Risk Management in Green Retrofit Projects

Eco Uncertainties

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Risk Management in Green Retrofit Projects

Eco Uncertainties

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Acknowledgments

This is the last task I am doing that is related to my master's thesis at Delft University of Technology. Right now, I am grappling with a fear of missing out on university life, coupled with excitement about what's coming next in life. That's life have to move on and keep thriving.

I would like to dedicate my master's thesis to my family and extended family, i.e., my friends, well-wishers, and the people of Narpala. This dedication extends to all CME students who are working on their master's thesis without an internship.

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Concluding Remarks:
If I have inadvertently omitted any names, please know that it wasn't intentional. Every individual who has been part of my journey holds a special place in my heart, and I am immensely grateful for your contribution to my life.

(Saketh Reddy Narpala)

Executive Summary

Introduction& Research Design
The construction industry, often referred to as "the industry of 40" due to its significant carbon emissions and waste production, is facing increasing scrutiny, particularly within Europe. With the EU's pledge to achieve net-zero emissions by 2050, there's an urgent push towards sustainable construction, leading to a surge in green building initiatives. However, given the environmental footprint of existing infrastructure, there's a compelling need to focus on green retrofitting, which involves modifying existing buildings for improved energy efficiency and eco-friendliness. While risk management is an important aspect of the construction domain, there's a limited exploration of the distinct risks associated with green retrofit projects. Most of the prevailing literature is slanted towards traditional risk management, often neglecting the overarching sustainability challenges. Furthermore, there's an absence of studies delving into risk identification techniques tailored for green retrofit projects. The aim of this study is to investigate risk identification practices in environmental retrofitting to explore how construction companies deal with risks once they commit to retrofitting and to highlight existing knowledge differences. To achieve these objectives, a research question is formulated: ***How do companies operating in the built environment (in the Netherlands) identify and deal with risks related to green retrofit buildings?***

The research methodologies are a Literature Study, drawing from academic databases, books, and theses to set a foundational understanding of sustainability and risk management in green retrofitting; a Field Study at a residential green retrofit site in Voorburg, a combination of observations and interviews to capture real-world risks and practices in action. Semi-structured interviews with experts, employing qualitative content analysis to distill key insights from discussions about sustainable construction, risk identification and analysis; Together, these methods provide a comprehensive theoretical framework, expert perspectives, and practical, on-ground insights.

Findings
The research delved into the risks associated with green retrofit projects, which involve updating older buildings to make them sustainable. Unlike constructing a new green building, retrofitting an existing structure presents unique challenges due to its outdated materials and methods. The literature review highlighted a lack of universal risk management solutions, emphasizing the need for tailored approaches per project. Building Information Modelling (BIM) was explored as a tool to aid in the green retrofit process. A field study in Voorburg, Netherlands, revealed practical risks in retrofitting a home, such as performance risks, supply chain disruptions, scheduling issues, and uncertainties in return on investment. The Dutch company, Royal Haskoning DHV (RHDHV), uses a threefold approach i.e. meeting with clients, on-site assessment and Fast-Lane Method, with dynamic mapping. The study found that while RHDHV's Fast-lane technique efficiently predicts energy use, it's less adept at estimating carbon emissions and adapting to broader retrofit tasks. This prompted a recommendation for an integrated approach using BIM, which would provide real-time data, facilitate collaboration, and improve risk identification and management. In a hypothetical application of this model to the Voorburg house, BIM could predict performance outcomes, streamline material orders, enhance project scheduling, and provide insights to optimize returns on investment. Additionally, a comparison of data

was gathered between young project managers vs senior project managers. Further, the client's awareness of green retrofit buildings was noted. Recommendations to improve them are provided, where communication is given the largest priority.

Limitations and Future Recommendations

This research examined risk identification and management in the built environment, specifically within the Netherlands and based on insights from Royal Haskoning DHV. The study's limitations include its narrow focus on a single company and a single residential building. Furthermore, the recommendation model's application in the "What if" section is entirely hypothetical. The study underscores the need for broader research, involving diverse firms and real-world testing, for more comprehensive findings.

Future research recommendations include expanding the study beyond just risk identification and assessment to encompass evaluation, prioritization, and ongoing monitoring. Gaining perspectives from clients, suppliers, and other stakeholders can offer deeper insights into real-world risk implications. Comparative studies across multiple companies can shed light on industry standards and innovative practices in green retrofitting risk management. Exploring long-term performance, maintenance challenges, and costs of new equipment can provide valuable information. Focusing on specific retrofit aspects, like carbon reduction, could refine risk management methodologies. Additionally, examining the role of technology and market tools in aiding risk management in green retrofit projects is suggested.

Abbreviations

Abbreviation	**Definition**
MRQ	Main Research Question
SRQ	Sub Research Question
BIM	Building Information Modelling
TECOP	Technical, Environmental, Commercial, Operational, Political.
PESTEL	Political, Economic, Social, Technological, Environmental, Legal
EU	European Union
i.e.	That is
HVAC	Heating, Ventilation and Air Conditioning
RHDHV	Royal Haskoning DHV

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1
Introduction

This chapter begins by providing background information on the research topic in Section 1.1. It then proceeds to explain the need for research in Section 1.2, followed by a statement of the research objective in Section 1.3. Subsequently, Section 1.4 formulates and outlines the main research question along with related sub-questions. Finally, the chapter concludes with a discussion of this study's research and practical significance in Section 1.5.

1.1 Background Information

The globe is dealing with climate change, deforestation, rising global temperatures, rising sea levels, and natural resource depletion as a result of growing populations, urbanization, and industrialization(Jagarajan et al., 2017). In recent years, the sustainability concept has become more common. The United Nations has set sustainability goals that all industries must think about for their future plans.(Oyedokun, Jones, & Dunse, 2015). Further, the construction industry is facing significant issues, the industry is responsible for climate change by releasing greenhouse gases and is also accountable for carbon emissions(Müller, Krick, & Blohmke, 2015). Overall, when compared with global emissions from different industry sectors, the construction industry is responsible for around 40% of carbon emissions, 40% natural resource consumption and 40% waste generation. Specifically, if we lower the data statistics only to Europe, the construction industry is responsible for 40% energy consumption, many call the construction industry "the industry of 40"(De Lassio, Franca, Santo, & Haddad, 2016).

The European Union (EU) has committed to achieving climate neutrality with net-zero emissions by 2050, aligning with its global climate action responsibilities under the Paris Agreement. This ambitious goal reflects the EU's dedication to creating a sustainable future for generations to come(EU, 2019). However, the construction industry, a significant contributor to climate change, poses a considerable challenge. To counteract this, green buildings have gained prominence, focusing on ecological sustainability in design, construction, and maintenance. Green buildings make either a neutral or a positive contribution to the environment in terms of factors such as carbon emissions, energy conservation, and waste management etc. Yet, a critical issue remains: existing buildings, with their substantial environmental footprint, are often overlooked. To address this, green retrofitting emerges as a solution(Jagarajan et al., 2017). Green retrofitting involves strategic enhancements to occupied buildings, aiming to boost energy efficiency, reduce water consumption, compensate for carbon emissions, enhance indoor quality, and mitigate noise pollution(Mohd-Rahim, Pirotti, Keshavarzsaleh, Zainon, & Zakaria, 2017). Embracing green retrofitting is pivotal in the journey towards the EU's 2050 climate objectives, bridging the gap between new green constructions and the urgent need to transform existing infrastructure for a more sustainable future.

In Green projects, technical-related studies have always dominated less technical studies(Mohd-Rahim et al., 2017). Risk management is a crucial aspect of project management and is considered one of the most critical areas in the construction industry(*PMBOK*, 2017). Every project in the construction industry is one of a kind and is heavily dynamic and complex in nature, it is associated with various risks that need to be identified and addressed. Hence, risk management has become a significant part of any construction project as it helps to identify and eliminate or mitigate risks(Renault & Agumba, 2016). The challenges in the green retrofit projects vary from the conventional projects, due to the added sustainable objectives.

This study contributes to research on risk management for green retrofit construction projects in two main ways:(1) It explores risk management, with a particular focus on how construction companies operating in the built environment identify and address risks (2) It presents a comprehensive model for risk management by considering uniqueness of green retrofit projects.

1.2 Research Gap

Risk management is an integral component of project management, a well-established and extensive discipline that has undergone extensive research and development over the years. When the topic of risk management is narrowed down to the construction industry, there are significant studies conducted on the process of risk management and its usage in different kinds of projects. However, it has been identified that based on the literature study, there are limited studies regarding risk management in sustainable projects, more specifically green retrofit projects. Existing literature primarily focuses on risk management aspects such as safety, cost, and schedule. Few studies explore the TECOP & PESTEL models, which enable a comprehensive assessment of risks by integrating crucial sustainability dimensions, such as environmental impacts and socio-political factors, alongside these traditional aspects.

Risk management consists of steps such as planning, identification, analysis, and evaluation. Of these steps, the identification step is the most common in the literature review due to its importance. Identifying risks in construction projects can become challenging when we look at these projects from a broader perspective, considering the entire project life cycle. Archibald(2012) highlighted that it's crucial to take the extended view to evaluate projects thoroughly. This is because many risks can crop up during the operational phase of a project after the construction is completed.

Any change made to the building during the operational phase is called retrofitting. If systems in the building are changed during the course of the operational phase, to make the building sustainable, it is called green retrofitting. The decision of green retrofitting is taken during the operational phase of the building, where different challenges arise. There are very few or limited studies on risks in green retrofit projects, and there are no studies on how companies in the built environment identify and deal with risks which arise in the operational phase, after taking the decision to green retrofit the project.

The existing knowledge about sustainable construction practices, often associated with green and green retrofit buildings, doesn't fully cover the aspect of risk identification, especially during the operation phase. This becomes especially critical when we consider that new materials and systems are constantly being introduced, and they might encounter performance issues. Since many of these materials and systems are tailor-made for specific projects, there's a limited track record of their performance. In simpler terms, there's a gap between what we know about sustainable retrofit construction and how we deal with the potential risks that arise, particularly when we experiment with new materials and systems in real-world projects.

1.3 Research Objective

The research objectives of this study are:- (1.)To investigate the current practices of risk identification employed during the operational phase of green retrofit projects. (2.)To understand how companies in the built environment manage risks arising, especially after deciding to undertake green retrofitting. (3.)This research intends to explore the gaps that currently exist between the comprehensive understanding of green retrofit construction and the practical application of risk management. (4.)To provide insights and recommendations for more effective risk management strategies in sustainable retrofit construction. (5.)To contribute to enhancing the overall success and sustainability of green retrofit initiatives by addressing the challenges identified through this research.

1.4 Research Question

The contextual backdrop and the identified research gap have culminated in the build-up of the following research questions:-

Main Research Question

"How do companies operating in the built environment (in the Netherlands) identify and deal with risks related to green retrofit buildings?"

Sub-Research Questions
1. How green retrofit buildings are different from general buildings?
This sub-question, will try to differentiate green retrofit buildings from conventional buildings and conventional retrofit buildings. This question provides more clarity to the research by providing a baseline on what are green retrofit buildings and will be answered through a literature study.

2. What are the risks specifically associated with green retrofit buildings?
This sub-question aims to distinguish the unique risks associated with green retrofit buildings, highlighting those risks that do not typically apply to conventional buildings. To address this question comprehensively, a combined approach involving a thorough literature study and interviews will be employed.

1.5 Intended Contributions

Research Relevance In terms of its scientific and theoretical significance, this thesis explores the risk identification and management strategies employed by companies in green retrofit projects. By shedding light on current practices, it not only serves as a foundational data source for subsequent research but also bridges existing knowledge gaps. The introduction of a recommendation model further advances the field by presenting actionable improvements. Consequently, this study enriches the academic literature by providing practical insights that can guide future theoretical and empirical inquiries in sustainable retrofit construction.

Practical Relevance The knowledge and information acquired from this research will offer practical guidance to project managers, risk analysts, and sustainability advisors. Additionally, the proposed model developed as part of this study will function as an advisory tool for managing risks in future green retrofit projects throughout their extended life cycles. This contribution aims to support professionals in making informed decisions and enhancing the overall sustainability and success of such projects.

2

Research Design

In this section, an introduction to the research design is provided, and further we delve into the research scope in Section 2.1, followed by an exploration of the research methodology in Section 2.2. Finally, the chapter concludes with the report outline in section 2.3.

Each research has its distinct qualities, yet nearly all research problems and objectives can be categorized into one of three common research designs: descriptive research, causal(experimental)research, and exploratory research(Thomas & Lawal, 2020). A descriptive study is made with the aim of illustrating how one or more variables are distributed, without delving into causal relationships or making any other specific hypotheses(Aggarwal & Ranganathan, 2019). Experimental design involves conducting research in a systematic and controlled manner to ensure accuracy and enable us to draw specific conclusions about a hypothesis(Bell, 2009). Exploratory research is carried out when there isn't sufficient information available about a particular phenomenon(Thomas & Lawal, 2020). **This thesis is an exploratory research**.

Researchers use exploratory approach to gather background information and clarify research questions and hypotheses, helping to set research priorities. Exploratory research, due to its preliminary nature, often utilizes a range of techniques. These include quantitative research through the examination of existing literature, informal qualitative methods like engaging in discussions with various stakeholders such as consumers, employees, management, or competitors, as well as formal qualitative research methods such as conducting in-depth interviews, organizing focus groups, utilizing protective methods, analyzing case studies, and conducting pilot studies. These diverse approaches help researchers gather valuable insights and form a comprehensive understanding of the subject of study(Jamia, 2016)(Thomas & Lawal, 2020).

2.1 Research Scope

A research scope delineates the research's limits, its overall coverage, and the intended audience. This particular research project is being carried out at the Delft University of Technology in the Netherlands. Further, this research takes into account all major green retrofits i.e.installation of a new systems for energy efficiency, curbing carbon emissions, usage of renewable energy, and increasing ventilation.

Risk management plays a crucial role in project management and is extensively discussed in various studies. As shown in Figure 2.1, this research specifically focuses on the initial stages of risk management: identifying and assessing potential risks. These critical areas are highlighted in green text in the figure. This thesis is an exploratory research, delving into the methods construction companies use to spot and tackle risks, depicted by a cloud in Figure 2.1.

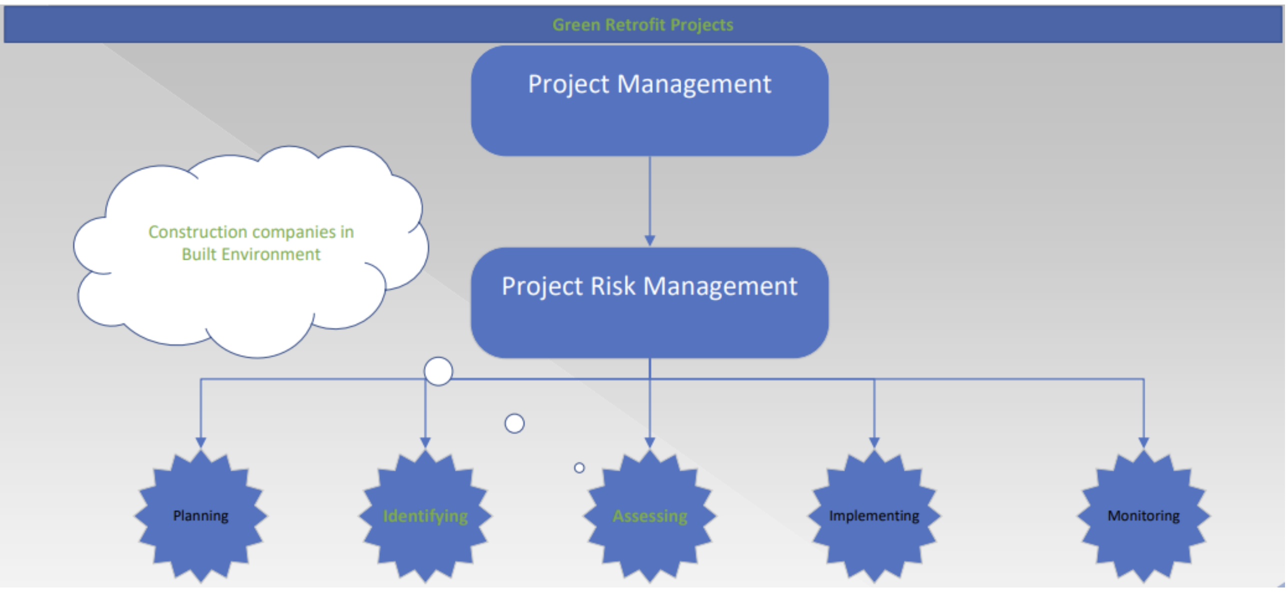

Figure 2.1: Research Scope

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2.2 Methodology

A methodology manifests the methods and techniques used in order to answer the research questions. The methodology used in this literature can be divided into two parts:-

- Literature Study
- Semi-Structured Interviews + Field Study (Empirical Study)

2.2.1 Research Strategy

Figure 2.2 presents the research strategy using a flowchart model. This visualization illustrates the progression of data and indicates the stages at which specific research questions are addressed. The overarching research approach is exploratory and adheres to a qualitative research format.

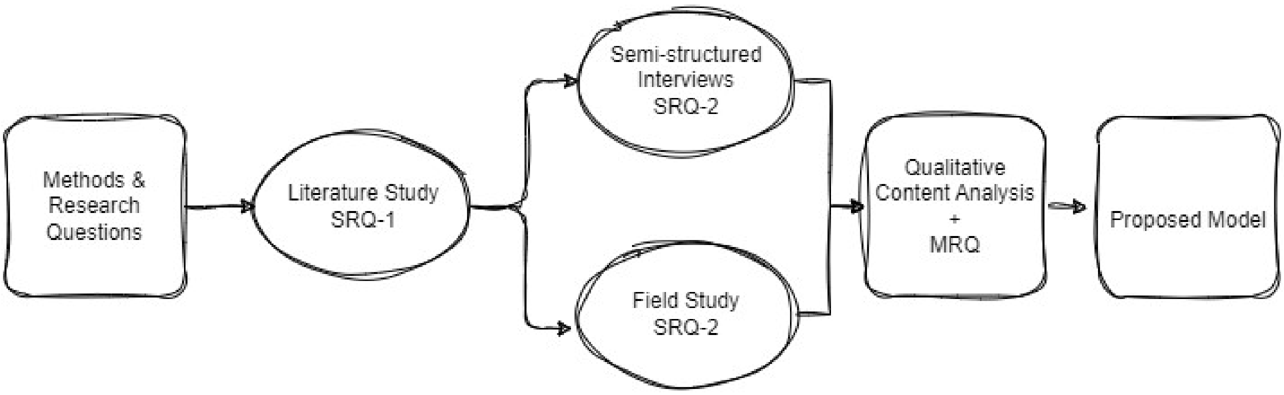

Figure 2.2: Research Strategy

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2.2.2 Literature Study

This section of the report explains the concepts and key relations involved and needed for the research. Sustainability, green buildings, green-retrofit buildings, project-life cycle and risk management concepts are explained in detail. A relation is established in between them in order to form a baseline for this research.

The data required for this section of the research is meticulously obtained through systematic searches utilizing key search terms "project management", "risk management", "green-retrofit buildings", "sustainability", "project-life cycle" etc. These searches are conducted across reputable academic databases such as Scopus, Elsevier, Science Direct, the TU Delft library, and the ASCE library. In addition to database, an exploration of pertinent literature from books and journals encompassing areas of project management, risk management, sustainability, and green buildings supplements the data collection process. To further expand the data-set, previously published theses available in the TU Delft Repository, lecture notes, assignment records, and related academic resources were also examined. This multi-faceted approach makes sure we collect a wide range of data from different sources, giving us a complete and well-rounded view.

