

AI enhancing knowledge exchange about university buildings

Exploratory research on how Artificial Intelligence (AI) can be utilized to enhance knowledge exchange about university real estate buildings



Colophon

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Abstract

Efficient knowledge exchange is important for organizational success, especially in the multifaceted real estate industry. As the industry navigates rapid changes, complexity, and diverse stakeholders, the ability to share information, expertise, and insights is crucial. When managing big real estate portfolios, in the case of universities, the exchange of knowledge about real estate can play a beneficial role for the management of the buildings. However, barriers such as the lack of shared databases and repositories, inconsistencies in knowledge sharing tools, and limited technological utilization hinder the effective exchange of knowledge and collaboration between universities. Existing literature recognizes the potential benefits of AI in everyday use and the importance of tools in overcoming challenges regarding knowledge exchange. But the optimal contribution of AI remains an area requiring further research. Therefore, this research explores how Artificial Intelligence, through the creation of a project database and Tailored GPT model, can address these barriers and enhance knowledge exchange about university real estate buildings.

This research aims to address this gap by exploring the effectiveness of AI enhancing knowledge exchange about university buildings. Drawing on theoretical frameworks and empirical evidence, the research seeks to investigate how a knowledge database can be created for university real estate with the help of AI. Therefore, the goal of this research is how the exchange of knowledge between Dutch universities can be enhanced by the quick and effortless creation of a centralized AI-driven knowledge database for university real estate projects. The research uses a mixed-method approach, combining qualitative and quantitative analyses. The quantitative method involves the theoretical background and creation of the knowledge database using four steps: finding, collecting, creating an overview, and analyzing and identifying. The qualitative method involves interviews with campus managers, in which the created knowledge database will be explained and in which the campus managers can give their feedback. In the synthesis, the results from the theoretical and empirical research will be demonstrated in an expert panel. In the expert panel the project database is evaluated and the Tailored GPT is tested by people working in campus management to get a final understanding on how the database and GPT can be further improved. Resulting in a database and GPT model that can be used by people working in campus management as a stepping stool for the enhancement of the exchange of knowledge.

Keywords: knowledge exchange, Artificial Intelligence (AI), university real estate, barriers, drivers, project database, Tailored GPT

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INTRODUCTION



1. Introduction

The university campus is rapidly evolving, driven by technological advancements, an aging portfolio of buildings, higher user demands, scarce resources, less predictable student intake, and the university ambitions to attract, retain, and optimally facilitate top talent (Den Heijer, 2011; Den Heijer et al., 2016). In their efforts to provide an optimal learning environment and meet the diverse needs of the users, campus managers recognize the importance of well-designed and sustainable real estate (Den Heijer, 2011). Therefore, campus managers are faced with the challenging task of ensuring that their campus aligns with modern educational goals and environmental standards.

Den Heijer (2011) states that campus managers increasingly acknowledge that campus decisions can both positively and negatively affect the organizational performance. According to Argote & Ingram (2000), the ability to efficiently exchange knowledge is an important factor determining the organizational performance. Therefore, the utilization of the rich body of knowledge derived from university projects can facilitate the alignment of the campus with the contemporary educational goals and sustainability standards to reach successful campus management. Given the complex and challenging nature of campus management, characterized by the many stakeholders, opportunities, and threats (Den Heijer, 2011), the ability to share information, expertise, and insights, is vital for organizational performance. Regardless of whether they operate in the public or corporate sector, organizations that manage real estate are confronted with a multitude of challenges that necessitate the seamless sharing of knowledge, information, insights, and expertise. Since universities do strive for collaboration and knowledge exchange to ensure effective campus management (Den Heijer, 2011; Den Heijer et al., 2016), an improved exchange of knowledge could enhance their performance of campuses and could support campus decision-making.

Artificial Intelligence (AI) has emerged as a transformative force across multiple industries, including the real estate industry, but also in everyday use, such as with ChatGPT, face recognition, chatbots, and virtual assistant like Siri and Alexa. In the future, AI is expected to start providing services like fast and accurate medical diagnoses, self-driving cars, human like robots, and much more (Ministerie van Economische Zaken, 2022). Artificial Intelligence is the science and engineering of making intelligent machines, algorithms, and computer programs, that perform tasks that were thought to require human intelligence (McCarthy, 2004; Ministerie van Economische Zaken, 2022). AI has shown considerable potential addressing challenges associated with knowledge management and exchange (Liebowitz, 2001). In the context of the real estate industry, AI has the potential to streamline the collection and analysis of data and knowledge. Therefore, the question arises if AI can be utilized to enhance the knowledge exchange in university real estate development. By leveraging AI, campus managers may be able to overcome knowledge exchange barriers, such as a lack of shared databases and

repositories, difference in tools, communication barriers, and information overload, thus enabling more effective collaboration, performance, innovation, and decision-making (Argote & Ingram, 2000; Bektas et al., 2015; Birdi et al., 2020; Milagres & Burcharth, 2018; Rego et al., 2020; Tzavides et al., 2020).

