildings can use the results of this research during or prior to their renovation practices. To specify the transferability of this research results to other target groups, more extensive research is needed. However, I expect that general findings can be easily transferred.

During the execution and development of the research and after publication, several ethical aspects should be taken into consideration. Appendix B already elaborates thoroughly how ethical aspects are considered during and after publication of this research. During the interviews with the participants, some sensitive information is shared which can negatively impact the organisation of the case projects, or any other third parties who were involved or mentioned by the participants. Therefore, sensitive information is left out of the research report and the interview transcripts are not shared with others. Besides, all interview transcripts are shared with the respondent firstly, to ensure that the participant is aware of the answers that are given during the interview and which information is used for the data collection and analysis of this research.

Research methodology and approach

To gain insights into the decision-making process of the initiators of office renovations, I have chosen the case study method coupled with semi-structured, in-depth interviews as the appropriate research approach to answer my research questions. However, this does not mean that the research methodology is also carried out the best way possible with this graduation process. Primarily, due to a delay in my graduation process, the data collection had to be conducted during the summer holidays. This posed difficulties in reaching out to many organisations and scheduling interviews efficiently. Fortunately, I was able to identify suitable cases that met the selection criteria, allowing me to complete data collection on time and still allow sufficient time for the data analysis. Nevertheless, I must admit that I enjoyed experiencing the use of different research methods during my academic journey. This also allowed me to make the decision for an appropriate research method more considerate.

Throughout the graduation process, research and design/recommendations have been interconnected and mutually influential. The initial literature study helped define the problem statement of this research and identify areas in need of further exploration within the literature review study. Consistent feedback loops, by means of (online) meetings, with my mentors allowed me to refine the research focus and adapt the research approach and methodology where needed. It took some time for me to realise that these feedback sessions were primarily aimed at enhancing the graduation project rather than indicating possible shortcomings. Consequently, this dynamic has resulted in research that continuously evolved, leaving me with a sense that it would never be truly complete. Determining when to draw the line in terms of adjusting the research or shifting my focus to finalise other aspects of the project has been challenging for me.

Personal reflection | Product, Process, and Planning

The entire process of this graduation project was an intense and rewarding journey at the same time. Looking back at the final project, I can feel accomplished and satisfied as I know that I have given a lot of dedication to the process and end product of this thesis. Throughout this journey, I had to learn that conducting research is never finished and you will always find yourself raising more questions. It was hard to draw a line and make decisions on aspects that were within and out of the scope of this research. Fortunately, my mentors were as dedicated to this process as I was and were always supportive in providing useful feedback. The feedback always challenged me; sometimes into new directions, but always to optimise the product. I am aware that a graduation

product will never be perfect and I learned along the way that it does not need to be perfect as well. This journey taught me to adapt my approach when needed and to be resilient. This was challenging for me, being a perfectionist and a dedicated hard worker. When I noticed that I could not dedicate my time or prioritise my graduation project during the past months, I was very disappointed. However, this also taught me to be resilient and flexible, as I had to adapt my approach and planning when it was necessary. Additionally, it pushed me to seek guidance even more, something I was not used to before. Asking for guidance after having decided to postpone my graduation was uncomfortable for me. However, I learned to ask my mentors to guide me and set milestones for the following months to ensure that I would continue developing my research.

Connecting with the stakeholders during the conduction of interviews was enriching for me. It helped me to understand their decision-making process and I experienced that the guidance of graduated project managers is always welcome in fields where stakeholders are not as familiar with the building industry as we are as Managers of the Built Environment. Not only did it provide me valuable insights for my research, it also allowed me to develop myself as a researcher and made me more comfortable to have interesting conversations with people I did not know before. Besides, it encouraged me to finalise this graduation project, as I am motivated to continue my working career, at the company I already enjoy working at for the past year. After all, I view this graduation project not only as a culmination of my student journey at Delft University of Technology, but also as a reminder of my personal growth during the process of this thesis. The final product stands as a tangible representation of my research and I will always remember the process as a highlight of the lessons that I learned as a researcher and as a young adult, preparing for my professional career. I look forward to building upon these lessons as I approach the next challenges in my profession as a graduate and project manager.