2.2.3 Empirical Study

There are several approaches for conducting empirical research, which may involve either quantitative or qualitative analysis. **For this thesis, we have chosen to use qualitative research methods**. The qualitative research methods involved in are semi-structured interviews and field study.

Semi-structured Interviews
Interviews stand out as one of the most commonly utilized methods for gathering qualitative data. Semi-structured interviews, whether conducted individually or in groups, often serve as the primary source of data for qualitative research projects, representing the most widely employed format for qualitative research interviews.(DiCicco-Bloom & Crabtree, 2006). As discussed in previous sections, the main aim of semi-structured interviews in this thesis is to find out the process on how companies in built environment identify and deal with risks in green retrofit projects, by answering the research questions.

The interviews involved discussions with experts in the field of sustainable construction and risk analysts, scheduled for one-hour sessions. These interviews took place in a virtual setting via the Microsoft Teams platform. To ensure a structured approach, an interview guide comprising 10 questions was meticulously prepared after reviewing relevant books and research papers on semi-structured interviews. During the interviews, certain questions were posed based on participants' responses, and additional spontaneous inquiries were introduced to enrich the data collection process. With the permission of the interviews the meeting is transcribed using the application Otter AI.

The gathered transcripts from interviews, are used to perform a Qualitative content analysis. A Qualitative content analysis is described as a research approach employed for the subjective interpretation of textual data content. It involves a systematic process of categorization and the identification of themes or patterns(Hsieh & Shannon, 2005). Within the transcripts, there exist a substantial amount of interview data, some of which may be extraneous to the research objectives. Qualitative content analysis allows us to efficiently filter through and exclude this unwanted information, enabling a focused concentration on the data that is pertinent to the research goals(Flick, 2014). Another notable aspect of qualitative content analysis is its adaptability, which allows for the integration of both data-driven and concept-driven categories within a single coding framework. This approach ensures that the resulting coding framework provides a reliable and comprehensive representation of the research material and its relevance to the study. (Flick, 2014)(Massaad, 2021). This analysis will be done with the help of a software called Atlas.ti, it helps with coding qualitative data, which eases in identifying themes and concepts. The procedure and criteria for semi-structured interviews will be discussed in chapter 4.

Field-Study

The predominance of literature on the subject originating from regions outside the Netherlands highlights a significant gap in localized data, which is crucial for addressing research questions specific to the Dutch context. To bridge this gap and ensure the relevance and accuracy of the findings, a field study was conducted within the Netherlands. This approach allowed for the collection of authentic, region-specific data and facilitated direct engagement with a local company to understand how they assess the risks. This methodological choice ensures that the research outcomes are both relevant and applicable to the Netherlands.

A field study can encompass both qualitative and quantitative research approaches. In our specific case, the field study is focused on gathering qualitative data. The main reason for selecting field research is its capacity to yield real, hands-on data and insights directly from active sites. In the context of our study, it's particularly beneficial as it allows us to directly observe and understand the measures implemented for green retrofitting and the accompanying risks encountered on the ground.

To obtain authentic and real-world data, we conducted this field study within a residential house where a green retrofit construction project was in progress. The selection of this site was deliberate, chosen for its relevance to our research topic, offering ample opportunities to identify various types of risks. This field study encompassed a combination of interviews and on-site observations. The field study will be further explained in Chapter 4.

2.3 Research Outline

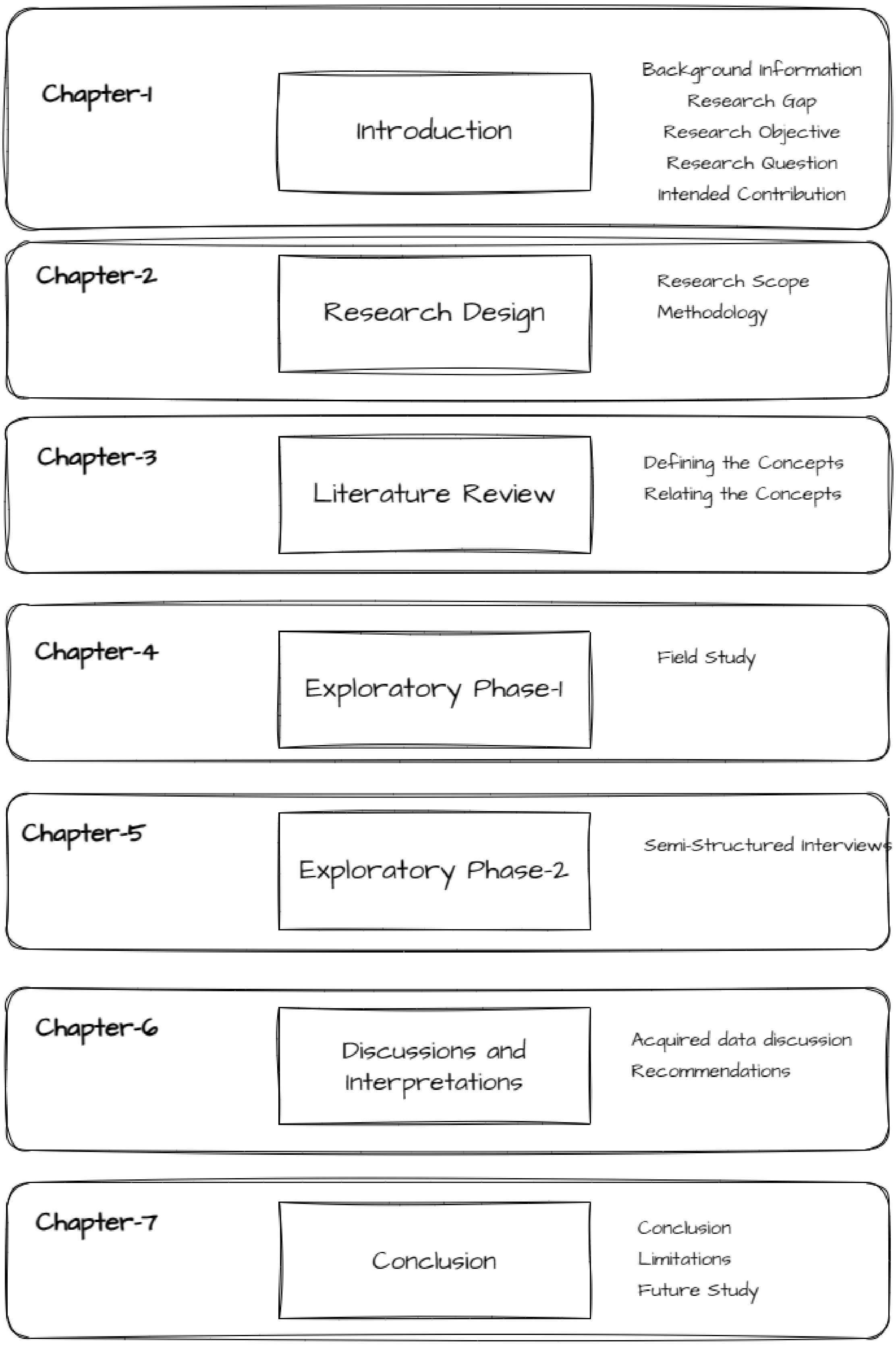

Figure 2.3: Research Report Outline

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3

Literature Review

This chapter begins with a literature study on Risk management in Section 3.1. It then sheds light on sustainability in the construction industry in Section 3.2, followed by a comparison of sustainable construction in a project life-cycle in Section 3.3. Subsequently, risk management in green retrofit projects is studied in Section 3.4. Later, the study explores BIM's role in Risk Management in Section 3.5 and finally, the chapter concludes with key takeouts in Section 3.6.

3.1 Risk Management

3.1.1 Project Risk Management

A project is a journey to accomplish tasks and achieve goals. A project in any industry is risky because of the complexity involved. According to Clarke and Varma(1999) *"Project is a strategic business process"*. Project risk management consists of a process that involves identifying, analysing, managing, and monitoring risks. The fundamental objective of risk management is to leverage or improve positive risks while taking actions to avoid or mitigate the impact of negative risks(*PMBOK*, 2017).

According to Wideman (1992), the motive of project risk management is :-

- Identifying the factors that likely affect the project objectives.
- Quantifying the impact of each factor
- Providing a baseline for project non controllables.
- Mitigating impact by influencing the project controllable

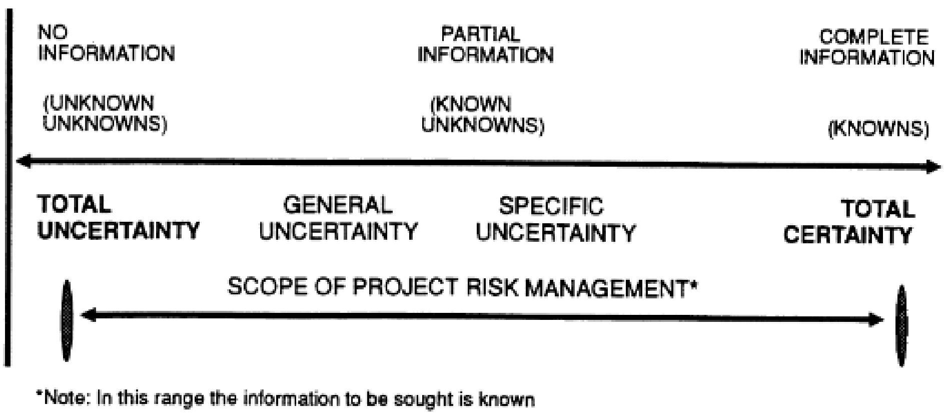

Figure 3.1: Uncertainity-Risk Spectrum.
Source: Widerman, 1992

Wideman(1992) explained in his book that uncertainty, opportunity and risk are closely connected. When we consider the project's future, many unknown factors could lead to either positive or negative outcomes. Uncertainty refers to a lack of knowledge about future events, encompassing all potential results, whether favourable or unfavourable. Within this context, the likelihood of favourable outcomes can be seen as opportunities, while the likelihood of unfavourable outcomes represents a risk, this can be observed in figure 3.1. Further, the author defined project risk as the "cumulative effect of the chances of uncertain occurrences adversely affecting the project objectives". Risk is conceptualized as (a) the probability of an undesirable occurrence and (b) the impact of the occurrence. Risk can be further described as

$$R = P * I$$

- R=Degree of the Risk
- P=Probability of the Risk Occurrence
- I=Degree of Risk Impact

Influence of Risk Management on Project

Project Goals and Success Every project is tailor-made to reach different goals. In the domain of projects, unforeseen circumstances such as delays, overruns, and unsatisfactory outcomes are very common occurrences. To effectively navigate through such challenges, a proactive approach is needed by preparing for potential setbacks and taking measures to minimize their impact wherever feasible. By adopting a mindset that embraces a proactive risk management process, organizations can enhance their ability to cope with unexpected outcomes and increase their chances of project success(Raz, Shenhar, & Dvir, 2002). The application of a risk management process encourages greater team engagement by establishing a structured process for identifying and reporting potential issues. It also establishes procedures to ensure that management receives well-structured risk data on time, enabling them to implement corrective measures promptly. This proactive approach facilitates the development of realistic schedules and cost projections(Tinnirello, 2017). With the integration of risk management into the project framework, team members become more invested in the project's overall success. This involvement stems from their active participation in identifying and addressing potential problems, fostering a collaborative and proactive approach towards achieving project objectives, which leads to the success of the project.(Kishk & Ukaga, 2008).

3.1.2 The Risk Management Process

Risk management in projects involves a cogent logical sequence of actions undertaken by decision-makers to ensure that the project stays on track within predefined parameters. These decision-makers are responsible for identifying, analyzing, and assessing risks throughout the entire project life cycle(Rodrigues-Da-Silva & Crispim, 2014).

3.1.2.1 PMBOk- Risk Management

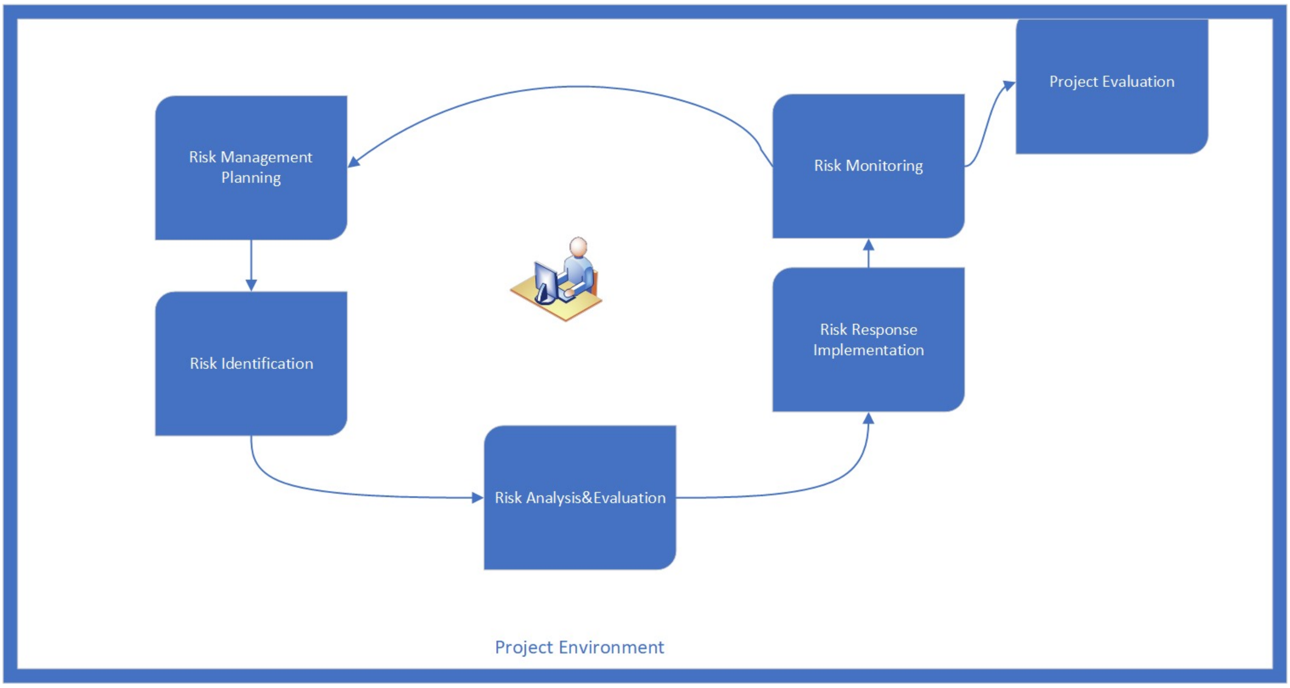

Figure 3.2: Risk Management Process

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Source:(Own Illustration)

Figure 3.2 illustrates the general risk management process based on PMBOK(2017) and Francisco(2022). The phases in the illustration are further explained:-

- **Risk Management Planning** This phase consists of steps like brainstorming, and choosing the right risk management strategy. The main benefit of this approach is its ability to ensure that the level of risk management aligns proportionately with the risks involved (*PMBOK*, 2017). In essence, the risk management plan aims to strike the right balance between addressing potential risks and the project's overall significance, ensuring a well-calibrated approach to risk mitigation and project success(Francisco, 2022).

- **Risk Identification** The initial and vital phase of the risk management process is risk identification. This phase entails an approach to identify, acknowledge, and document potential risks that could affect a project. The primary objective of risk identification is to reveal both known and unknown risks that may emerge at any stage throughout the project's duration(*PMBOK*, 2017).

- **Risk Analysis and Evaluation** This section involves the process of comprehensively understanding each risk, its potential consequences, and the likelihood of those outcomes(Zhou, Mao, Wang, Zhang, & Dong, 2019). Whether data is expressed qualitatively, semi-quantitatively, or quantitatively, gaining this understanding necessitates evaluating the impact and effectiveness of existing controls, as well as identifying any areas where controls may be insufficient or missing(Purdy, 2010). Zhou(2019) further classified the types of risk evaluation methods:-

  - **Qualitative** (1.) The questionnaire survey method, (2.) the collective discussion method, (3.) the expert investigation method, (4.) the safety checklist method, and (5.) the risk assessment matrix (RAM).
  - **Quantitative** (1.) The fuzzy comprehensive evaluation method, (2.) The factor analysis, (3.) The analytic hierarchy process, (4.) The cluster analysis, (5.) The regression analysis, (6.) The Bayesian analysis, (7.) The logit model, (8.) The time series analysis method, and (9.) The Dempster-Shafer theory.

- **Risk Response Implementation** Risk response implementation, according to*PMBOK*(2017), involves the process of executing the agreed-upon risk response plans, ensuring they are integrated into the project activities.

- **Risk Monitoring** Risk monitoring is a procedure for observing, assessing, and recording risk management activities during a project. This continuous monitoring helps in the execution of planned risk responses. Further, identifies new risks, and ensures adjustments to the risk management strategy as necessary(*PMBOK*, 2017).

Both qualitative and quantitative methods provide data tailored to the situation and nature of the project. The goal of risk analysis and assessment is to enable informed decision-making and proactively address risks to improve a project's resilience (Francisco, 2022). Using risk analysis and assessment, project managers develop risk management strategies and frameworks.

3.1.2.2 Risk Management ISO 31000

ISO 31000:2009 stands as an internationally acknowledged benchmark for risk management, offering foundational principles and detailed guidelines in the field. This standard emerged from a consensus-based approach, incorporating insights and contributions from a global pool of risk management experts(Purdy, 2010).

Figure 3.3: Risk Management process from ISO 3100:2009
. *(Purdy, 2010)*

The risk management process under ISO 31000 by Purdy(2010) involves:

1. Establishing the context: Understanding the organization's objectives, environment, and factors influencing success, setting the stage for risk identification.
2. Risk assessment: This includes risk identification (understanding what could happen and why), risk analysis (comprehending each risk, its consequences, and likelihood), and risk evaluation.
3. Risk treatment: Responding to risks identified and analyzed, using various strategies such as avoiding, accepting, removing the risk source, changing likelihood or consequences, sharing, or retaining the risk.

Further, it involves monitoring and reviewing along with communication and consultation. An overview with comparision of risk management standards can be seen in table Table 3.1

Table 3.1: Comparative analysis of ISO 31000 and PMBOK risk management standards

Feature	ISO 31000	PMBOK
Scope and Application	Universal, applicable to any organizational risk	Project-specific risk management
Approach	High-level, strategic	Detailed, procedural
Universality	Applicable to any organization or sector	Tailored for project management
Process	Continual, systematic approach to risk across the organization	Project life cycle-oriented risk approach
Integration	Emphasizes organization-wide integration	Focuses on integration within project management processes
Customization	Allows for broad customization	Provides specific, detailed practices and tools

3.1.3 Risks Categorization

There are few models where risks can be categorized and dealt with

3.1.3.1 TECOP

TECOP is an analytical model designed for risk assessment and management in various projects and business ventures in a structured and organized manner. It is highly used in the oil and gas industry. It encompasses(Iqbal, 2023):-

- Technical Risks: These are connected to issues like malfunctioning technology, software glitches, or hurdles in adopting new technical innovations.
- Environmental Risks: These concern natural calamities, shifts in climate conditions, and other environmental elements that might disrupt project execution or business functioning.
- Commercial Risks: These risks stem from market conditions, competitive landscape, price fluctuations, and consumer trends, potentially impacting financial performance.
- Operational Risks: These are risks tied to the internal processes of a business, including disruptions in the supply chain, equipment breakdowns, or operational inefficiencies.
- Political Risks: These involve changes in governmental policies, regulatory shifts, or political unrest that could negatively influence business activities or investment prospects.