However, the optimal utilization of AI to enhance knowledge exchange in university real estate development remains an area that requires further research. Therefore, this research explores how AI can be used in the exchange of knowledge about university real estate. The question that will be answered in this research is: *'How can Artificial Intelligence (AI) be utilized to enhance knowledge exchange about university real estate buildings?'*. By exploring this question, this research aims to improve the campus of the future by the quick and effortless creation of a knowledge database of university real estate.

1.1 Problem statement

Despite the promising potential of AI in enhancing knowledge exchange (Liebowitz, 2001; Olan et al., 2022; Bolisani & Nakash, 2024; Jarrahi et al., 2023) and the widely recognized benefits of AI in knowledge management practices (Bolisani & Nakash, 2024), research into its adoption remains limited. There is lack of empirical research that examine ways on how AI technologies can positively impact knowledge exchange (Bolisani & Nakash, 2024).

Current knowledge exchange processes between organizations face barriers on individual, socio-organizational, and technological level (Rego et al., 2009). The barriers on these levels hinder efficient knowledge sharing, collaboration, and innovation. In theory, AI has the potential to transform knowledge sharing barriers into drivers by improving knowledge collection, structuring information, and making knowledge more accessible (Bolisani & Nakash, 2024; Jarrahi et al., 2023).

The fourteen universities in the Netherlands strive for collaboration and the exchange of knowledge to ensure effective campus management (Den Heijer et al., 2016). To improve and strengthen the collaboration between the Dutch universities, Den Heijer (2011) and Altinkaya Genel et al. (2023) both developed a project database about university real estate. Literature highlights the lack of shared databases and repositories, as well as the poor utilization of technology as significant barriers to knowledge exchange on the technological level (Bektas et al., 2015; Birdi et al., 2020; Rego et al., 2020; Tzavides et al., 2020). The project databases by Den Heijer (2011) and Altinkaya Genel et al. (2023) demonstrate that there are shared databases to improve knowledge exchange. However, these two databases are no longer up-to-date and are incomplete. Therefore, to further enhance the exchange of knowledge, potentially AI can be utilized to develop an up-to-date and complete database.

This research aims to fill this research gap by investigating how AI can be utilized to create a shared project database about university real estate projects. The database that will be developed builds upon the databases by Den Heijer (2011) and Altinkaya Genel et al. (2023). Using AI to collect the data about university real estate is more time-efficient making it easier to update the database so that it remains complete and relevant. Since AI will be used to collect the knowledge, the type of knowledge that will be collected is explicit knowledge, because this type of knowledge can be easily documented and transferred (Milagres & Burcharth, 2018; Williams, 2007). This database can become a stepping stool for campus managers to use to enhance the knowledge exchange between universities. With that further fostering collaboration between the organizations.

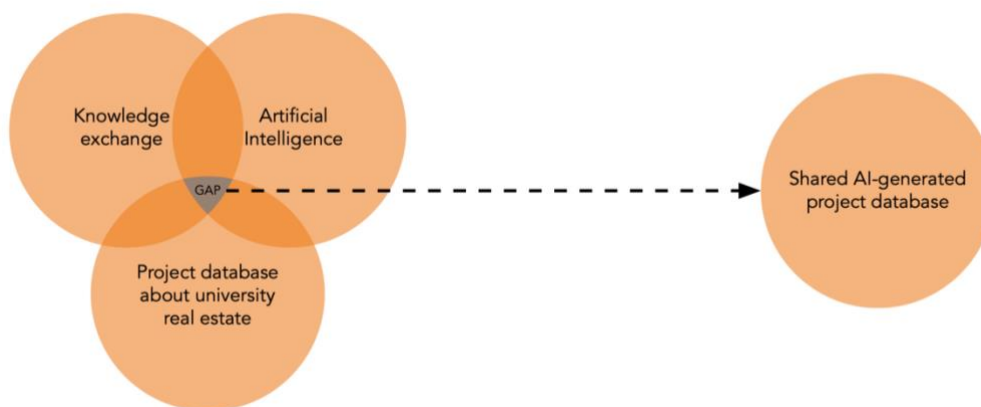


Figure 1.1: Problem statement with the knowledge gap (own illustration, 2025)