3.1.3.2 Pestel

PESTEL analysis is an extensive approach that businesses use to assess the macro-environmental factors influencing their operations. This methodology helps in pinpointing potential threats and vulnerabilities within an organization's landscape by examining six critical areas: Political, Economic, Social, Technological, Environmental, and Legal factors. By understanding these external elements, companies can devise strategies to mitigate their impacts(Islam, 2017). Expanding the critical areas(Andrei & Prisecaru, 2016):-

- Political: This factor determines the extent to which government and political events or policies may impact an organization or a specific industry.
- Economic: These factors include the purchasing power of consumers and the organization's cost of capital. They include economic growth, exchange rates, inflation rates, interest rates, etc.
- Social: These factors examine the social environment of the market and include demographics, cultural trends
- Technological: These factors pertain to innovations in technology that may affect the operations of the industry and the market favourably or unfavourably.
- Environmental: These factors include all those that influence or are determined by the surrounding environment. This aspect of the PESTEL analysis includes weather, climate, and environmental offsets.
- Legal: These factors have both external and internal sides. they often deal with government policies and regulations.

An overview with comparsion of the two risk categorization models can be seen in Table 3.2.

Table 3.2: Comparative Analysis of PESTEL and TECOP Frameworks

Aspect	**PESTEL**	**TECOP**
Focus	Macro-environmental factors	Project-specific environmental factors
Components	Political, Economic, Social, Technological, Environmental, Legal	Technical, Environmental, Commercial, Organizational, Political
Application	Strategic planning, market analysis, business positioning	Risk identification and management in engineering and construction projects
Purpose	Understanding external environment	Assessing project-specific risks and influences
Scope	Broad (external factors)	Specific to project environment
Approach	Analytical framework	Risk categorization
Outcome	Strategic insight, opportunity, and threat analysis	Risk assessment and mitigation strategies

3.1.4 Risk Management in Construction Projects

Why Risk Management in Construction?
There are risks in any task, any industry and any sector. In the construction industry risks are inborn and there is no escape as projects in construction are unique in their way and are dynamic in nature(Szymański, 2017). This makes risk management the most important aspect of construction project management, further, the complexities involved in the construction sector, make risk management a key area to execute(Ibidapo, 2014). Efficiently implementing risk management is a critical component of project management that directly contributes to the success of the project(Majeed, 2023). Risk management involves a systematic process of identifying sources of uncertainty, analyzing the potential consequences of uncertain events or conditions, and developing response strategies based on expected outcomes. This iterative process continues throughout the life cycle of a project to ensure that project objectives are successfully achieved (Zavadskas, Turskis, & Tamošaitienė, 2010).The risk factors linked with construction projects mainly impact project timelines, costs, and quality outcomes(Akintoye & Macleod, 1997). . These unique aspects will need proficient risk management strategies that are imperative for effectively mitigating the inherent uncertainties and risks(Zou & Zhang, 2009).

3.2 Sustainability in Construction Industry

3.2.1 What is Sustainability and Why it is important in the Construction Industry?

The genesis of the sustainability concept as a policy can be traced back to the Brundtland Report of 1987. This report centred on the conflict between humanity's desires for improved living conditions and the inherent constraints set by the natural environment(Kuhlman & Farrington, 2010). Building upon the insights of the United Nations Brundtland report of our common future, sustainability can be described as "*meeting the needs of the present without compromising the ability of future generations to meet their own needs*" (Mrcgp, 1988). As discussed in the Introduction about the impact of the construction industry, the amount of damage this industry is causing would affect the natural resources, which would leave the future generations in deficit. Hence, sustainability has become a prominent and increasingly emphasized domain within the construction sector, drawing significant attention in recent times.

Sustainability in construction is a complex topic involving multi-dimensional aspects of economic, environmental, and social aspects(Sourani & Sohail, 2011).Raynsford(2000), in his book explained that sustainable constructions involve a process in which a competitive industry produces assets like buildings and structures, these assets enhance quality of life, adapt to future needs, and create positive environments along with efficient resource usage. Another author Sourani(2008), described sustainable construction as applying sustainable development principles to the construction sector. This involves ensuring a better quality of life for present and future generations by addressing social needs, maintaining economic growth, and safeguarding the environment while using resources wisely. Drawing from the perspectives on sustainability in construction provided by Raynsford(2000) and Sourani(2008) it becomes evident that the concept of sustainability finds application in both technical and managerial domains within the construction sector. This thesis focuses on the management part of the sustainability constructions.

3.2.2 Sustainable Constructions

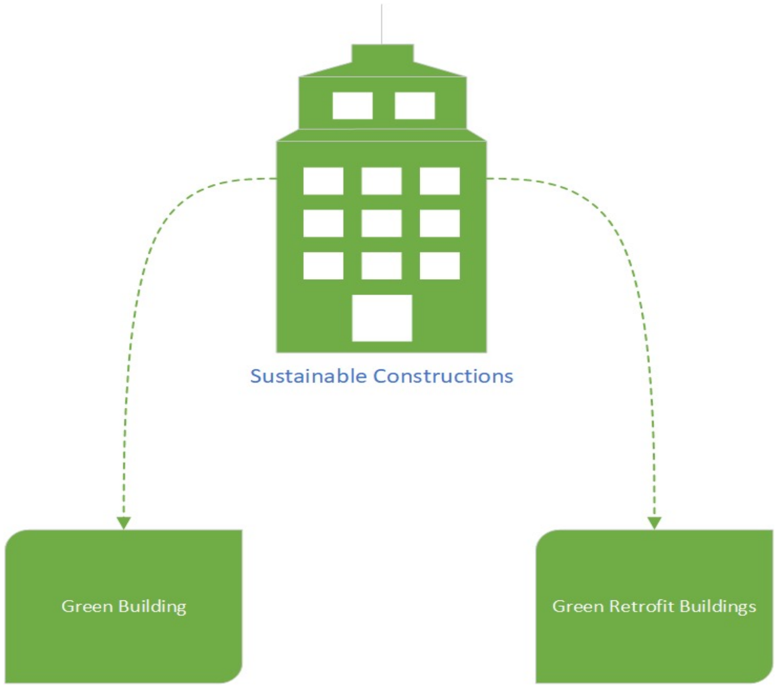

Figure 3.4: Types of Sustainable Constructions

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Source:(Own Illustration)

Figure 3.3 illustrates two main types of sustainable constructions:-

- Green Building
- Green Retrofit Building

Green Building
A green building belongs to the realm of sustainable architecture, standing out for its exceptional performance. It is meticulously crafted with a dedicated emphasis on curtailing its environmental and human health repercussions. This objective is realized through detailed planning, conscientious design, and judicious material selection, all directed towards minimizing energy consumption, carbon emissions, and water usage. Furthermore, the goal is to mitigate the life-cycle environmental impacts of its components, as highlighted by Yudelson(2007). Although some view green building as synonymous with high-performance building, a notable consistency across different author definitions lies in the shared aspects of contributing positively to the community, environmental sustainability and the environment's life cycle(Zuo & Zhao, 2014). Zuo(2014) further discussed about different type of approaches to achieve green building:-

- **Technological Approach**
  - Usage of Renewable Energy, which reduces energy usage and GHG emissions. It helps in achieving the Net Zero goals(Eg;-solar heat water, geothermal heat pump, mini wind turbine etc).
  - Installation of energy efficient systems(Reduced Energy costs).
  - Usage of recycled and reusable C&D waste during construction.
- **Life cycle Assessment Approach**

- In Life Cycle Assessment (LCA), a building is treated as a system, enabling an in-depth examination of material and energy flows across its life cycle stages. LCA's strength lies in its holistic approach, extending beyond isolated phases to include manufacturing, transportation, energy consumption, water use, and greenhouse gas emissions. This comprehensive perspective enhances understanding and aligns with sustainable construction practices.
- It can be applied to the whole building or a single component

- **Managerial Approach**
  - Organizational and Procedural Barriers: Häkkinen and Belloni(2011) emphasize that obstacles to green building development are primarily related to organizational and procedural challenges, outweighing any lack of technological innovation.
  - Project Level Management: Specific skills are required for effective green building project management, including engaging specialist consultants, implementing green assessment methods like LEED, offering training, and involving external stakeholders(Robichaud & Anantatmula, 2011).
  - Company Level Implementation: Environmental management systems (EMS) adoption leads to substantial energy, waste, and resource savings. Playing pivotal roles are commitment from top management, utilization of green specifications, and adoption of sustainability reporting practices(Zuo & Zhao, 2014).
  - Market-Level Dynamics: The green building market's growth is influenced by public policies. Initiatives like the Commercial Building Disclosure (CBD) Program, a mandate for disclosing building performance information, and incentives such as Building Energy Efficiency Certificates (BEEC) drive energy-efficient building development(Li, Cooper, Daly, & Ledo, 2012).

Green Retrofit Building
Green buildings are new buildings, while there are many existing buildings that contribute to the negative impact on the environment. To address this, buildings are retrofitted to meet sustainability goals and criteria, reducing the buildings' impact on the environment and offsetting the pollution they cause in their early years. This retrofitting of buildings to achieve sustainable goals that positively impact the environment is called Green Retrofitting, and the buildings that have undergone this process are called Green Retrofitted Buildings. The drive for green retrofitting is underpinned by extensive research into its cost-effectiveness and benefits. Key benefits include reductions in global energy consumption and greenhouse gas emissions, providing a practical alternative to the counterproductive practice of replacing existing buildings with new "green" construction(Jagarajan et al., 2017). In addition to reducing energy consumption, carbon emissions and protecting the environment, green retrofits are also about extending the life of buildings, improving occupant comfort and developing a healthy work environment(Mickaityte, Zavadskas, Kaklauskas, & Tupenaite, 2008).

There are different ways in which green retrofitting can be implemented, Figure 3.5 points out the most common ones.

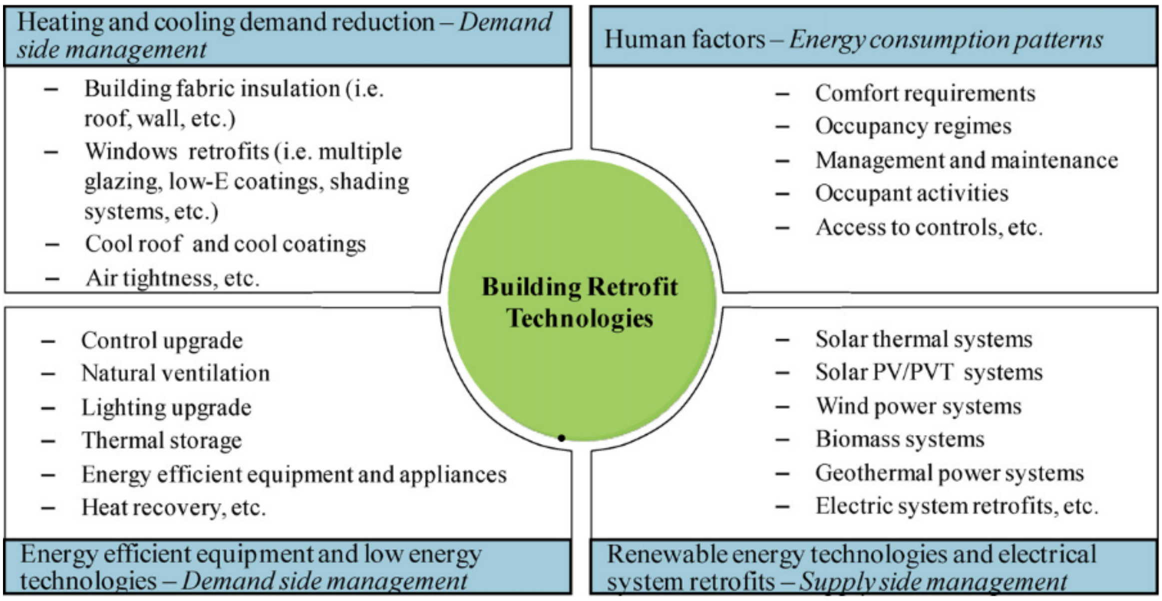

Figure 3.5: Different Technologies in Green Building retrofits

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Source:((Li et al., 2012))

Green Building/Green Retrofit Assessment Tools: Across the globe, diverse green building assessment tools have been designed to streamline construction processes. Prominent examples encompass LEED (USA), BREEAM (UK), DGNB (Germany), CASEBEE (Japan), Green Star (Australia), GBI (Malaysia), HK BEAM (Hong Kong), PRSE (UAE). These tools are region-specific, like LEED in the USA or BREEAM in the UK, tailoring their criteria to local contexts. In the Netherlands, both LEED and BREEAM are in use based on the client's requirements. Green building rating systems focus on three fundamental aspects: indoor environmental quality, energy efficiency, and ecological considerations. These criteria are essential at both individual and larger scales. These tools help the projects to align with strategies for achieving sustainable constructions(Mohd-Rahim et al., 2017).

3.3 Sustainable Constructions – Project Life-Cycle

The purpose of this section is to clarify the research question by providing a rationale for distinguishing green retrofit buildings from various new buildings in terms of the project life cycle. To this end, a visual representation derived from the previous sections is presented to illustrate the relationship between these factors.

Project Life-Cycle The project life cycle describes the sequential arrangement of processes and phases used in project execution. It provides an overview of the major phases in the execution of a project and the actions required for its successful completion. It also documents valuable organizational lessons learned to promote continuous improvement of processes across project phases and their application in future similar projects(Aston, 2023)(Archibald et al., 2012). Figure 3.5 illustrates the project life-cycle and extended project life-cycle, along with the phases involved in it. Each project follows a structured schedule that begins at a unique starting point and ends at a specific end point, similar to the individual phases that can be represented by a project life cycle(*APM body of knowledge*, 2012).To achieve successful project outcomes, effective project management endeavors are essential.This includes skillfully identifying and managing project activities not only in the initial phase, but also throughout the project (Pica & Montanari, 2015).

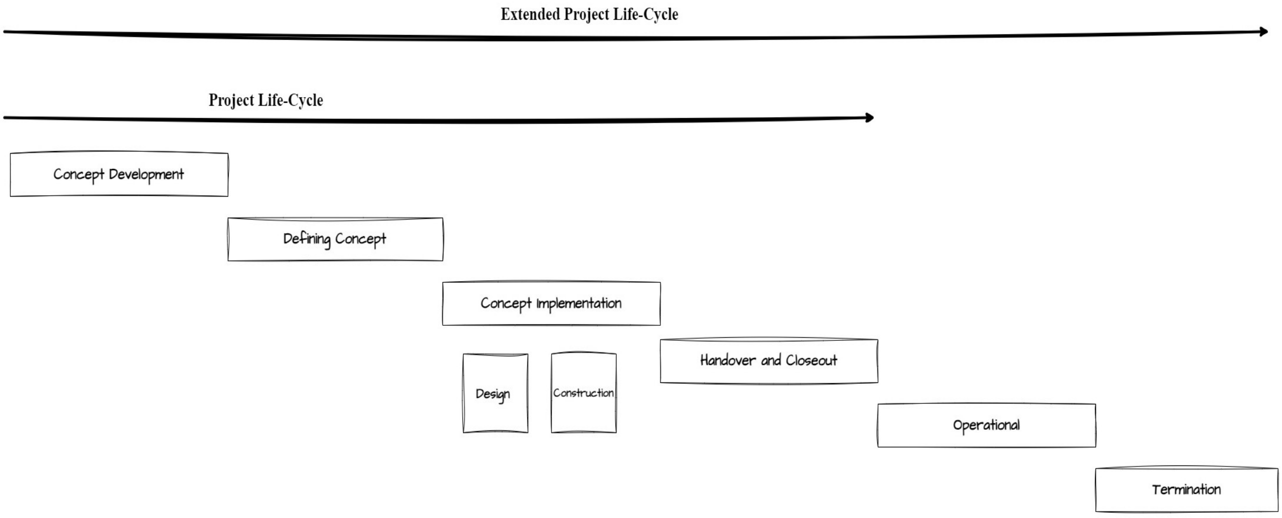

Figure 3.6: Project Life Time vs Extended Life Time

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*Source:(Own Illustration, Inspired by (Archibald et al., 2012) and (*APM body of knowledge, *2012))*

Figure 3.6 provides a visual representation of the distinctive patterns that differentiate green buildings from green retrofit buildings within the cont ext of sustainable construction. Green retrofit buildings come to the forefront during the operational phase of a project-life time. As we discussed earlier, the reason for introducing green retrofits is often tied to sustainability concerns, and this typically happens when the building is already in use. In simpler terms, people decide to make green improvements to a building after it's up and running. Further, in terms of extended project life-cycle this happens during the operational phase of the buildings. Conversely, the genesis of green buildings and innovative design concepts can be traced back to the initial design phase. These buildings are intentionally planned with sustainability in mind right from the outset.

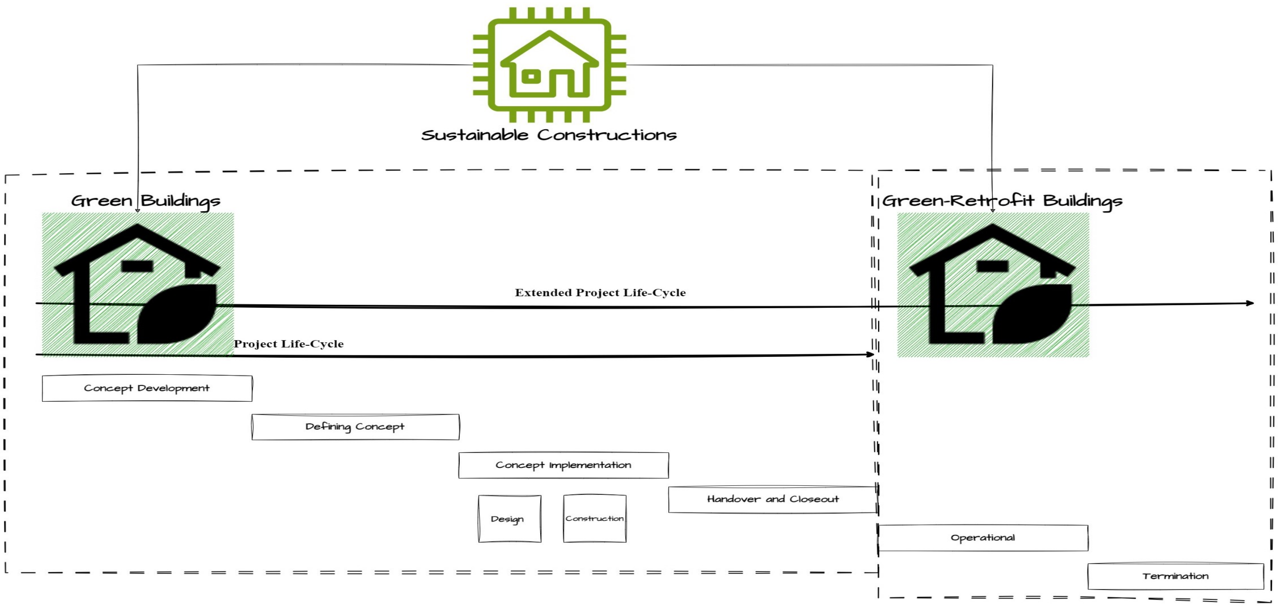

Figure 3.7: Sustainable Constructions - Life Cycle

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Source:(Own Illustration)

The process of green retrofitting takes place after the decision to proceed with retrofitting has been made. Lee, Mohamed, Masrom, Abas, and Wee(2020) in his paper gave a gist of the steps involved:-

- Project Pre-Survey
- Energy Audit and Performance Assessment
- Identifying the Retrofit Option
- Construction
- Commissioning and Validation

3.4 Risk Management in Green Retrofitting Projects

3.4.1 Risks in Green retrofitting

> *"Technical-centered issues have gained far more importance in green building construction, however, the role of less technical related issues still has been left untouched or given less attention"* -Mohd-Rahim et al.(2017).

Green retrofit buildings are inevitably accompanied by risks, encompassing both those inherent in all construction endeavors and those uniquely tied to the challenges of retrofitting for sustainability(Hwang, Zhao, See, & Yun, 2015). Based on the literature studies done by Ranawaka and Mallawaarachchi(2018) and Hwang et al.(2015), the main risks identified in green retrofit buildings are:-

- **Financial Risks**:-
  Here Financial risk can be two types, 1.Return on Investment (ROI) - Concerns about insufficient payback represent a significant barrier to the adoption of green retrofit projects, mainly due to the potentially extended time required for returns on investment to materialize. 2. Investment Risk-The supplementary initial expenses linked to green retrofitting could potentially jeopardize the attainment of schedule and budget goals within green retrofit projects.
- **Regulatory Risk**:-
  Regulatory risks in green retrofit buildings are all about the possible difficulties and uncertainties that come with following environmental and sustainability rules when renovating a building. These risks include things like changes in regulations, permits, zoning laws, and other legal stuff that could affect how the retrofitting project is carried out and whether it meets its long-term sustainability goals.
- **Failure to fulfill client requirements**:- The risk is linked to the inability to fulfil client requirements, it revolves around the potential difficulties and uncertainties in meeting the precise demands and anticipations of the client within the project. The client generally expresses dissatisfaction due to this.
- **Performance Risk**:-
  This risk is related to the anticipated performance of newly installed systems in green retrofit projects and becomes a concern when the actual performance falls short of expectations.

Insufficient experience and limited knowledge persist in the field of green retrofit projects. Combined with the ongoing development of new materials and technologies tailored to specific projects, these factors contribute to the above risks. Ultimately, these risks are reflected in the final construction cost of a project. Based on this we can say that there is a need for real-world data and a comprehensive framework which avoids most of the risks.

3.5 BIM for Risk Management

3.5.1 BIM and its impact in construction

BIM originated in the early 2000s, situated within the Architecture, Engineering, and Construction (AEC) sector. Its advent marked a significant evolution in the construction industry, driven by the incorporation of Information and Communication Technology (ICT) into construction methodologies. This integration aimed to substantially improve diverse facets of project management. BIM is a comprehensive digital approach that enhances productivity and efficiency, minimizes errors, and saves time and cost, ultimately leading to more sustainable construction processes(Al-Ashmori et al., 2020). Further, it is more than just technology; it's a key process for making and managing digital versions of a place's real-world features. This approach improves how information is shared at all stages of a building's life, helping people make better decisions, manage more effectively, and plan and carry out projects more efficiently(Joblot, Paviot, Deneux, & Lamouri, 2017). Integrating existing structures into Building Information Modeling (BIM) involves techniques like laser scanning, photogrammetry, or manual measurements. Laser scanning captures detailed point cloud data for precise digital reconstructions, while photogrammetry uses multi-angle photos to generate a 3D model. Once integrated into BIM software, the digital representation of the existing building can be linked with other elements, facilitating enhanced visualization and efficient project lifecycle management(Sung & Lee, 2014). Additionally, BIM tools offer stakeholders the ability to handle project information through various phases within a digital setting. These tools have diverse applications in both new constructions and retrofitting projects (Sheth, Price, & Glass, 2010). Consequently, there is a significant opportunity to utilize BIM tools, including 4D BIM, to facilitate the retrofitting process(Chaves, Tzortzopoulos, Formoso, & Shigaki, 2015).

Volk, Stengel, and Schultmann(2014) in his literature review found that BIM improves project management and lessens risks by enabling the evaluation of different strategies and enhancements. It also upgrades facility management with on-the-ground progress tracking and monitoring. Furthermore, he mentioned that it aids in closely watching hazardous elements and growing attention toward sustainable features, options for reusing/recycling, and emissions control. In addition, Mohammad, Abdullah, and Ismail(2018) noted in their literature review that BIM plays a central role in modern construction projects, primarily by promoting better teamwork and clarity. It further serves as a platform for simultaneous collaboration and ensures that all stakeholders are communicating clearly and are on the same page. This minimizes potential data discrepancies and reduces confusion among project members. Additionally, BIM streamlines workflow by consolidating various aspects of the design process. This way, all changes are immediately reflected in all project areas, increasing both accuracy and productivity in the project lifecycle.

Joblot et al.(2017) in his literature review concluded that BIM becomes exceptionally instrumental in thermal integration too. Thermography is a technique that involves the detection and measurement of thermal variations on building surfaces, primarily used to identify points of energy inefficiency such as heat loss or gain, often due to insufficient insulation or thermal bridging. When this thermal data is integrated into a BIM model, a more comprehensive, layered understanding of the building's thermal performance is achieved. The integration process begins by capturing thermographic data, usually through infrared cameras or other heat-sensing technologies. This data, which is often visualized through heat maps, illustrates the temperature disparities along the building's structure, pinpointing areas of concern. When this data set is imported into the BIM software, it allows for a three-dimensional, data-rich model of the building, combining spatial relationships with surface temperature information. This model serves as a dynamic thermal performance simulation, enabling engineers, architects, and energy consultants to identify precisely where energy inefficiencies occur, down to the finest detail(Lagüela, Díaz-Vilariño, Martínez, & Armesto, 2013).

Building Information Modelling (BIM) does play a role in green retrofitting. BIM platforms, such as Bentley AECOsim Building Designer, Tekla Structures, Autodesk Revit's Architecture, Structure, MEP, and Navisworks, can handle various types of data input and offer simulation and visualization options. BIM tools can be used to analyze the energy performance of existing buildings and facilitate energy-driven refurbishments. By using BIM technologies, sustainability goals of retrofitting existing buildings, such as reducing energy consumption and achieving sustainability ratings, can be achieved more efficiently(Khaddaj & Srour, 2016).

With the various tools available from BIM, construction risks can be better controlled by providing a complete picture from the beginning to the end of a project. This allows teams to identify issues early on that might otherwise be overlooked, such as design or scheduling problems. With BIM, teams can also test different build scenarios to see which one poses less risk. In addition, BIM uses a lot of data, so decisions are based on real information. All of this means fewer surprises and better planning of construction projects(Mohammad et al., 2018).
In summary, the adoption and integration of BIM in the construction sector is a transformative change that leverages the power of technology to improve project management, sustainability, and overall risk management efficiency.

3.6 Key-Takeouts

The main objective of this thesis is to answer the research question ***"How can companies operating in the built environment (in the Netherlands) identify and deal with risks related to green retrofit buildings?"*** To answer this question, several data domains related to risk management and sustainable buildings were explored.
In addressing this question, it is first important to establish a clear understanding of the differences between green retrofits and novel constructions. This delineation provides the basis for examining the link between sustainable construction practices and the whole life of a project, a link established through a comprehensive review of the relevant literature.
In the field of sustainable retrofitting, the decision to undertake such a project is always made during the operational phase of a building. This key phase is characterized by a deliberate consideration of retrofit measures based on specific goals such as increasing energy efficiency, reducing carbon emissions, and improving waste management.
An inherent aspect that significantly underlines the sustainable retrofit process is comprehensive risk management. This aspect is of particular importance because there are a number of risks in addition to those encountered in conventional projects, in which few are mentioned in the previous section. Given the complex nature of retrofit projects, they are vulnerable to a spectrum of challenges and uncertainties that can hinder their successful implementation. Therefore, effective risk management strategies are essential to anticipate, assess, and address potential obstacles to ensure the smooth progress of the retrofit initiative.

BIM is reshaping the AEC sector with the integration of ICT, leading to improved project management, by digitally representing real-world structures. It allows testing of construction scenarios, enabling proactive risk management. BIM's data-driven approach ensures informed decisions, minimizing unforeseen challenges and enhancing construction sustainability. Using BIM as a tool for the risk management process, not only protects the project from potential setbacks but also promotes a proactive stance in mitigating the unique risks associated with sustainable projects.

Overall this literature section provided

- Differentiating Green Retrofit Projects
- Importance of Risk Management
- Types of risk management
- Models for categorizing risks
- Common risks in green retrofits
- Need for Sustainable Constructions
- Relating Sustainable Constructions with Project Life-cycle
- Identifying Risks Locally in Green Retrofit Buildings
- Influence of BIM on risk management.

The literature data collected will serve as a valuable resource for formulating the appropriate interview questions. Subsequently, the insights gained from the interviews will be merged with the collected data to facilitate the creation of a predictive model.

4

Exploration Phase-1 - Field Study

This chapter begins by providing background information about the case in Section 4.1.1. It then proceeds to the primary findings in Section 4.1.2, followed by a concluding key-takeouts section 4.1.3.

4.1 Field-Study

4.1.1 Background Information

The main aim of the field study is to unveil the genuine risks that arise during the green retrofitting process in the Netherlands. This research method proves highly effective as it offers a practical insight into the risks associated with retrofitting projects. The field study involves simultaneous on-site observations and semi-structured interview with the house owner.
The field study took place in a residential property currently undergoing green retrofitting at Voorburg, a city in the Netherlands, the property can be viewed in figure 4.1. The retrofitting of this property is taking place 32 years after its initial construction, which occurred in the year 1991. As discussed during the literature study this green retrofitting happens during the operational phase.

Figure 4.1: Property where field-study was conducted
.

The primary objective of the owner of the house is to achieve sustainability in their home and align with the net-zero renovation objectives set forth by both the country and the European Union. Additionally, by pursuing sustainability, the homeowner's objectives involve diminishing energy consumption, lowering carbon emissions, harnessing renewable solar energy, enhancing indoor lighting, and thereby qualifying for government subsidies. On top of that homeowner has a plan to generate additional electricity during peak summer through, and sell it for a good value. The main triggers for the homeowner to opt for green retrofitting are high energy prices and increased comfort. This will be further elaborated upon in Section 4.1.2, where we will delve into the methods employed to achieve these sustainable objectives.

4.1.2 Findings

The findings are divided into two sections i.e sustainability measures and identified risks.

4.1.2.1 Sustainability Measures

As mentioned in section 4.1 the primary objectives for green retrofitting are to make the property sustainable and also to meet the renovation standard net-zero goals. In order to achieve this the house owner has adopted few methods:-

1. **Reduced energy consumption**:- To lower energy consumption and mitigate the high heating costs, the homeowner has chosen to install underfloor heating, replacing conventional heaters. Underfloor heating is characterized by a grid-like arrangement of pipes beneath the floor, which ensures uniform heating throughout the room. Furthermore, this system boasts attributes of energy efficiency, low maintenance requirements, and the ability to maintain a consistent indoor temperature. Figure 4.2 illustrates the area where the pipes will be evenly distributed on the floor, with tiles to be subsequently placed on top of them.

Figure 4.2: Area where underfloor heating grid pipes will be arranged

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2. **Transition to renewable energy**:- The homeowner transitioned from a gas-powered central heating system to an electric underfloor heating system, a move aimed at decreasing fossil fuel use, which can be seen in Figure 4.3. Further, as part of the gradual transition toward renewable energy, the homeowner installed solar panels as shown in Figure 4.4 to

harness electricity from solar energy. However, it's important to note that solar energy alone cannot entirely substitute the utility electricity required for the house, primarily due to regional weather constraints. Nevertheless, during the peak summer months in the region, the homeowner can produce surplus energy to fulfill the house's needs. In such cases, any extra energy generated can be sold, helping to recoup a portion of the initial investment costs.

Figure 4.3: New Electric Energy System

Figure 4.4: Solar Energy panels

3. **Insulation improvement and Ventilation**:- Insulation serves as a thermal barrier, effectively obstructing the transfer of heat. It enhances the comfort of the room by diminishing heat loss during the winter months and curbing heat gain during the summer. To improve the house's insulation and increase indoor lighting/ventilation, 23 old windows were replaced with new HR++ glass windows, as seen in Figure 4.5a, which also contributes to energy efficiency. Further, insulation chips, as illustrated in Figure 4.5b, were used below the concrete floor to improve floor insulation, and the insulation for the roof was redone.

(a) HR++ Glass Windows

(b) Insulation chips

Figure 4.5: Insulation Treatments

4. **Curbing carbon emissions and Reusing construction materials**:- During the improvement of insulation of the roof, the homeowner needed 20% additional tiles. Instead of purchasing new tiles, the homeowner opted for second-hand tiles in good condition sourced from another property, which can be seen in Figure 4.6. This choice not only contributed to a reduction in construction and demolition waste but also lessened the embodied carbon footprint. Additionally, enhancements were made to the gutters and the roof surface. Each reused tile required individual securing with clips to enhance wind resistance, as some had been dislodged during previous high winds. To further fortify tile attachment, round top bars along the edges were reinforced. These upgrades to the roof, including an improved insulation layer below the roof and tile attachment, served to minimize heat loss and enhance the home's energy efficiency and sustainability.

Figure 4.6: Reused roof tiles

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4.1.2.2 Risks Identified for implementing sustainable measures

In the effort to green retrofit, the homeowner adopted several sustainable measures, and in the process, identified certain associated risks:-

1. **Performance Risk**:- With the aim of reducing energy consumption and achieving net-zero energy use, the homeowner installed new energy systems in the house. These systems are relatively new to the retrofitting market and lack a proven long-term track record. Though they are claimed to last long by the suppliers, there is no guarantee provided during the long-term use. Among these systems, the heating system and the solar panels are the main elements contributing to performance risk. There is significant uncertainty regarding the new heating system's ability to effectively maintain the warmth of the entire area or if supplementary traditional heaters will be required to fulfill this purpose. Similarly, with respect to the renewable energy generator, i.e., the solar panels, there is a considerable level of uncertainty concerning whether the arrangement of solar panels can generate a sufficient amount of electricity to power the house, particularly during peak sunny hours, which leads to uncertainty in energy savings.

2. **Supply chain risk**:- The retrofitting project of the property was delayed for a considerable time due to the lack of material availability in the market mainly due to the energy crisis caused by the Ukraine-Russian war. Specifically, when the homeowner wanted to replace the roof, they discovered roof tile manufacturers had stopped taking new orders due to

high energy prices. Other materials like windows, solar panels, and heat pumps also faced very long lead times, due to supply constraints.

3. **Schedule Risk**:- Retrofitting projects typically occur during the operational phase of a building, with occupants residing on various floors or rooms. They coexist with ongoing construction activities. Any delays in these construction activities can lead to considerable inconveniences for the occupants, affecting their comfort and daily routines. In the case of this specific project, delays occurred due to various reasons:-

   - Overly Optimistic Subcontractor Estimates: The project relied on subcontractors' estimates of task durations, which often proved to be overly optimistic.
   - Advisor Involvement: Every minor correction or improvement, no matter how small, necessitates a visit by the advisor to the site. Subsequently, discussions are held with team heads and contractors, followed by implementation. This thorough process, while ensuring quality, can sometimes lead to delays in inspections by the advisor.
   - Coordination Challenges: Coordinating the schedules of multiple subcontractors (such as electricians, plumbers, and roofers) and ensuring their work was properly sequenced to avoid delays presented a challenge.
   - Unforeseen Issues: Unanticipated issues arose that extended the duration of specific tasks. For instance, the extensive window-removing process doubled the time required for replacement.
   - Task Dependencies: Dependencies between tasks were a factor. For example, the installation of flooring couldn't commence until the underfloor heating pipes were laid, and the concrete had fully dried.

   These factors contributed to long project duration and delays, impacting the occupants' daily lives and comfort.

4. **Return on Investment**:- As previously discussed in Section 3.4, the concept of return on investment (ROI) and the associated payback period remain subject to a level of uncertainty, and this applies to the current case as well. While the homeowner expressed confidence in recouping their investment within a span of 7 to 10 years, this outlook remains tentative due to several variable factors.

   For instance, energy price fluctuations introduce an element of uncertainty. Payback estimations rely on assumptions about future energy costs, which may undergo changes. Sudden price drops can offset the anticipated savings. Moreover, evolving technology plays a role; newer and more efficient products emerging over a decade or more may render existing upgrades less optimal.

   Financial risks are also in the picture. Taking on debt to fund the project incurs interest costs over the extended payback period. If the actual returns fall short of the initial estimations, it can lead to an increased financial burden.

4.1.3 Key Take-Outs

The field study, conducted in Voorburg, Netherlands, examined a residential property undergoing green retrofitting, revealing both sustainability measures and associated risks. The homeowner's primary objective was to increase comfort and align with national and European Union net-zero renovation standards. By adopting these measures, they aim to lower energy consumption, curb carbon emissions, and possibly generate a surplus for resale.

Sustainability Measures:-

- Energy Efficiency: Transition to underfloor heating and introduction of solar panels, though full energy substitution via solar remains questionable.
- Insulation and Reuse: Use of HR++ windows, insulation chips, and reused roof tiles, emphasizing energy efficiency and reduced carbon footprint.

Identified Risks:-

- Performance Risk: Uncertainties exist in the long-term efficiency of the new heating systems and solar panels.
- Supply Chain Risk: The energy crisis post-Ukraine-Russian war led to material shortages and project delays.
- Schedule Risk: Project delays emerged from over-optimistic estimates, advisor interventions, coordination challenges, unforeseen issues, and task dependencies.
- ROI Risk: The expected return on investment remains unpredictable due to energy price fluctuations and emerging technologies.

In essence, green retrofitting, while promising to achieve sustainability, brings forward real-world challenges. Comprehensive planning and proactive strategies are paramount for success.

5

Exploration Phase-Semi-Structured Interviews

In this chapter, section 5.1 introduces insights about semi-structured interviews, while Section 5.2 documents the discoveries made during these interviews. Concluding the chapter, Section 5.3 highlights the key takeaways derived from the findings.

5.1 Semi-Structured Interviews

The purpose of conducting semi-structured interviews is to gather insights on risk identification and assessment from professionals in the field of sustainable retrofitting within the built environment.

5.1.1 Selection of Interviewees and Their Background Information

To gather qualitative data for the research, interview professionals who have significant experience and knowledge in the field of sustainable construction were chosen. These experts hold roles such as project managers, energy transition and sustainability advisors, and senior consultants.

- Project managers are included because as discussed in earlier sections, managing risks is a crucial aspect of project management, which makes their views on the process of risk management prominent.
- Energy consultants and sustainability advisors are part of the interviewee group because of their specialized expertise in achieving sustainability and energy-related objectives while overcoming associated challenges. Their perspectives on how they happen within the built environment are important. Additionally, they are also part of the risk management team in the company.
- Senior consultants have also been selected because they play a pivotal role in shaping the future direction of projects, weighing the benefits against the drawbacks, and making strategic decisions. Their insights on the portfolio level are significant.