1.2 Research structure, output and goal

The goal of this research is to investigate how the exchange of knowledge between Dutch universities can be improved through the creation of a shared project database about university real estate projects. Further building upon the databases by Den Heijer (2011) and Altinkaya Genel et al. (2023), but through AI data collection improving time-efficiency, making it easier to update the database so that it remains complete and relevant. With this the research aims to further overcome the knowledge exchange barriers on a technological level and with that enable better collaboration and knowledge exchange among universities in managing their campuses.

The development of the knowledge database consists of four steps. These steps form the structure of the empirical part of the research. The four steps are:

1. Using AI to **find** university real estate buildings in open project databases and websites.
2. Using AI to **collect** information about university real estate building.
3. Using AI to create an **overview** per building.
4. Use AI to **analyze** and **identify** patterns, trends and innovations in university real estate buildings.

With these four steps, the products for this research are:

- Comprehensive list of university real estate buildings
- Collected data per university real estate building
- Detailed overview of individual university real estate buildings
- A Tailored GPT with the previous products as knowledge base

This research is a part of the Campus NL research project from the TU Delft, which focuses on exploring the past, present, and future of campuses from the fourteen Dutch universities (Den Heijer, 2017). The Campus NL project provides insights into how universities can manage their portfolios, with the aim of improving their ability to best support teaching, research, and knowledge valorization (Den Heijer, 2017). One of the research missions of the Campus NL project is that the exchange of knowledge can help campus managers (Den Heijer, 2021). This graduation thesis can support the Campus NL research by creating a shared database in which knowledge is exchange and campus managers can easily and quickly access and retrieve knowledge about university buildings in the Netherlands. In addition, there is a focus on data in the Campus NL research project, in which this research can contribute through how AI can play a role in the management of the university campus.

1.3 Research questions

The main research question that will be answered in this research is:

How can Artificial Intelligence (AI) be utilized to enhance knowledge exchange about university real estate buildings?

To answer the main research question, the following sub questions will be answered first:

1. What are the knowledge exchange barriers and drivers?
2. How can Artificial Intelligence (AI) facilitate knowledge exchange?
3. What knowledge do the campus managers need in a project database?
4. How can a Tailored GPT be developed to serve as a knowledge database about university real estate buildings?

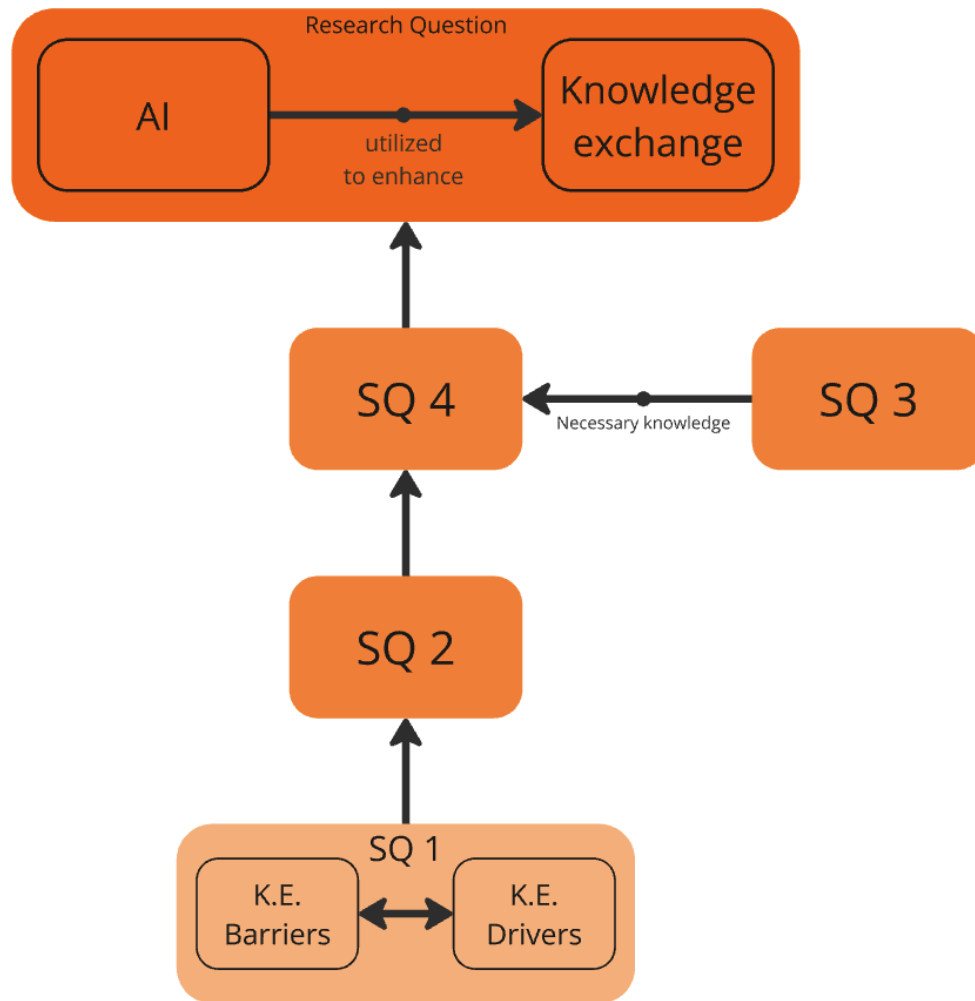


Figure 1.2: Conceptual framework (own illustration, 2024)

RESEARCH OUTPUT



2. Research output

2.1 Dissemination and audiences

The target audience for this research includes campus managers and other stakeholders responsible for managing the university campus and developing new university real estate. This research aims to demonstrate how AI can be used to create a project database for university real estate to enhance the exchange of knowledge between universities. By improving the exchange of knowledge through such a database, the benefits could extend beyond only universities to other real estate organizations or different types of organizations facing similar knowledge exchange challenges. Therefore, the secondary audience for this research includes professionals or organizations who encounter similar challenges in sharing knowledge effectively.

2.2 Goals and objectives

The main goal of this research is enhancing the exchange of knowledge between Dutch universities by the quick and effortless creation of a shared AI-generated knowledge database about university real estate buildings. To achieve this goal, the research focuses on the following objectives: investigating what the knowledge exchange barriers and drivers are, how AI can facilitate knowledge exchange, what knowledge should be in a database, and how a database can be created with the help of AI.

2.3 Deliverables

This research aimed at enhancing the knowledge exchange between real estate organization with the help of AI tools will result in several deliverables. These deliverables are:

1. The knowledge exchange barriers and driver organizations encounter.
2. How AI can facilitate knowledge exchange.
3. Comprehensive list of university real estate buildings
4. Detailed overview of individual university real estate buildings
5. Project database about Dutch university real estate buildings
6. Tailored GPT model about university real estate buildings

2.4 Personal study targets

Starting this graduation process, I was sure that I wanted to research something regarding Artificial Intelligence. Recently, I have been using AI more and more and therefore I thought it would be interesting to see how AI can be beneficial for the real estate industry. At first, I found it difficult how exactly I could link AI and the real estate industry together in a research study,

but after some brainstorming the link with knowledge was made. I am curious to the results of my research on how an AI tool eventually is going to enhance real estate projects. Therefore, my second study target is that I want to learn how to do extensive research on a topic that I find interesting and how to carry out a research proposal and do the research.

My final study target is that I want to enhance my knowledge of the real estate industry by doing a graduation internship with a company. Since I am not sure yet in what field I want to work in, this feels like a great opportunity to experience the industry from the company side as well instead of only from the literature side.

RESEARCH METHODOLOGY



3. Research methodology

In this chapter, the research methodology that will be used to answer the before mentioned questions will be explained. Firstly, the type of study will be explained. Then the methods and techniques used to gather the necessary information will be explained. The way of data collection and how the data is analyzed will be elaborated. Lastly, within the data plan and ethical consideration, it will be explained how the data is stored, and which ethical consideration will be taken to ensure the well-being of the participants.

3.1 Type of study

This research is based on a mixed method research approach to investigate how AI can be utilized to enhance the knowledge exchange about university real estate buildings. Within a mixed method research approach the collected and analyzed data from both quantitative and qualitative research methods are integrated to draw conclusion for the research (Kasirye, n.d.), this allows for a comprehensive exploration using both numerical data and in-depth insights.