Interview invitations were sent to roughly 20 individuals from various companies in the building and construction sector. Among these, representatives from Royal Haskoning DHV, a major player in the construction and real estate industry, agreed to provide information. Subsequently, interviews were conducted with six professionals from Royal Haskoning DHV to collect the necessary data.

5.1.1.1 Royal Haskoning DHV Background

Royal HaskoningDHV is an independent, international engineering and project management consultancy with over 140 years of experience. Founded in the Netherlands, the company has grown into a global leader, providing solutions and services for various sectors, including aviation, buildings, energy, industry, infrastructure, maritime, mining, transportation, urban and rural planning, and water. Their deep-rooted commitment to enhancing society, combined with their vast expertise, positions them at the forefront of sustainable development, ensuring that their projects not only meet current needs but also benefit future generations.

The company's vision revolves around "enhancing society together." This motto reflects their belief in collaborative innovation, where they work alongside clients, stakeholders, and the wider public to deliver sustainable and innovative solutions to complex challenges. Royal Haskoning DHV's rich history and dedication to social and environmental responsibility have made them a trusted partner for both public and private sector clients worldwide. Their integrated approach and ability to adapt to the ever-evolving technological landscape underline their reputation as one of the leading engineering and project management consultancies globally.

5.1.1.2 Interviewee Professional Background

The details of the interviewees have been anonymized to respect their privacy, with pseudonyms assigned to simplify discussion and maintain confidentiality. The background information of the interviewees can be viewed in Table 5.1.

Interviewee's Name	Profession	Education Background
Kiara	Project Manager focusing on sustainability	M.S in Building Engineering
Dave	Project Manager& Sustainability Advisor	M.S. in Construction Management
John	Senior Project Manager	M.S in Project Management
Paul	Senior Project Consultant	M.S in Architecture
Leon	Sustainable Building Consultant	M.S in Building Physics and Services
Ryan	Sustainable Building Consultant	M.S in Mechanical Engineering

Table 5.1: Background information of interviewees

5.1.2 Interview Guide

An Interview guide consisting of 10 main questions, designed to align with the core purpose of our interviews is crafted. You can locate this interview guide in Appendix A. Additionally, Each interview question's intended objective is explained, for reference each question is given a title which can be cross-referenced in Appendix A.

1. Company Sustainable Goals: This question assists in pinpointing the primary sustainable objectives pursued by the company. It aids in anticipating the outcomes they aspire to achieve and reveals insights into their future aspirations. This, in turn, informs how they incorporate sustainable goals into their projects.

2. Definition of Sustainable Retrofit Building: This question aims to clarify the interviewee's definition of a "sustainable retrofit building" within the scope of their project involvement. It serves the purpose of establishing a shared understanding of the term and offers insights into the interviewee's viewpoint on sustainability within retrofit construction projects.

3. Green Retrofit vs. Conventional Buildings: This question aims to identify and understand the primary differences that the interviewee perceives in the domain of risk management between green retrofit buildings and conventional buildings.

4. RHDHV Risk Identification and Prioritization Process in green Retrofit Projects: This question is designed to have the interviewee provide a step-by-step explanation of the mandatory process Royal Haskoning DHV (RHDHV) follows to identify and prioritize risks in green retrofit projects.

5. Challenges and Common Risks in Identifying Risks for Green Retrofit Buildings: The objective of this question is to have the interviewee elaborate on the primary challenges they've faced when identifying risks unique to green retrofit buildings. Additionally, it aims to identify common risks encountered in the process.

6. RHDHV's Approach to Assessing and Mitigating Identified Risks: This question is intended to have the interviewee explain how Royal Haskoning DHV assesses and addresses the risks mentioned by the interviewer along with the risks in the question. It seeks to understand the company's strategies and methods for managing these risks in green retrofit projects.

7. Involvement of technology/tools: This question aims to inquire about the specific technology or tools like BIM employed by the interviewee or Royal Haskoning DHV to evaluate potential risks associated with green retrofit projects. It seeks insights into the risk assessment process used by the company.

8. Engagement of Stakeholders and Team Members in Sustainable Retrofit Risk Identification: This question aims to explore how both the interviewee and Royal Haskoning DHV engage stakeholders and team members in the risk identification process for green retrofit projects. Its purpose is to reveal effective collaborative approaches and methodologies that they have employed in the risk management process.

9. Enhancements for Effective Risk Identification and Management in Green Retrofit Projects: The goal of this question is to have the interviewee share their insights on potential improvements or refinements that they believe could elevate the effectiveness of risk identification and management in the context of green retrofit projects. It aims to gather suggestions for enhancing practices.

10. Additional Insights on Risk Management and Sustainable Goals in Green Retrofit Projects: This question serves to invite the interviewee to provide any additional thoughts, insights, or information they may have concerning risk management and sustainable objectives within green retrofit projects. Its objective is to encourage the interviewee to share any valuable perspectives or details that haven't been covered in previous questions.

5.1.3 Coding Framework for QCA

As discussed in Section 2.2.3, qualitative content analysis is the chosen research approach for subjectively interpreting textual data content. This method involves a systematic process of categorization and the identification of themes or patterns within the text(Hsieh & Shannon, 2005). To facilitate and support this process, software tools such as Atlas.ti and Otter.Ai are employed.
As mentioned in section 2.2, the six semi-structured interviews were conducted virtually on the Microsoft Teams analysis. These interviews were transcribed using Otter.ai software, notable for its ability to condense unnecessary data while effectively conveying the interviewer's perspective. The condensed data from Otter.ai is subsequently imported into Atlas.ti for further analysis, aiding in the generation of themes and narrative stories through quantitative data analysis. The procedure of quantitative data anlysis can be found in Figure 5.1.

In Atlas.ti, the interview transcripts are thoroughly reviewed. Relevant and significant data related to the research is identified, highlighted, and quoted within the software. Simultaneously, these quotations are associated with specific codes based on the concepts and areas they address. Creating the codes is a systematic, data-driven process guided by a subsumption strategy as outlined by Mayring and Fenzl(2014). This approach involves a meticulous examination of each quotation, following a series of defined steps. To begin, there is a careful reading of the quotations, during which they are summarized into core concepts or ideas. Subsequently, for each quotation, there is a check to determine if an existing code already encompasses its corresponding concept or idea. If such a code exists, the concept or idea is subsumed under that pre-existing code. However, if no suitable code is found, a new one is generated to encompass the concept or idea in question. This method continues iteratively until all the pertinent concepts and ideas within the data have been accounted for. It's a methodical process aimed at effectively categorizing and organizing the textual data for subsequent analysis and interpretation(Massaad, 2021).

From the six interview transcripts, a total of 54 quotations were generated. With the help of the interview guide, subsumption strategy and the context of the transcripts a total of 40 codes were generated in Atlas.ti. To make them concise and narrow down for ease of working based on the interview guide manually 10 code groups were generated i.e sustainability goals, green retrofit, type of retrofit, standard process, risk management-identification, risk management- assessing, challenges, key risks, technology/tools involvement, improvement of the process. Subsequently, the identified codes and quotations are utilized to derive and interpret the results, as detailed in Section 5.1.4.

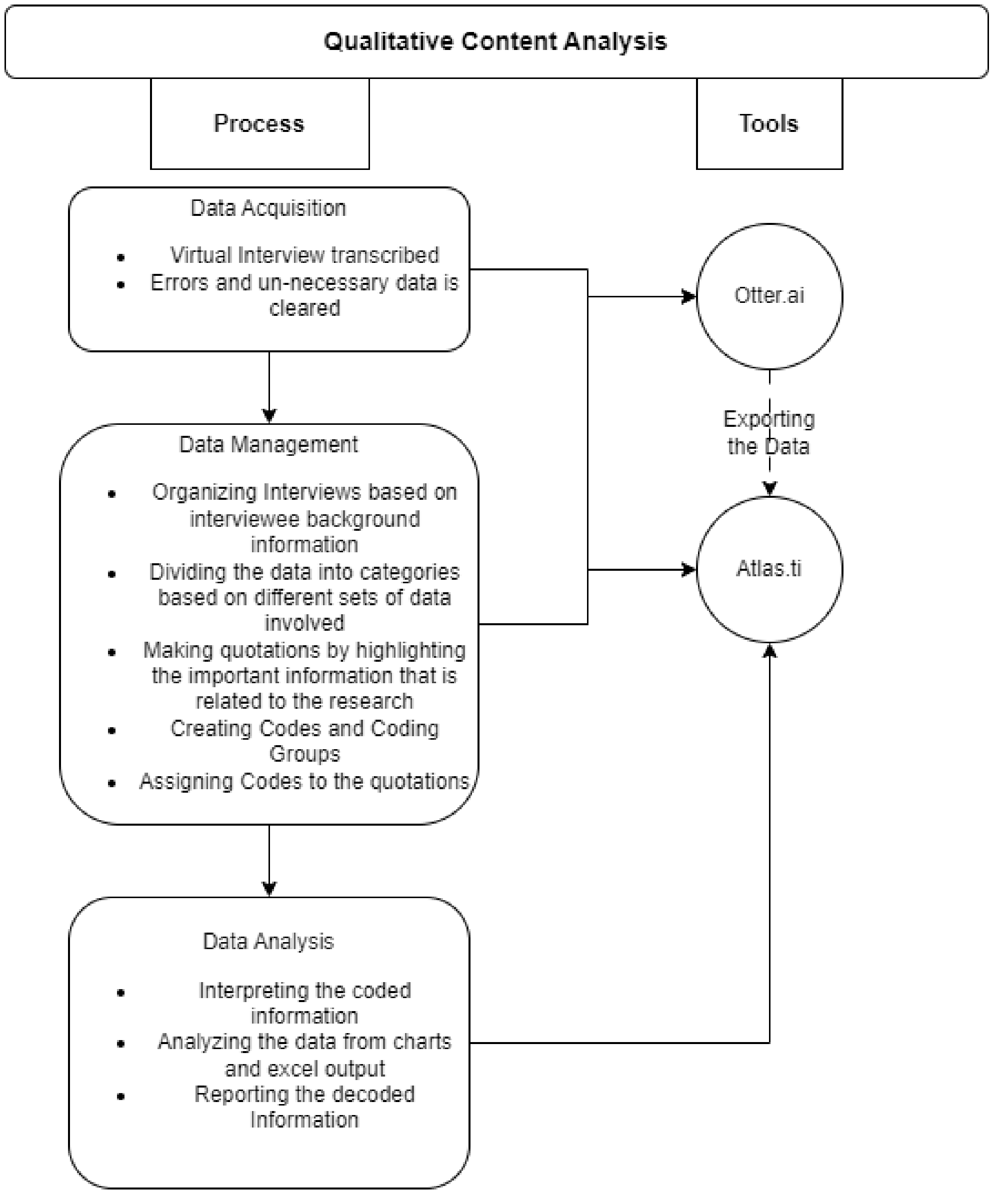

Figure 5.1: The procedure and tools used for Qualitative content analysis

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5.2 Exploratory Phase Findings

5.2.1 Sustainability Goals & Green Retrofit Projects

The Netherlands Government Sustainability Goals for constructed buildings The Netherlands government was one of the countries which have signed the Paris net-zero agreement. The objective of the agreement is to become completely net zero by the year 2050. To cope with this there is a renovation standard set up by Rijksdienst voor Ondernemend Nederland, a department within the government of the Netherlands. A renovation standard is a guideline for retrofitting buildings, which is currently a voluntary action for implementation till the year 2030, and it will be made compulsory post-year 2030 to meet the 2050 net-zero goals. In summary, the purpose of the renovation standard is to provide a preliminary framework before the mandatory final standard is implemented. If the building is to be made sustainable, it is necessary to follow this renovation standard, which contains few laws and regulations. These laws and regulations include (1)building decree which deals with multiple aspects of retrofitting like ventilation, airflow, energy performance and insulation. (2) Energy performance-NZEB which deals with making buildings nearly energy neutral.(3) Energy Label- which indicates the sustainability level of the building from G to A++++(G is the lowest sustainable rating and A++++ is the highest sustainable rating possible)(*Rijksdienst voor Ondernemend Nederland*, 2021).

Royal Haskoning Sustainable Goals

Royal Haskoning DHV takes responsibility for promoting a positive impact on the world and actively promotes the development of sustainable solutions to local and global challenges. The company demonstrates its commitment to ethical behaviour and transparency by adhering to strict environmental and social governance principles. Royal Haskoning for its projects uses a strategy called Stronger 25 which provides an overarching framework to guide teams towards more sustainable outcomes. It deals with 5 strategies:-

1. Climate Adaptation- Making buildings and infrastructure more resilient to climate change impacts
2. Resources and Circularity- Using materials efficiently and reducing embodied carbon through choices like reuse
3. Biodiversity- Adding green elements to buildings to support biodiversity
4. Social Equality- Ensuring projects consider social impacts
5. Wellbeing and Safety - Enhancing occupant health, comfort and user experience.

Figure 5.2: Challenge 25 strategy

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"These are five themes that integrate to develop a stronger 25 goal, which is that all our projects should demonstrate in some way or the other how we are contributing to these five topics."-

Kiara. These five themes further cover the UN sustainable development goals, which can be seen in Figure 5.2
In the context of environmental retrofitting, Royal Haskoning DHV aligns its sustainability principles and goals with the Dutch government's environmental and retrofitting goals. This alignment serves as a roadmap to achieve energy neutrality.

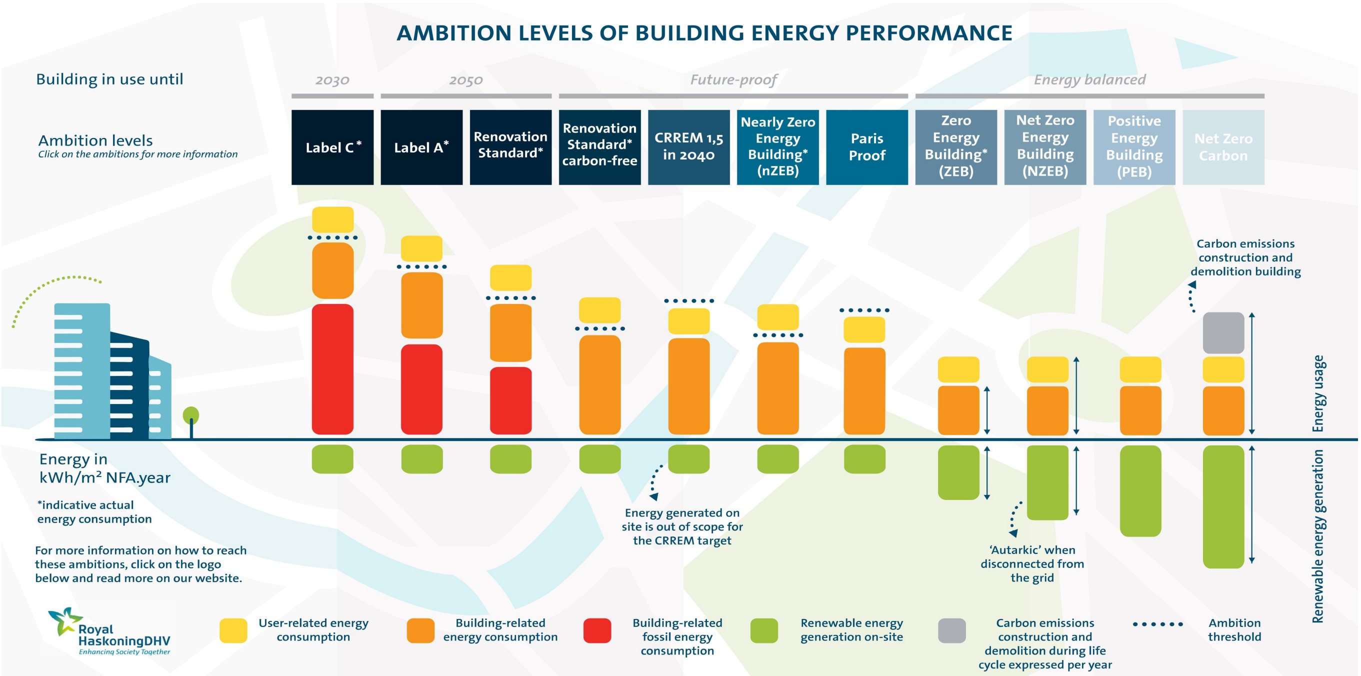

Figure 5.3: RHDHV-Dutch roadmap to energy neutrality

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5.2.2 Risk Management in Royal Haskoning DHV

Royal Haskoning DHV follows a basic risk management strategy from the PMBOK, which is the most common one among different sectors as shown in Figure 3.2 consists of risk planning, risk identification, risk analysis, risk response planning and risk monitoring and control added with a small framework consisting of four questions:-

1. Does the output meet the requirements of most stakeholders?
2. Does the output serve additional added value for the client and society as a whole?
3. Is the result lasting, is it future proof?
4. Can we meet the client's demand while using a minimum of natural resources and energy?

This risk management strategy, paired with these four impactful questions, serves as the foundation for all projects, as shown in Figure 5.5. Modifications are made in accordance with each project's objectives, rendering risk management tailored to the specific needs of each unique project.

In Royal Haskoning DHV risk management is mostly related to the project management department. In the case of innovative/unique projects, the specialised relevant departments will be involved in the risk management process. In sustainable projects, mainly green buildings, and green retrofit building, sustainable and strategic advisors are involved. The risk management process initiates a conversation between these two units, resulting in the determination of the particular risk approach for a given project. This selected approach is then refined through workshops and brainstorming sessions, which serve to pinpoint the essential risks to be managed during the project's execution.

Figure 5.4: Questions analysed by RHDHV during risk management
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Given that this thesis centres on risk identification and assessment in green retrofit projects, once the client approaches the company for retrofitting of his property during the operational phase, our primary emphasis will be on how Royal Haskoning approaches these two aspects.

5.2.3 Risk Identification

5.2.3.1 The First Approach

The first approach always starts with the client approaching the company. When a client approaches the company intending to implement green retrofitting in the operational phase of a building, the company needs to gain insights into the client's goals and the current status of the building. To gain details about the building RHDHV asks the client two main questions before taking up the project i.e. *(1)"What specific retrofit or sustainable goal the client is looking forward to? (2) "What is the present energy label of the building and what do they aim to achieve"*- John. The client details and project are recorded, and a team is assigned.

5.2.3.2 The On-Site Assessment

The subsequent stage entails an on-site assessment conducted by the RHDHV delegation, headed by a project manager and a specialist advisor. This process is critical for a detailed evaluation, enabling tailored strategic advice based on direct observations. The following activities take place during the on-site Assessment:-

- Meeting with the client:- Advisor meets the client to understand the scope of the project, previous incidents, and any specific concerns the client might have. This stage often involves gathering information about the past and present condition of the home.
- Visual Inspection:- The advisor conducts a thorough walk-through of the property. This visual inspection includes identifying potential environmental risks, such as areas prone to mould, lead, or asbestos, energy inefficiencies, water wastage points, and structural

problems that could affect the retrofitting process. Further, he explores the area to install the equipment which will help in converting to green retrofit.

- Review of Existing Documentation: If available, the advisor reviews documents related to the home's construction, maintenance records, and any previous retrofitting or renovations. Understanding the history of the building can provide insights into potential hidden risks.
- Compliance Check: The advisor assesses the current status of the home against existing legal and environmental regulations to identify non-compliance areas that need immediate attention.