The quantitative component in this study entails the creation of a knowledge exchange database with data from existing university real estate projects, with the focus on recently developed projects to keep the database up to date. The process of creating a knowledge exchange database consist of four steps: finding university real estate buildings, collecting information about the buildings, creating an overview per building, and analyzing and identifying patterns, trends, and innovations about university buildings. These four steps will be done with the help of AI to reach the goal: enhancing the exchange of knowledge between Dutch universities by the quick and effortless creation of an AI-generated knowledge database about university real estate buildings.

The qualitative component in this study consists of interviews with campus managers and other stakeholders involved in the development of university buildings. These interviews aim to identify the needs of campus managers for a knowledge database about university real estate buildings, the types of information that should be in the knowledge database, and a validation of the quantitative research. These qualitative insights will help in understanding the practical applications and implications of how AI can enhance the knowledge exchange about university real estate buildings.

By combining the data from the quantitative and qualitative approaches, this study will provide an understanding on how AI can be utilized to enhance knowledge exchange about university real estate buildings, leading to the development of a framework that integrates both insights to show how AI can be used to quick and effortless create a knowledge database.

In figure 2, the research framework is shown. The research framework shows the process of addressing the main research questions by answering the sub questions. It shows the research methods applied to each type of research and it highlights how the outcomes of the sub questions are related. This framework ensures that each sub question contributes to building an answer to the main research questions.

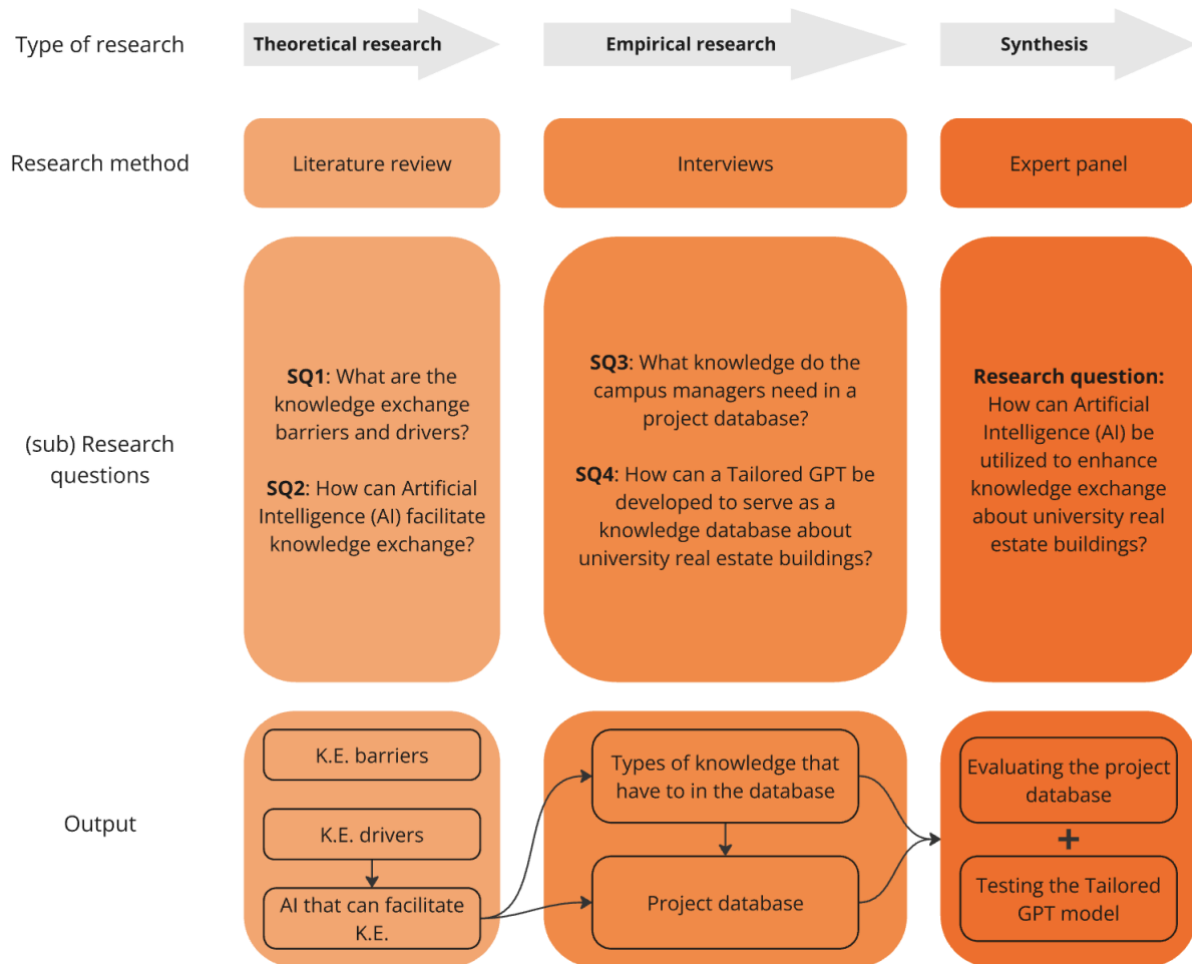


Figure 2: Research framework (own illustration, 2024)

3.2 Methods and techniques

As shown in figure 2, the research in this report is based on both theoretical and empirical research. This indicates that the multimethod research approach will be used (Blaikie & Priest, 2019). Through theoretical research, knowledge is gathered about the concepts of knowledge exchange, Artificial Intelligence, and university real estate. The theoretical part will result in the knowledge exchange barriers and drivers that organizations encounter and how AI can be utilized to overcome those barriers and further enable the drivers. The knowledge gathered in the theoretical part will be used in the empirical part of the research. Within the empirical part of the research interviews will be conducted with campus managers and other involved stakeholders.

In the synthesis part of the research, the literature review and the findings of the empirical data will be combined to conclude on how AI can be utilized to enhance knowledge exchange about university real estate buildings.

3.2.1 Theoretical research

The theoretical research component of this study will involve an in-depth literature review to build a comprehensive understanding of the key concepts for this research: knowledge activities, Artificial Intelligence (AI), and university real estate. The type of literature review that has been done in this research is a narrative (traditional) literature review. This entails a comprehensive, critical, and objective analysis of the current knowledge available on the concepts that are researched (Baumeister & Leary, 1997; Green et al., 2006). The difference from a systematic literature review, where all available literature on a concept is reviewed rigorous and explicit, is that the findings from the literature are summarized and reported in a readable format (Green et al., 2006). The literature review is completed when new literature does not show new information.

Knowledge activities

This chapter explores knowledge exchange, a component of knowledge management, which involves the creation, sharing, storing, and application of knowledge. By understanding the concept knowledge exchange, the barriers and drivers of knowledge exchange will be identified and analyzed.

Artificial Intelligence

In this chapter the concept of Artificial Intelligence will be explored. It shows how ChatGPT and other Large Language Models function, what the benefits are, and the ethical and societal considerations that should be considered. The concepts of prompt engineering and tailored GPTs are introduced, highlighting their relevance in customizing AI tools for specific purposes,

in this case a university real estate project database. Finally, the chapter elaborates on how Artificial Intelligence can facilitate knowledge exchange.

University real estate

This chapter delves into the fourteen universities in the Netherlands and their real estate. It discusses the management of university real estate through the campus management framework and how the performance of universities can be evaluated based on the Corporate Real Estate Management theory (Den Heijer, 2011). Finally, the chapter discusses existing project databases developed by Den Heijer (2011) and Altinkaya Genal et al. (2023).

3.2.2 Empirical research

Following the theoretical research, the empirical research will be conducted to gather practical insights and validate the theoretical findings. In this part in-depth semi-structured interviews with campus managers and other stakeholders involved in university real estate development will be conducted, and the project database and Tailored GPT will be developed.

Quantitative research

For the quantitative component in this research the project database and Tailored GPT will be created. AI will be used to fill the database with knowledge that in turn can be used by the campus managers. The database builds upon the existing project database created by Den Heijer (2011). The existing database contains of buildings constructed till 2010. Therefore, the updated database will consist of buildings constructed from 2011 till 2024. There are four steps to collect the data and fill the database:

1. Using AI to **find** university buildings in open project databases and websites.
2. Using AI to **collect** university building information.
3. Using AI to create an **overview** per building.
4. Use AI to **analyze** and **identify** patterns, trends and innovations in university buildings.

Qualitative research

The qualitative component of this study is to contextualize and validate the findings of the quantitative analysis and investigate the wants and needs of campus managers regarding a knowledge database about university real estate buildings. The qualitative research consists of conducting seven semi-structured in-depth interviews with campus managers and other stakeholders that are involved in the development of university real estate.