5.2.3.3 Fast-lane method

Introduction

Once the data is collected a fast-lane method is employed. A fast-lane method is a structured strategy designed by RHDHV to create sustainability plans and solutions for real estate, ranging from single buildings to entire portfolios. It identifies the most economical sustainability actions and synchronizes them with maintenance schedules. By combining sustainability efforts with maintenance plans, activities are better coordinated. Furthermore, Fastlane's user-friendly dashboard(Figure 5.5) helps in decision-making by presenting detailed scenarios, enabling involved project stakeholders to visualize energy transitions, evaluate alternatives and build strategies.

Figure 5.5: Visualisation of Fastlane dashboard

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A tool for risk identification

The Fast-lane method is a very useful tool in the risk identification process, especially concerning energy transition, the adoption of renewable energy, and carbon emissions. Here's how:-

- **Data-Driven Insight**:- Fastlane's platform offers real-time energy data, showcasing current energy consumption patterns with potential scenarios. Such data-driven insights can highlight vulnerabilities, helping stakeholders identify risks related to energy consumption or inefficiencies.

- **Scenario Comparison**:- The platform allows for the comparison of different energy scenarios as seen in Figure 5.6. By analyzing the potential outcomes of various sustainability interventions, one can pinpoint risks related to high costs, low energy savings, or non-compliance with standards like the Paris proof.

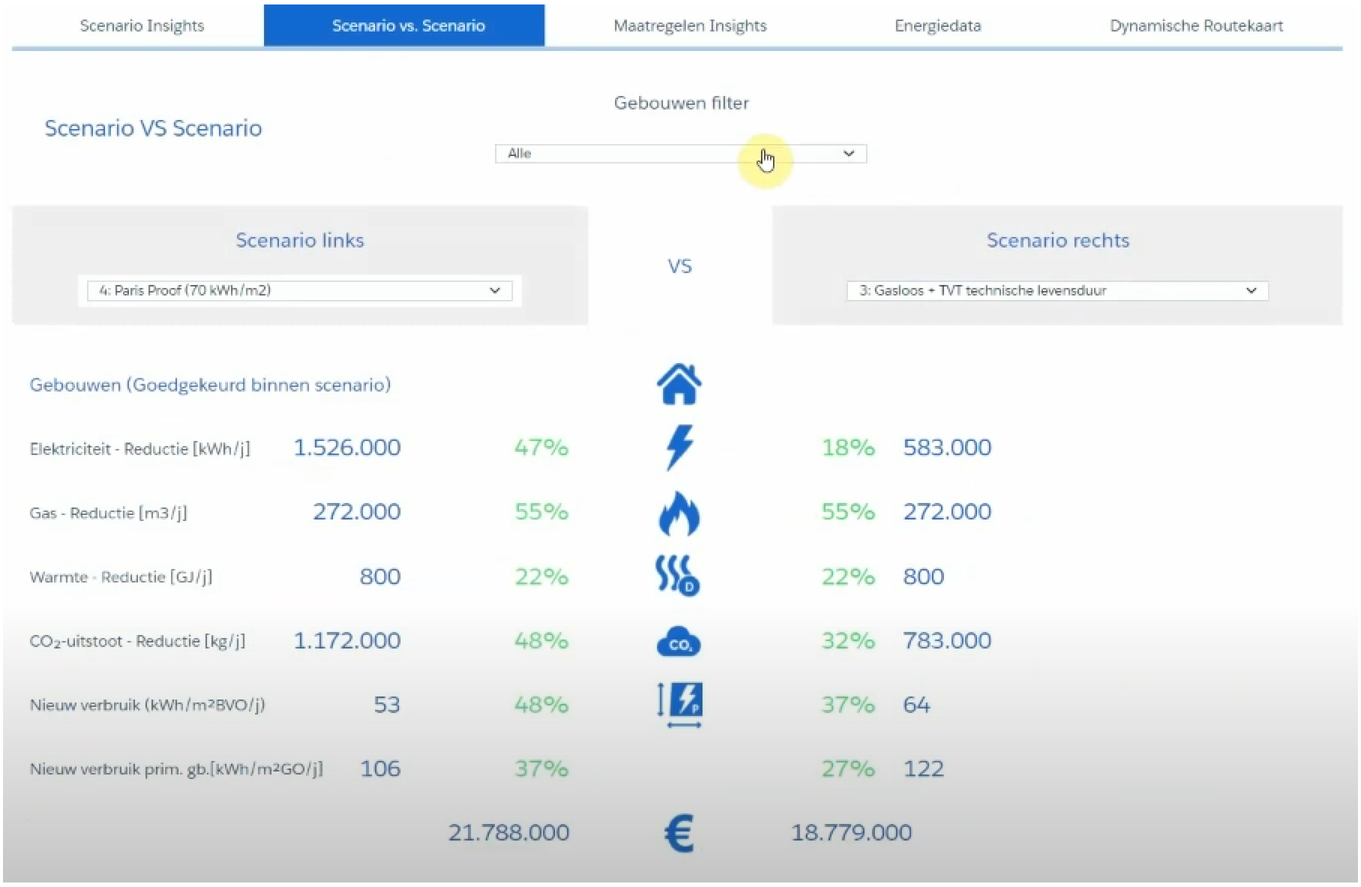

Figure 5.6: Visualisation of Fastlane dashboard scenario comparisons

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- **Measure Analysis**:- By detailing the effects of specific sustainability measures per building, stakeholders can identify which interventions might present more risks than benefits in terms of cost-effectiveness and carbon impact.

- **Dynamic Monitoring**:- *"In the fourth tab of the fast-lane dashboard, believe the energy data with smart meters through a software interface. This gives you insight into the energy items, the monthly consumption and energy consumption per hour."*-Kiara. The platform has the ability to provide real-time energy consumption data. This can reveal discrepancies between expected and actual energy, highlighting potential risks related to energy inefficiencies or underutilized renewable sources.

- **Flexibility and Control**:- Fast-lane's dynamic data flow facilitates timely adjustments at the building level. Such flexibility ensures that as external factors change or as new risks emerge, strategies can be realigned, ensuring optimal decisions in the evolving energy landscape.

Dynamic Road-Map

The Fastlane method's dynamic roadmap provides an evolving view of sustainability initiatives over time, emphasizing their impact on energy use and carbon decrease, which can be seen Figure 5.7. This systematic process plays a crucial role in identifying risks for several reasons.

By organizing sustainability actions over time, it's possible to foresee associated risks early on. From a regulatory perspective, knowing when buildings will achieve "Paris-proof" standards helps pinpoint compliance risks. The roadmap's adaptability also means it stays current, avoiding reliance on outdated approaches. Moreover, coordinating sustainability initiatives with other operations helps manage financial risks, keeping costs reasonable and within budget constraints. Importantly, a clear roadmap improves stakeholder communication, enhancing trust and teamwork, which are essential for successful risk management. In summary, this evolving roadmap is key in handling the intricacies of sustainability, providing clear guidance, and making risk identification and reduction more straightforward.

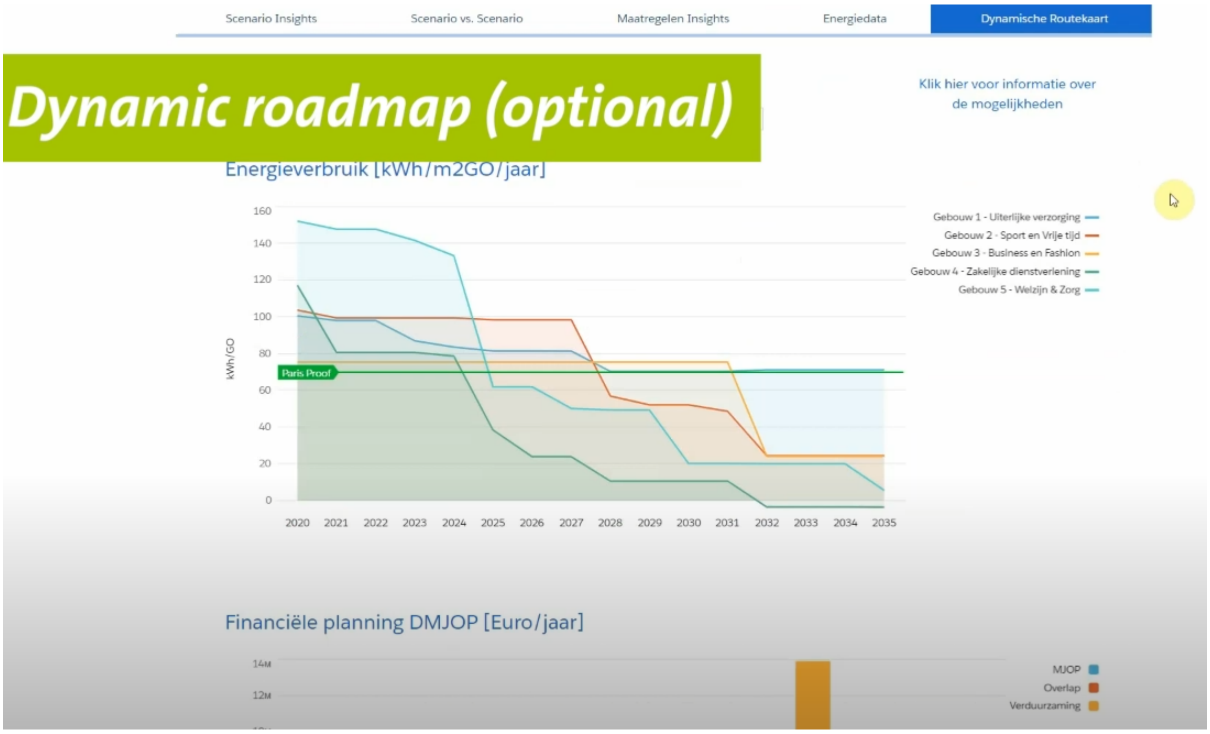

Figure 5.7: Visualisation of Fastlane dashboard-dynamic roadmap

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5.2.3.4 Determining the risks

After collecting data from the site and using the predictions from the Fastlane method, the project team engages in a comprehensive brainstorming session. Through in-depth analysis of the accumulated data, they identify and determine the risks associated with the project. The nature and severity of these risks dictate the involvement of senior management. Specifically, if the identified risks are deemed significant or of a specific nature, the Executive Board, Corporate Director of Project Excellence, Corporate Director of Legal, and the Risk Manager are brought into the decision-making process. In this way, Royal Haskoning DHV identifies its risks related to green retrofit projects.

5.2.3.5 Limitation

The risk identification techniques employed exhibit certain constraints, particularly with the fast lane method, which primarily focuses on energy efficiency forecasts. Its estimations related to carbon emissions show minor inaccuracies, and it lacks the capacity to encompass diverse retrofit measures. Although proficient in making predictions, the fast lane method faces challenges when future market prices fluctuate, resulting in data deficiencies. In cases of alternative green retrofits, RHDHV persists with physical site evaluations and brainstorming sessions.

Regarding enhancements in risk identification methods, three project managers advocated for an integrated approach to green retrofitting. This holistic strategy could facilitate comprehensive risk identification for various retrofit activities simultaneously.

5.2.4 Dealing with the Identified Risks

To explore Royal Haskoning DHV's risk-dealing response in green retrofitting, several risks were selected from literature reviews, field studies and interviews(Table 5.2). Recognizing the complexity of addressing all possible risks, the study concentrated on six notable and predominant risks. The selected six risks are:-

Table 5.2: Identified Risks from different Methodologies

Green Retrofit Risks	***Literature Study***	***Field Study***	) ***Semi-Structured Interviews***
Performance Risk	yes	yes	yes
Return of Investment	yes	yes	yes
Technical Risks			yes
Schedule Risks		yes	
Supply Chain and Market Risks		yes	
Regulatory Risks	yes		

Table 5.3: Action Response by Company

Green Retrofit Risks	***Deals With***	***Company's Response Action***
Performance Risks	New Equipment	Guarantee up to few years, later transferred to client
Return of Investment	Finance	Risk is completely transferred to client
Technical risks	Structure	Risk is completely borne by the company, the allotted expertise to the project takes care of this
schedule risks	Activities	Project team expertise and experience, still effect will be shown on the client
Supply Chain and Market risks	Material availability and property value	Volatile risk, the risk is shared by all the stakeholders equally.
Regulatory Risks	Legal rules & Regulations	Risk is taken by the company."We clearly define beforehand, if the government regulations are not met"- Dave

Table 5.3 highlights the risks and outlines how the company assess them, ensuring clarity and transparency for all stakeholders involved.
The Performance Risks are associated with new equipment installed in buildings either for heating systems or renewable energy. It also includes higher operating expenses. While the company provides a guarantee for these installations for a specified duration, this risk responsibility is eventually transferred to the client after a few years. Another important risk is the Return

of Investment. This Financial risk arises due to the unpredictability of returns, by the energy systems and the decrease of the property value is borne entirely by the client and the company is not responsible for this, even though they give you an estimation. Additionally, RHDHV addresses Technical Risks linked to the project. Such risks can include challenges ranging from engineering complexities to unanticipated structural alterations that might arise during the execution phase. recognizing these the company completely takes care of these risks, trusting its specialized experts to handle and mitigate any arising complexities during the green retrofitting projects. Over the project timelines, Schedule Risks come into play. Although the project team's expertise and experience play a crucial role in maintaining the schedule, any delays or hitches inevitably affect the client. Supply Chain and Market Risks encompass the uncertainties related to material availability and property value fluctuations. *"This risk is volatile you have to live with this, the client and company have to bear with the time"*-Kiara, highlighting the interconnected dependencies within the supply chain and market.
Lastly, the Regulatory Risks revolve around legal and regulatory compliance. RHDHV takes the lead in this aspect, ensuring all projects align with governmental regulations. A representative from the company, Dave, emphasizes their proactive approach by stating, *"We clearly define beforehand if the government regulations are not met,"* ensuring clarity and preemptive measures in their operations.

5.2.5 Additional Findings

5.2.5.1 Awareness and Usage of Technology and Tools

In the following section, the results are categorized according to the experience levels of the project managers. They are classified into two groups: young project managers and senior project managers, with the latter having over 14 years of professional experience, the comparison can be viewed in Table 5.4 .

When looking at risk management, young project managers and senior project managers handle risks and technology differently. There is a clear distinction between the approaches of young project managers and their senior counterparts, particularly concerning technology use and risk management. Young project managers seem to be more updated with new technology advancements. They are comfortable using various tools, whether it's the Fastlane method, dynamic mapping, or even advanced tools like BIM when the project needs it. They also keep track of risks by using risk registers, which helps them plan and tackle challenges better. Even though, they are familiar with the tools there is a hesitation to use them in the projects, by junior project managers, due to the impact of their senior hierarchy roles and lack of budget unless the clients specifically demand it.

In contrast, senior project managers tend to stick to what they know. They often prefer to work with their experience and are hesitant to try new tools and technology. Their hesitancy is further noticeable by the fact that some aren't even fully aware of the tools at their disposal. When it comes to risk management, their approach contrasts sharply. While junior project managers are ahead of the curve, in maintaining comprehensive risk registers, many senior managers perceive the concept of a risk register as nascent and still in the developing stage. Some even lack a formalized system or document for risk listing.

Table 5.4: Comparison of Young vs. Senior Project Managers

Criteria	Young Project Managers	Senior Project Managers
Technology Awareness	High	Limited
Tool Flexibility	Adaptable	Hesitant
Methodologies	Fastlane, Dynamic mapping	Traditional
Digital Tools	BIM usage	Rarely used
Risk Management	Active registers	Minimal registers
Approach	Proactive	Conservative

5.2.5.2 Awareness in client for green retrofitting

In recent years, there has been an increase in awareness among clients regarding the benefits of green retrofitting for buildings. This heightened interest can be attributed to several factors. Primarily, escalating electricity and gas bills have driven many to seek more energy-efficient solutions. Additionally, the government has introduced new renovation standards set to take effect by 2050. To incentivise homeowners, various subsidies are available to enhance the sustainability of residences, details of which can be found on www.rvo.nl. These subsidies often vary, taking into account the energy label rating of the house. However, it's important to mention that even though many clients are interested in sustainable retrofitting, the starting cost often holds them back. *"Many clients approach us for retrofitting to become sustainable. However, after hearing the quote, they often don't come back unless they have substantial funds or an understanding of the payback period. I truly believe that there should be greater awareness raised about the payback period".*-Kiara.

5.3 Key-Takeouts

Sustainability and Retrofitting Goals of NL & RHDHV:-

- The Netherlands aims to be net-zero by 2050, endorsing the renovation standard set by Rijksdienst voor Ondernemend Nederland. This standard will become mandatory after 2030.
- The renovation standard comprises regulations such as the building decree, energy performance-NZEB, and energy labeling, categorizing sustainability levels from G to A++++.
- Royal Haskoning DHV (RHDHV) aligns with the Netherlands government's goals, emphasizing environmental retrofitting to achieve energy neutrality. The company's commitment manifests through the "Stronger 25" strategy, encompassing climate adaptation, resource efficiency, biodiversity, social equality, and wellbeing and safety.

RHDHV Risk Management Approach RHDHV utilizes a PMBOK-informed strategy, integrating stakeholder needs and specialized departments for innovative projects, refined through workshops and brainstorming to identify pivotal risks.

Risk Identification:-
Client Initiation: The green retrofitting process commences with the client's approach to RHDHV, with queries regarding retrofit objectives and the existing energy label of the building. The company proceeds by documenting the details and designating a team.

On-Site Assessment: The RHDHV team conducts a detailed on-site assessment. This incorporates: Direct interaction with the client for a deeper understanding of project scope and history. Comprehensive visual inspection, spotlighting environmental risks and potential retrofitting challenges. Examination of available documentation related to the building's history. A check for current compliance with environmental and legal regulations.

Fast-lane Method: RHDHV employs the Fast-lane method, integrating real-time energy data and sustainability planning. The method enables:Real-time monitoring of energy consumption. Comparison of energy scenarios for assessing potential risks.

Using data from on-site assessments and Fast-lane predictions, the team undergoes intensive brainstorming to pinpoint potential risks. Significant risks necessitate involvement from senior management levels.

Selected Risks: The study recognizes six prominent risks: Performance Risk, Return of Investment, Technical Risks, Schedule risks, New Technology credibility Risk, Regulatory Risk.

RHDHV Risk Assessment: The company follows a structured approach to risk assessment, ensuring clear definitions of responsibility. Performance risks associated with new equipment are guaranteed for a set period but later transitioned to the client. Financial risks, such as Return of Investment, lie entirely with the client. Technical and regulatory risks, due to their complexities, are assumed by RHDHV.

Project Managers' Approach: Young project managers are tech-savvy, utilizing tools like the Fastlane method and BIM. They actively manage risks using risk registers. Senior managers, however, lean on traditional methods, with limited tech use and minimal risk registers.

Green Retrofitting Awareness: Rising energy costs and government renovation standards have boosted client interest in green retrofitting. Though government incentives are in place, the initial costs often dissuade clients. There's a call for greater awareness about the payback period in retrofitting projects.

6

Discussions and Interpretations

This chapter begins by restating the key findings from the previous chapters in Section 6.1. It then focuses on the interpretation of key findings in section 6.2. Subsequently, Section 6.3 and 6.4 proposes recommendations and a recommendation model respectively. Finally, the chapter concludes with a hypothetical discussion of implementing the recommendation model in a field study in Section 6.4.