These interviews will serve multiple purposes:

1. Insight into the needs: The interviews will provide an insight into the needs of campus managers and other involved stakeholders regarding knowledge exchange and the creation of a knowledge database about university real estate buildings.
2. Insights into the types of information: The interviews will provide an insight into what types of information are necessary in the knowledge database according to the campus managers or other involved stakeholders.
3. Validation of Quantitative research: The qualitative interviews will help verify the knowledge exchange database created in the quantitative research. The database and way of gathering knowledge about university real estate projects will be shown and insights from experts on this knowledge database will be gathered.

The reason that semi-structured interviews will be held is because semi-structured interviews will get different reactions of the interviewees to a question and interviewees are free to respond to these open-ended questions as they wish, and the interviewer may probe these responses (McIntosh & Morse, 2015).

To analysis the interviews, a semi-deductive coding scheme in Atlas.ti has been used (Vila-Henninger, 2019). This entails that before the interviews were conducted, several codes were generated to analyze the interviews on. The codes in the initial round of coding have been developed from the insights of the literature review. During the interviews and after the interviews were conducted, new codes emerged bases on observations and insights gathered during the conversations. These additional codes were added in a second round of coding to capture important themes that were not yet identified in the codes.

Each interview has been analyzed on the full set of codes. When new codes were created after, for example the third interview, the first and second interviews were re-analyzed on the newly identified codes. This ensured that all interviews were examined consistently and comprehensively.

3.2.3 Synthesis

By integrating the results from the quantitative and qualitative research in the synthesis part of this study, a comprehensive understanding of how AI can be utilized to enhance knowledge exchange about university real estate buildings will be provided. In the synthesis, the results from the theoretical and empirical research will be showed in an expert panel workshop. In the synthesis, ten experts from seven different universities in the Netherlands will be asked to review the findings from the empirical research. The experts are campus managers or other related stakeholders. The experts will be asked to evaluate the project database by reviewing a university building from their own university and they will be asked to test the Tailored GPT

model. The purpose of this expert panel is to assess the usefulness, accuracy, relevance, completeness, and limitations of these tools. With the results from the expert, recommendations for improving both the project database and the Tailored GPT model can be implemented. These improvements will focus on enhancing the criteria both tools have been evaluated on to further enhance and facilitate the exchange of knowledge of university real estate.

3.2.4 Methods and techniques per sub question

The objectives and the methods and techniques used per sub question are described below.

Sub question 1: What are the knowledge exchange barriers and drivers?

Objective and methods: Exploring the drivers and barriers of knowledge exchange through literature review.

Sub question 2: How can Artificial Intelligence (AI) facilitate knowledge exchange?

Objective and methods: Gathering insights into how AI can be used to facilitate knowledge exchange and exploring what types of AI tools there are and what their key features and functionalities are through a literature review.

Sub question 3: What knowledge do the campus managers need in a project database?

Objective and methods: Exploring, through interview with campus managers or other stakeholders related to managing the university campus, what knowledge is necessary to have in a project database about university real estate.

Sub question 4: How can a Tailored GPT be developed to serve as a knowledge database about university real estate buildings?

Objective and methods: Training a Tailored GPT with the knowledge from the previous questions to create a knowledge database about university real estate buildings.

3.3 Data analysis

Once the interviews have been analyzed as explained and the data from the expert panel has been collected, the next step is to further analyze this data to draw conclusions. The data analysis phase of this research will involve the systematically analyzing the collected data from the theoretical and empirical research. Qualitative data analysis methods, such as content

analysis, and thematic analysis are used to gain insights and identify commonalities and differences within the data (Blaikie & Priest, 2019). Finally, out of the data analysis conclusions can be drawn as the results of this research.

3.4 Data plan

The research methodology involves collecting data from interviews and questionnaires. The researcher takes full responsibility of storing, sharing, and processing the data. The collected data will be stored and secured on a personal project storage drive, OneDrive, controlled by the researcher. If necessary, authorized individuals can be granted access to the data without the ability to alter or share the collected data. The gathered data will adhere to the TU Delft Research Data Framework Policy, which ensures that data needed to produce research findings are appropriately documented and shared in a research data repository in accordance with the FAIR principles, Findable, Accessible, Interoperable, and Reusable, for at least 10 years from the end of the research project (Ahlers et al., 2018). In this study a references chapter using APA 7 style is included. This ensures the proper citation of references used in this research. When the research is finished the final report will be made accessible through the TU Delft Repository. The Data Management Plan is created using the TU Delft platform DMPonline. This plan will ensure that all measures are being taken to safely collect and store the data. The DMP can be seen in Appendix VI: Data Management Plan.