6.1 Restatement of key findings

In this section, we will restate the key findings, for discussion purposes, which were found through the literature study, field study and semi-structured interviews to answer the main research question i.e. ***How do companies operating in the built environment (in the Netherlands) identify and deal with risks related to green retrofit buildings?***.

Literature Study:

- Green retrofit projects distinctly differ from new constructions.
- Retrofit decisions emerge in the operational phase, focusing on sustainability metrics such as energy efficiency and carbon reduction.
- Effective risk management is crucial for sustainable retrofit projects due to inherent challenges.
- Building Information Modeling (BIM) enhances risk management through data-driven decision-making.

Field Study:

- Sustainability measures in Voorburg include underfloor heating, solar panels, and efficient insulation methods.
- Risks identified encompass- performance uncertainties, supply chain disruptions, scheduling challenges, and unpredictable return on investment.

Semi-Structured Interview:

- The Netherlands targets net zero by 2050, with mandatory sustainability standards post-2030.

- Royal Haskoning DHV (RHDHV) aligns with national goals, emphasizing energy-neutral retrofitting.
- RHDHV employs a detailed risk identification process, including client initiation, on-site assessments, and the Fast-lane method.
- Prominent risks include performance, ROI, technical hurdles, and regulatory challenges.
- Young project managers at RHDHV utilize modern tools, while senior managers prefer traditional approaches.
- A heightened interest in green retrofitting is observed, but initial costs deter many clients, indicating a need for increased awareness of long-term benefits.

Table 5.2 indicates that Performance Risk, Return of Investment, and Technical Risks are the three risks that have been consistently identified across all three methodologies: Literature Study, Field Study, and Semi-Structured Interviews. These risks are common concerns in green retrofit projects, suggesting that they are well-established challenges in the field, recognized through various research methods. The uniform acknowledgement of these risks in multiple forms of study emphasizes the need for careful consideration and strategic planning in these areas when undertaking green retrofitting initiatives.

6.2 Interpretation of Findings

The research was initiated with an extensive review of literature, including books and articles, to understand and identify the risk identification and risk assessing part of the risk management process in green retrofit projects. It has been shown that upgrading older buildings is quite different from starting a new sustainable building project like a green building. This is because these old buildings, built with outdated methods and materials, are modernized halfway through their lifetime. The literature has also shown that there is no specific, universal way to manage the risk of green redevelopment projects; each type of project requires its own approach. Additionally, the research delved into the use of Building Information Modelling (BIM) as a tool to facilitate the green retrofit process and identify potential risks. Furthermore, the literature study provided some insights into the risks involved in green retrofit projects but was not related to the location of the project and detailed explanations were missing. Therefore, a field study was conducted to explore the specific risks and their reason for arising, which were not covered in the literature study.

The field study in Voorburg, Netherlands focused on a house being updated with green features. The homeowner's main goal was to make their house more eco-friendly, following European standards. They made changes like using special heating under the floor, putting solar panels on the roof, and using better insulating windows. However, there were some challenges and risks. The new heating and solar panels might not work as expected in the long run. The war between Ukraine and Russia caused a shortage of materials needed for the project, causing delays. Other delays happened because workers gave too positive time estimates, and tasks depended on each other. Additionally, there were challenges in coordinating between different workers. Lastly, it's uncertain if the homeowner will get back the money they invested in these changes within a short period. The identified challenges/risks are concisely written as Performance Risk, Supply Chain Risk, Schedule Risk and Return on Investment Risk. Now to answer the MRQ, which focuses on how companies in the built environment in the Netherlands identify and deal with risks in green retrofit projects an exploratory study in a semi-structured format was conducted.

The Netherlands plans to have no carbon footprint by 2050. To do this, they will follow a set of building and energy rules from the Rijksdienst voor Ondernemend Nederland, which will be a mandatory requirement from 2030. This includes a labelling system that shows how sustainable a building is, ranking from G to A++++. Royal Haskoning DHV (RHDHV), a built-environment company, supports this plan. They are focused on improving buildings to use less energy and have introduced the "Stronger 25" strategy. This strategy also looks at other areas like climate change, saving resources, nature, fairness, and safety. Further, RHDHV uses the PMBOK method for managing risks. The Risk identification process at RHDHV for green retrofitting starts when a client tells what they want for their building. The Company then checks the building, talks to the client, looks at the building's history through an on-site assessment and ensures it meets all rules. They use the Fast-lane method, which checks energy and reduction in carbon emissions used in a real-time dashboard and helps plan for sustainability. By checking the building and using Fast-lane data, they discuss and find out the main risks. Some of these main risks are about the building's performance, the money spent and earned, technical issues, timing, new technology, and legal rules, which very well match with the risks identified through the field study. RHDHV deals with these risks with a clear plan. If there's a problem with new equipment, they will handle it for an agreed-upon period of a few years, but then the client will be responsible. The client will also have to handle any risks related to finance. Later, the company will deal with the technical and legal risks because they are complicated and it's the company's responsibility. Additionally, there is a limitation to their risk identification technique specifically, the Fast-lane method used for risk identification in green retrofitting primarily focuses on predicting energy efficiency but falls short in accurately estimating carbon emissions and adapting to other retrofit measures. It also lacks foresight regarding future market price changes, leading to potential gaps in data. For more complex green retrofit scenarios, company relies on direct on-site assessments and brainstorming. Several project managers suggest adopting an integrated approach for a more effective and inclusive risk identification process across different retrofitting activities.

Further, during the semi-structured interviews, a couple of notable observations were made: The findings indicate a distinct difference in how young and senior project managers approach technology and risk management in projects. Young project managers are more familiar with the latest technological advancements and tools. However, their usage is often limited by budget constraints and senior management's influence. On the other hand, senior project managers tend to rely on their experience and are generally hesitant to adopt new technologies, with some even lacking awareness of available tools. Their approach to risk management is more conservative, often lacking comprehensive systems like risk registers. This contrast in methodologies and tool usage between the two groups reflects a broader need for balancing experience and innovation in projects. Additionally, the findings indicate the growing awareness among clients about the benefits of green retrofitting is noteworthy, driven by rising utility costs and government incentives. However, the initial costs of such retrofitting projects pose a significant barrier, underscoring the need for better client education on long-term financial benefits.

Based on the discoveries, recommendations for additional findings and a recommendation model for the main findings are formulated. This model suggests an enhanced approach, leveraging the current technological tools available in the market. The detailed proposal of this model is outlined in section 6.3.

6.3 Recommendations for Additional Findings

6.3.1 Awareness and Usage of Technology and Tools

Based on the interpretation in the previous section, we can say that balance and communication between the two generations of project managers are important. It is important to maintain equilibrium between experience and new knowledge. This can be done through:-

1. **Cross-Generational Knowledge Transfer Workshop**:- The primary goal of this workshop would be to facilitate knowledge sharing and collaboration between younger and senior project managers. This approach would leverage the diverse strengths and experiences of each group. To ensure the success of this program, it's crucial to set clear objectives. These include improving technology adoption among senior managers, who can greatly benefit from the fresh perspectives and tech-savvy approaches of their younger counterparts. Simultaneously, to enhance the leadership and strategic planning skills of younger managers by tapping into the wealth of experience and practical knowledge that senior managers possess.

2. **Customised Training**:- Design training sessions tailored to the specific needs of each group/project. For senior managers, focus on hands-on training in new technologies and tools(how it can ease their work, and starting from the bottom), while for younger managers, emphasize the development of soft skills and strategic thinking.

3. **Awards & Rewards**:- Encouraging the senior project managers by providing awards and rewards based on using the available resources and technology available within the company/market.

6.3.2 Awareness in Client on Green Retrofitting

The primary apprehension of clients in engaging with the company for green retrofitting stems from concerns related to the cost estimates provided. To mitigate this, it is important to focus on elevating their awareness and understanding of the benefits of green retrofits. The following strategies can be employed:

1. **Presentation of a Case Study Demonstrating Success:** A detailed presentation of a case study where green retrofitting was successfully implemented and yielded the anticipated results can serve as a motivational factor for clients. It offers tangible evidence of the advantages and feasibility of such projects.

2. **Addressing the Knowledge Deficit:** It is crucial to assess the client's existing understanding of green retrofitting, including its environmental and long-term financial benefits, at the outset of the interaction. Depending on their current level of awareness, this knowledge gap can be bridged through tailored educational initiatives such as seminars and distribution of informative materials.

6.4 Recommendation Model

The intention behind this model is not to overhaul existing project risk management practices. Instead, it presents a proposition for refining the current methods, enhancing their effectiveness without fundamentally altering their nature.

This model originates from a comprehensive literature review and semi-structured discussions conducted with RHDHV professionals. It materialized in response to the project managers' call for a more integrated strategy. The literature indicates that an integrated approach to green retrofitting is achievable through Building Information Modeling (BIM). Thus, aiming to enhance risk identification techniques using available market tools, this recommendation model is proposed.

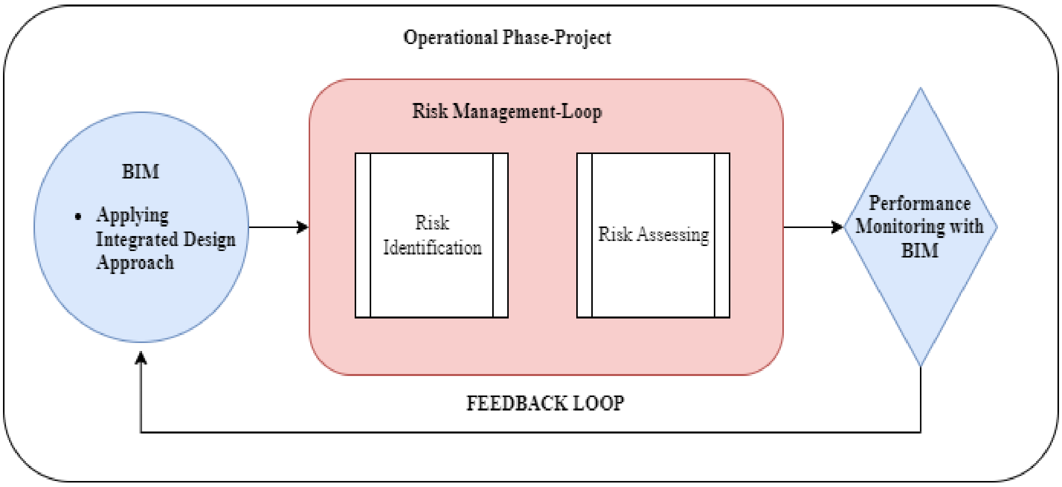

Figure 6.1: Recommendation Model

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This model in Figure 6.1 recommends to use of Building information technology(BIM), which has high capabilities to assess the data, as described in chapter 3. This model embraces the recommendation from RHDHV for an integrated methodology, a feat achievable through BIM. By employing BIM, risks can be more effectively identified and addressed. The model further advocates for the continual oversight of the project via BIM, enabling the exchange of real-time data and the identification of emerging risks due to shifting trends.
Moreover, by assimilating data from HVAC systems into the BIM model, stakeholders can oversee the performance of heating, ventilation, and air conditioning, ensuring efficient operation and swift resolution of any detected inefficiencies. BIM facilitates the creation of a building's digital twin, a comprehensive digital representation that emulates the building's every characteristic, system, and component. This virtual model can simulate the building's operation, offering updates in real-time as alterations occur. Further, the operational data from the retrofitted building can be re-integrated into the BIM model, promoting perpetual monitoring and recurrent enhancements. This feedback loop ensures the building's sustained efficiency and ecological sustainability throughout its lifespan(Joblot et al., 2017). Additionally, the model can help in categorizing the risks in either TECOP or PESTEL format for ease of risk assessment.

An integrated approach refers to the combination or coordination of different elements or components to work together in a unified manner. In the context of this model, with physical building processes to improve risk management performance(Chen, Lu, Peng, Rowlinson, & Huang, 2015). An example of BIM integrated design approach by (Chen et al., 2015)(2015) can be seen in Figure 6.2. This representation shows how various domains within a project can be interconnected through BIM. This methodology facilitates a comprehensive view, enabling diverse project aspects to be concurrently analyzed and managed within a singular platform. By centralizing information, BIM fosters a collaborative environment where data coherence and interdepartmental communication are streamlined, thereby optimizing decision-making processes and enhancing overall project efficiency.

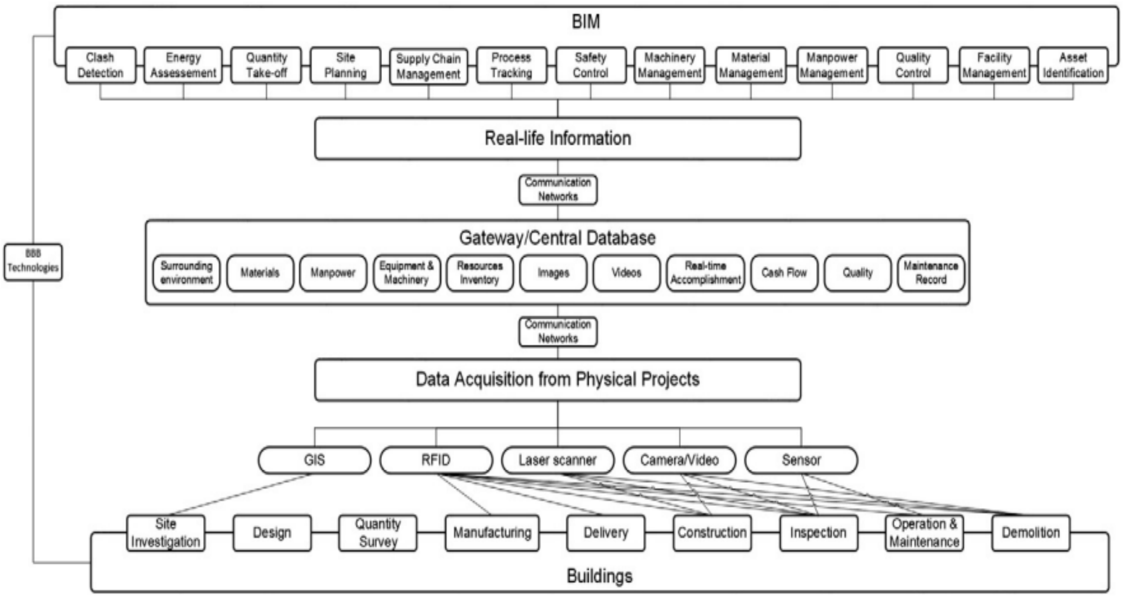

Figure 6.2: Example of BIM+Integrated approach

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6.4.1 Limitations

- High Initial Costs: BIM software and the necessary hardware can be quite expensive. This high initial cost can be a barrier, especially for small firms or projects with limited budgets.
- Interoperability Issues: BIM tools from different vendors may not be fully compatible with each other. This can lead to difficulties in collaboration when different stakeholders use different systems.
- Data Management: BIM creates and uses large amounts of data. Managing this data effectively requires robust IT infrastructure and can be complex, especially for larger projects.
- Resistance to Change: In some cases, there can be resistance to adopting BIM, particularly from those who are accustomed to traditional methods of design and construction. This cultural and behavioural barrier can hinder the full implementation and utilization of BIM.
- Dependence on Software Accuracy: The effectiveness of BIM is heavily reliant on the accuracy of the software used. Any errors in the software can lead to mistakes in the design or construction process

6.5 Recommendation Model in Field Study

"Better to have, and not need, than to need, and not have." — Franz Kafka

The aforementioned model presents both benefits and challenges. In the context of the field study, which focuses on an individual house, implementing BIM to mitigate risks could prove costly, particularly considering the homeowner's budget constraints. However, as the esteemed author Franz Kafka aptly put it, "Better to have, and not need, than to need, and not have."

This wisdom underscores the importance of being prepared, suggesting that it is more beneficial to possess resources even if they are not immediately used, rather than facing a situation where they are needed but unavailable. Therefore, despite the potential expense, equipping the homeowner with a BIM model is advisable, as it ensures readiness and mitigates future risks. To reduce costs, the homeowner can selectively apply Building Information Modeling (BIM) to specific areas of the home, aligning with their priorities. For instance, they might choose to focus on using BIM primarily for monitoring energy efficiency in HVAC systems and solar energy generation. Additionally, instead of investing in costly equipment like 3D scanners, the homeowner can opt for more economical and practical data collection methods, such as manual measurements or photography, to create the model. For energy analysis, cost-effective software options like EnergyPlus, eQUEST, or OpenStudio can be utilized in conjunction with RevitLT, enabling thorough yet budget-friendly energy simulations(Khaddaj & Srour, 2016).

This section tries to explain how the recommendation model can impact the risk found in the field study conducted at a residential space in Voorburg if applied, with hypothetical explanations, based on the knowledge gained from the literature study and findings from semi-structured interviews. For a full breakdown of each identified risk, please see Chapter 4. The risks discovered through our field study include:-

Performance Risk:- The implementation of BIM in the Voorburg house project allows for an elaborate digital twin to be constructed, which aids in the performance modelling of the house's new installations like heating systems and solar panels. BIM's predictive capabilities enable stakeholders to assess if the heating system will sufficiently warm the house and if the solar panels will produce the necessary electricity. While this forecasting is invaluable, the associated costs can be prohibitive, requiring a judicious assessment to ensure that the benefits justify the investment.

Supply Chain Risk and Schedule Risk:- BIM's ability to consolidate materials for batched orders from multiple projects can create efficiencies and provide leverage during supplier negotiations. The system's feedback loops can suggest alternative materials based on historical performance data, helping to mitigate risks of delays or unavailability. Enhancing the management of retrofitting projects, BIM improves the accuracy of time estimates and facilitates virtual inspections, which is particularly beneficial in a multidisciplinary setting and can reduce the delays caused by regular advisor visits. It enables better coordination among various subcontractors, such as electricians, plumbers, and HVAC specialists, by offering a unified management system. This not only streamlines the workflow but also promotes the timely execution of interdependent tasks.

ROI Risk:- BIM technology offers a multifaceted approach to managing the uncertainties impacting the return on investment (ROI) in the Voorburg project. By conducting energy simulations, BIM aids in predicting how fluctuations in energy prices could affect outcomes, while its real-time monitoring confirms if energy savings meet the expectations of the owner. When it comes to rapidly evolving technology, BIM ensures the building's adaptability by assessing the compatibility of new advancements and benchmarking performance, helping determine the economic sense of potential upgrades. Overall, BIM's continuous feedback and monitoring mechanisms allow for swift responses to any deviations, optimizing returns in the dynamic landscape of green retrofitting.

As previously mentioned, these are hypothetical assumptions based on the advantages of BIM as documented in the literature and various case studies. It is important to consider that disadvantages and limitations invariably accompany advantages. Researching the implementation of a cost-effective BIM solution could itself be a significant topic for future studies.

7

Limitations, Conclusions and Recommendations

This chapter begins by discussing the research limitations in section 7.1 . It then focuses on concluding the research by answering the research questions in section 7.2. Finally, the chapter concludes with views on future research recommendations in section 7.3.

7.1 Research Limitations

This research is an exploratory study conducted to find out risk identification and risk dealing processes by the companies in the built environment. This study comes with quite a few limitations.

- This study was confined to the context of the Netherlands, with insights drawn exclusively from interviews with personnel at Royal Haskoning DHV. The perspectives gathered, therefore, represent a single company's experiences within the Dutch market. Expanding the interview scope to include professionals from various companies both within and beyond the Netherlands could unveil diverse methodologies and insights, potentially altering the findings and recommendations of this study. It is important to acknowledge that the perspectives on green retrofitting may vary widely, even among employees within the same firm.

- The fast-lane method and the recommendation model haven't been used in real-life green retrofitting projects yet, so we don't know for sure how well they work. We have only checked how they might work based on what we learned from research and interviews. This means we cannot say these methods will work perfectly everywhere else, especially in different companies, without doing some actual tests in the real world.

- The study focused on just one residential building. If looked at several different buildings, different results might have been found.

- The recommendation model was not implemented within the company itself. There is a possibility that similar models might have been used by different companies in other areas for their projects.

- The model is made considering the optimistic characteristics of BIM.

- The 'What if' section (Section 6.5) where the recommendation model is applied in field study, is completely hypothetical and cannot be used for real-life scenarios.

7.2 Conclusions

This study is focused on exploring the risk identification and dealing, that the built environment companies in the Netherlands follow, with the research objective aiming to investigate risk identification practices in green retrofit projects, understand risk management in the built environment, especially post-decision for green retrofitting, explore gaps in theory and practice of green retrofit risk management, offer insights for improved strategies, and enhance the success and sustainability of green retrofit initiatives. To achieve the research objective, the following research question was formulated
How do companies operating in the built environment (in the Netherlands) identify and deal with risks related to green retrofit buildings?
To answer this main research question two sub-research questions were developed, to make the path to the MRQ easier

SQ 1: How are green retrofit buildings different from conventional green buildings?

Green retrofit building is a type of sustainable construction, retrofit means changes made to single or multiple components of a building. Green retrofit is done to existing buildings, to make them sustainable and reduce their negative impact on the environment by reducing energy consumption, and carbon emissions, increasing indoor lighting, extending the lifetime of the building etc. This is opposed to the concept of a Green building. Green building is a new construction, It is conceptualized and designed from the outset to be environmentally friendly and energy efficient and comes to the scene during the project initiation phase. Every aspect of green building, from site selection to material procurement, is executed with sustainability in mind. Whereas, a green retrofit comes to the scene during the operational phase of the project when the owner makes the decision to retrofit, by recognizing the environmental and financial benefits. This main difference can be seen in Figure 7.1.

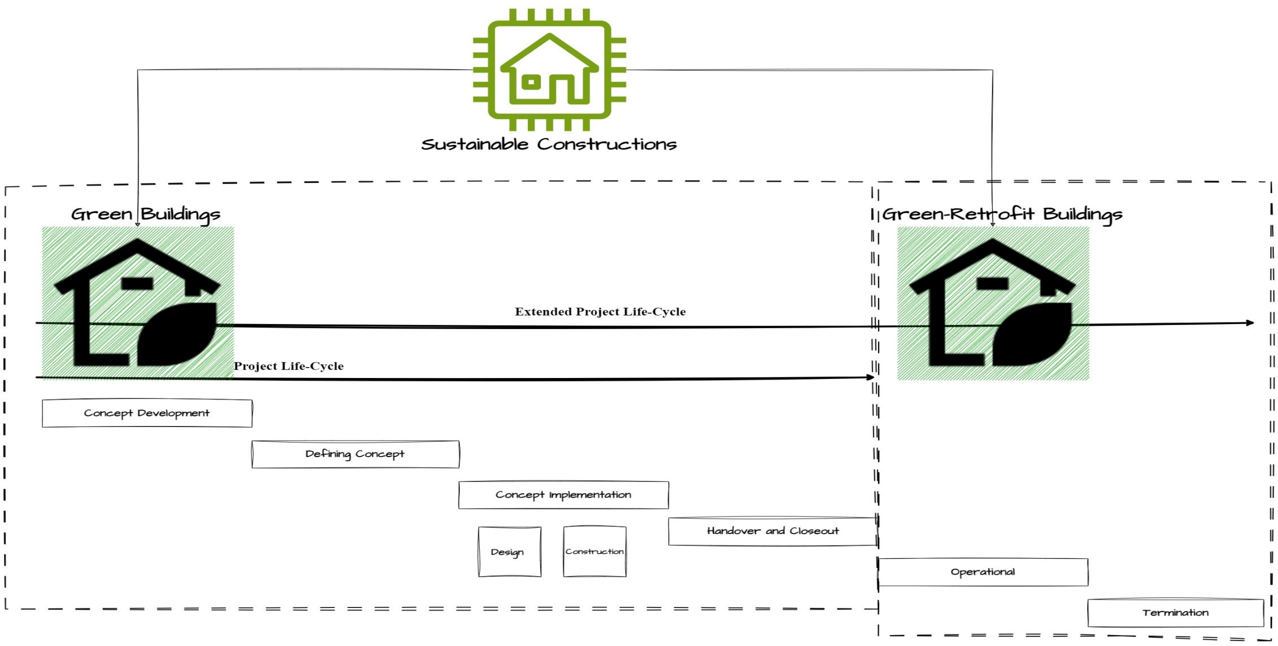

Figure 7.1: Sustainable Constructions - Life Cycle

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SQ 2: What are the common risks associated with green retrofit buildings?

There are many risks for the green retrofit building based on its goal, but after a field study, literature study and semi-structured interviews, the most common risks identified were Performance Risks, Payback(ROI) risks, Technical risks, Schedule risks, Supply chain risks and Regulatory risks.

- Performance Risks: These are related to the HVAC and solar energy systems, focusing on the reliability of these systems versus the expected outcomes. They address the concern of whether the installed systems will function as efficiently as anticipated.
- Payback (ROI) Risks: These risks involve the financial returns on the investments made for the green retrofitting of the building, focusing on whether the money spent will be justified by the benefits gained, both in terms of efficiency and property value.
- Technical Risks: These are associated with the challenges arising from the building structure's specific components, complicating HVAC systems' installation and the overall retrofitting process. They revolve around issues that might occur due to the existing technical constraints within the building.
- Schedule Risks: These concerns are tied to potential delays in the retrofitting construction timeline, where various factors could disrupt the adherence to the planned schedule.
- Supply Chain Risks: These risks pertain to potential disruptions in obtaining necessary materials and systems for retrofitting, often caused by unpredictable external events such as pandemics, wars, or other crises.
- Regulatory Risks: These risks revolve around the challenge of complying with governmental rules and regulations while balancing retrofitting tasks and budget constraints. They represent the difficulties encountered in navigating and adhering to mandatory standards and directives during the retrofitting process.

MRQ: ***How do companies operating in the built environment (in the Netherlands) identify and deal with risks related to green retrofit buildings?***
To answer this research question, A company called Royal Haskoning DHV was selected, and the question was applied to them, through semi-structured interviews. The question will be answered in two parts, with the first two paragraphs focusing on risk identification and the latter one dealing with the risks.

Royal Haskoning DHV (RHDHV) begins its risk identification by directly engaging with clients about their green retrofitting needs. Initial conversations focus on discerning the client's retrofit objectives and understanding the current versus desired energy status of the building. This foundational stage is pivotal for framing the project's scope and guiding the ensuing assessments. The firm then progresses to an on-site evaluation, conducted by expert teams, encompassing client interactions, detailed visual inspections of potential environmental hazards, historical document reviews, and rigorous compliance checks against existing legal standards.

In enhancing this assessment, RHDHV utilizes the Fast-lane method, an exclusive instrument that integrates sustainability considerations into maintenance planning, supported by an interactive, easily navigable dashboard. This platform provides real-time energy data, scenario comparisons, and continuous monitoring to spotlight potential risks. This method can only be used for energy and carbon-related retrofits. The project team analyzes data from the site and the Fast-lane method during a brainstorming session to identify project-related risks. Significant risks prompt the involvement of senior management. The Executive Board and the Risk Manager play key roles in the subsequent decision-making. Further, RHDHV acknowledges the limitations of the Fast-lane method, including inaccuracies in carbon emission predictions, limited to certain retrofits and sensitivity to market price changes. For other type of retrofits which does not include energy efficiency and carbon emissions, they prioritize on-site assessments and collaborative brainstorming.

To understand how Royal Haskoning addresses common risks in green retrofitting, six specific risks were highlighted and discussed: Performance, Return on Investment (ROI), Technical, Schedule, Supply Chain and Market, and Regulatory Risks. RHDHV secures warranties for new installations, although these assurances are passed to the clients after an agreed period of several years. Clients carry the financial uncertainties linked to ROI, whereas RHDHV takes on the technical risks, deploying their specialized units to address potential complications. Schedule risks, often dependent on the collective experience of the project unit, may affect clients if timelines are extended. Risks related to market and supply chains, marked by variations in material accessibility and real estate values, are mutual concerns among all participants. Upholding their dedication to legal adherence, RHDHV actively guarantees all undertakings meet legislative standards, assuming a central role in navigating regulatory risks.

In Conclusion, Royal Haskoning DHV applies a three-fold approach to most of the green retrofitting projects, initiating comprehensive client consultations and on-site evaluations, augmented by their Fast-lane method for precise risk identification. Further, RHDHV adopts a structured approach to managing green retrofitting risks, assigning clear responsibilities for varied risks between the company and the client. By providing guarantees, expert intervention, and proactive regulatory compliance measures, they ensure transparency and clarity for all stakeholders involved.

7.3 Recommendations for Future Research

- The scope of this research is limited to the identification and assessing phase of risk management. It does not encompass the subsequent stages of evaluation, prioritization, or ongoing risk monitoring. For a more comprehensive understanding, future studies should have a broader scope to investigate the various methods and tools that companies utilize in managing risks throughout green retrofit projects.
- A study into the perspectives and feedback of clients, suppliers, and other stakeholders involved can provide richer insights into the real-world implications of the identified risks and the effectiveness of the mitigation strategies employed.
- Future research should have an expanded scope by exploring and comparing the various strategies employed by multiple companies in risk management within green retrofitting projects. Such a comparative analysis would provide deeper insights into industry standards and innovative practices, potentially identifying more effective risk management techniques.
- While this study touched upon performance risks associated with new equipment, which is a broad topic, research on the long-term performance, maintenance challenges, and associated costs of these green retrofit solutions would offer valuable insights.
- Further Study could include narrowing down the scope of retrofit. For example, concentrating on risk management strategies related to carbon reduction retrofitting could yield more detailed insights and refined methodologies.
- Future Research could be done on exploring how the technology and tools available in the market will help risk management in green retrofit projects along with studies onhow BIM can be made suitable by overcoming the limitations mentioned in this study can be made.

8
Self Reflection

Doing this master thesis, was a roller coaster ride for me. It was exciting yet thrilling. Firstly, I am very happy that I was able to work on a topic that I really love. After taking the course Materials and Ecological Engineering, I was curious about how old buildings will be made sustainable and net zero to meet the 2050 Paris Agreement. That was the starting point for the formulation of the topic. I was further curious about the risk management process in green retrofit projects, as risk management is one of the most challenging parts of project management.

By working on this topic, I have gained abundant knowledge of green retrofit projects and risk management and BIM, through literature study and interviewing people. Additionally, I was fortunate enough to conduct a field study to identify the risks and retrofitting process at the ground level. Which helped me to gather quality data for my thesis.

Similar to the thesis topic about the identification of risks, during these few months, I have identified/discovered a few strengths and qualities. I will mention a few here:-

- I was unable to perform this thesis in a company which pushed me through a state of anxiety. But that did not stop me from working on my thesis topic, with proper research and with the help of the professors, I was able to work. There is a famous saying "where there is a will, there is a way". Through this journey, I learned to not give up in any circumstance.

- I became a lot more independent during the thesis, which even brought about a change in my personal life. My previous assignments and subjects were done in groups, and I always used to study with my friends. However, during the initiation of the thesis, I was very scared that I had to work alone. I was unsure of how to proceed if there was something I didn't understand. But, by being independent, I was able to take charge of my own decisions. Now, I feel more confident in my ability to work on my own, and I believe this will serve me well in my future endeavours.

However, it's important to acknowledge that my path was not without its share of drawbacks. The main drawbacks were: 1. Research Limitations: It would have been better if case studies related to companies were part of the thesis for more accurate data and project-wise evaluation. 2. Time Constraint: If there had been more time, the risk identification process of multiple companies could have been identified, which would have been very helpful in comparing the data of multiple companies in the Netherlands. Which would eventually have given the thesis better value

Finally, I can say one thing every task has its set of drawbacks, but this master thesis for me, ***is a journey of knowledge and self-development.***

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Appendix A

Interviewee: Name
Date: dd/08/2023

Profile questions:

No.	Question
1	What is your background and your current role in RHDHV?
2	How many years of experience do you have with retrofitting of buildings?

Main questions:

No.	Question
1	What are the sustainable goals of Royal Haskoning DHV?
2	How do you define a ”sustainable retrofit building” in the context of your projects?
3	What are the differences you mainly identify in risk management of green retrofit buildings when compared to conventional buildings.
4	Can you walk me through the compulsory process your (RHDHV) company follows to identify and prioritize risks in a sustainable retrofit project?
5	Could you please elaborate on the main challenges you've encountered when identifying risks specific to sustainable retrofit buildings and mention the risks that are commonly identified?
6	I will mention few risks Supply Chain risks, Performance risk, Schedule risks, ROI risk. These along with the ones you mentioned previously, how does Royal Haskoning DHV deal with them?
7	Do you use technology/tools like BIM in either risk identification process or risk mitigation process?
8	How do you involve stakeholders and team members in the risk identification process for sustainable retrofit projects?
9	What improvements or refinements do you believe could enhance the effectiveness of risk identification and management in green retrofit projects?
10	Is there anything else you would like to add or any insights you would like to share regarding the risk management or sustainable goals in green retrofit projects?

Appendix B

Table 8.1: Enhanced Key Points for Kiara, Dave & Leon

Interview Candidates: Kiara, Dave & Leon	
Aspect	**Key Points Noted**
Approach	On-Site Approach, Risk Management Approach
Methodology	Risk Identification, Fast-Lane Method, Dynamic RoadMap
Documentation	Dashboard Explanation, Limitations of Risk Identification Method
Improvement	Scope for Improvement
Risks	Risks Involved

Table 8.2: Enhanced Key Points for John & Paul

Interview Candidates: John & Paul	
Aspect	**Key Points Noted**
Process	Four Questions in Risk Management Process
Knowledge Gaps	Less knowledge on risk register, Less knowledge on resources available in company
Risks	Risks Involved, Technical Risks
Experience	Abundance of Experience

Table 8.3: Enhanced Key Points for Ryan

Interview Candidate: Ryan	
Aspect	**Key Points Noted**
Green Retrofit	Knowledge on green retrofit, Importance of green retrofit
Client Interaction	Awareness in clients, Reasons for clients not coming back

Appendix C

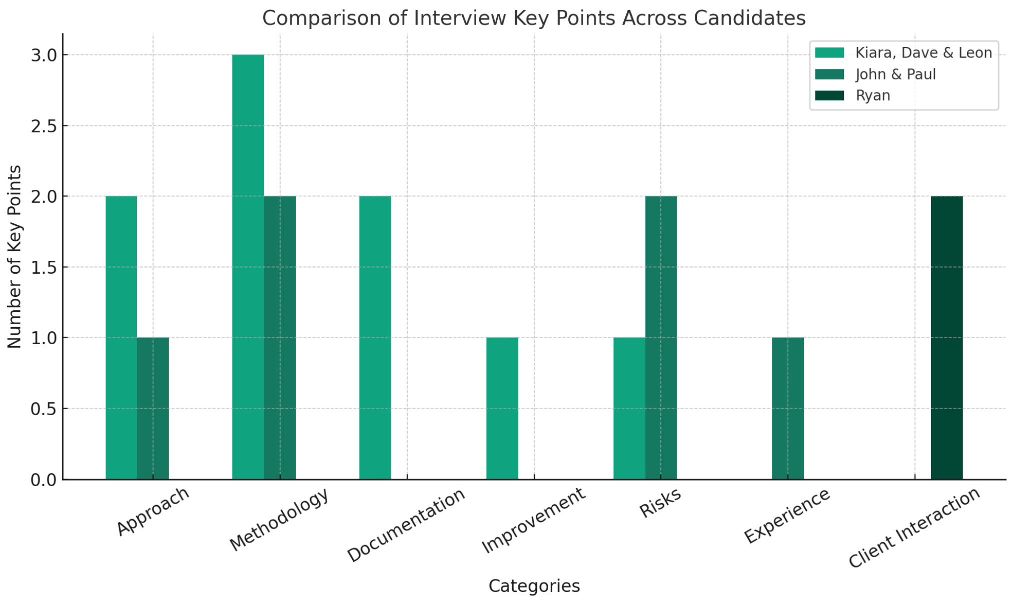

Figure 8.1: Comparison of Interview Key Points Across Candidates

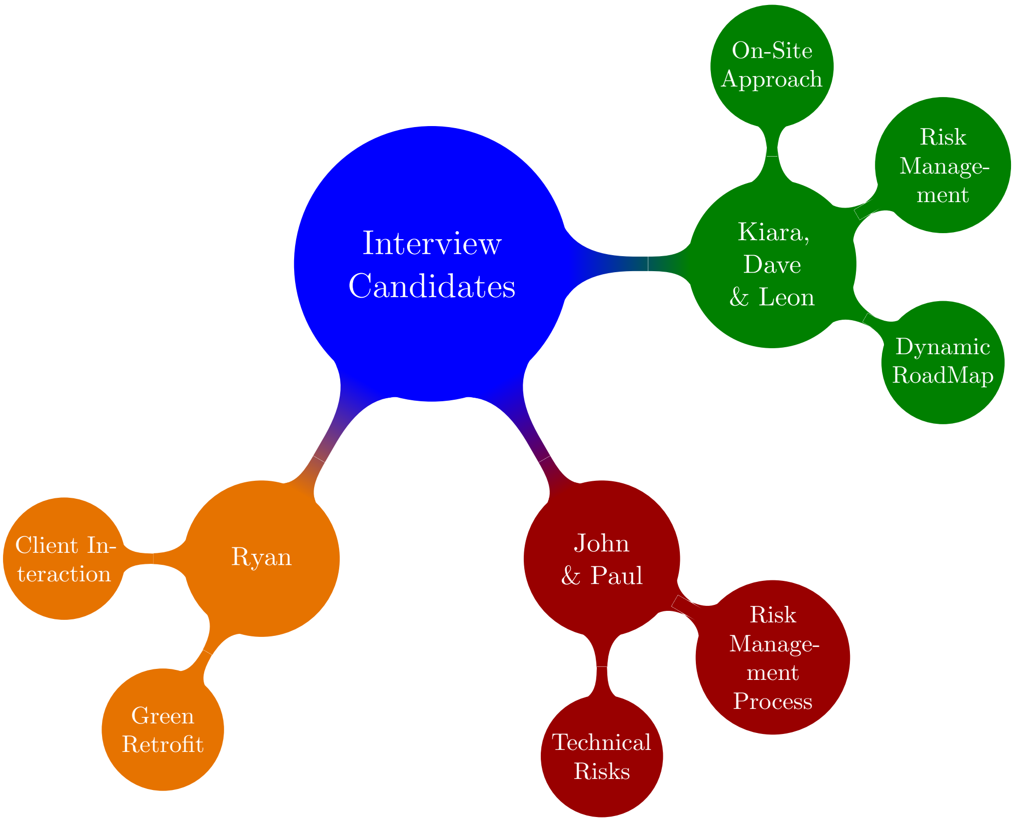

Figure 8.2: Conceptual Map of Key Points from Interview Candidates