3.5 Ethical considerations

Participation in this research will be entirely voluntary. Prior to collecting any information, the participants who choose to participate will be requested to provide an informed consent, ensuring they fully understand the nature and purpose of the study, see Appendix II: Informed consent. When a participant has not signed the informed consent, the collected data will not be used in this research. The well-being of the participants in this research is important. It is important that the participants are not harmed in any way by participating in this research. To avoid ambiguity, the participants will be provided with comprehensive information about the research, guaranteeing transparency and clarity. During the interviews, the participants have the right to decline answering any questions that violate their right to privacy, make them feel uncomfortable, or goes against their moral principles and the participants can stop the interview whenever they want to.

The participants will be ensured that their participation throughout the research will be anonymous. Personal identities and data will be kept confidential and protected throughout the study. During the research, all participants will have the freedom to withdraw from the study at any time, this will also be communicated at the beginning of the study.

LITERATURE REVIEW



Victor J. Koningsbergergebouw

4. Literature study

In this chapter the literature review is discussed. The aim of this chapter is providing a theoretical background for the research. In this chapter sub questions one and two will be answered. The literature review is divided into three concepts: knowledge activities, Artificial Intelligence (AI), and university real estate. The type of literature review that has been done in this research is a narrative (traditional) literature review (Baumeister & Leary, 1997; Green et al., 2006). This entails a comprehensive, critical, and objective analysis of the current knowledge on the concepts researched in this chapter. The literature review was completed when new literature did not show new information.

4.1 Knowledge activities

To answer the first sub question: *‘What are the knowledge exchange barriers and drivers?’*, first it is important to understand what knowledge exchange is and where it comes from. Knowledge exchange is a part of the activity knowledge management, to understand that first the concept knowledge activities will be explained.

Knowledge activities include the various processes through which knowledge is created, exchanged, collected, stored, and utilized within an organization or between organizations and individuals. When effectively implemented, these activities enable individuals to access and apply available knowledge and expertise efficiently when needed (Olan et al., 2022). This facilitation is crucial for fostering innovation and growth within organizations (Ayinde et al., 2021; Olan et al., 2022). Research carried out by Olan et al. (2022) indicates the importance of organizational knowledge as a critical strategic asset for competitive advantage. To sustain a competitive advantage, organizations rely on knowledge assets that are unique, valuable, and correctly stored. Consequently, properly implemented and executed knowledge activities not only enhance organizational performance but also contribute to project success. Therefore, it can be concluded that the implementation of knowledge activities is key in achieving and maintaining superior organizational outcomes.

4.1.1 Knowledge management

Knowledge management is the knowledge activity discipline that encompasses the processes and techniques for the creation, exchanging, collection, storing, and utilization of knowledge (Tsui et al., 2000). The definition of knowledge management according to Liebowitz (2001) is: “Knowledge management is the process of creating value from an organization's intangible assets. It deals with how best to leverage knowledge internally in the organization and externally to the customers and stakeholders.” (p. 1). According to several studies (Alavi & Leidner, 2001; Ayinde et al., 2021; Jarrahi et al., 2023; Lombardi, 2019; Ruggles, 1997) knowledge management consist of various activities, these activities with their characteristics are shown in Table 4.1.

Knowledge management activities	Characteristics	Literature
Knowledge creation / acquisition	<ul style="list-style-type: none"> - Developing new knowledge - Fostering innovation - Recombination and reconfiguration of existing knowledge - Acquiring knowledge from external sources 	Alavi & Leidner (2001); Ayinde et al. (2021); Jarrahi et al. (2023); Ruggles (1997)
Knowledge storing / retrieving	<ul style="list-style-type: none"> - Organizational memory that tracks generated and acquired knowledge - Making knowledge explicit and accessible - Recording knowledge systematically - Organizing knowledge 	Alavi & Leidner (2001); Jarrahi et al. (2023)
Knowledge exchanging / sharing	<ul style="list-style-type: none"> - Distributing knowledge throughout or between organizations - Distributing knowledge between individuals - Key factor in improving organizational performance 	Alavi & Leidner (2001); Ayinde et al. (2021); Jarrahi et al. (2023); Ruggles (1997)
Knowledge application / utilization	<ul style="list-style-type: none"> - Application of the newly generated knowledge - Bridging the gap between knowledge acquisition and application - Putting knowledge into practice 	Alavi & Leidner (2001); Jarrahi et al. (2023); Ruggles (1997)

Table 4.1: Knowledge management activities (own work, 2024)

As shown in Table 4.1, the four knowledge management activities have their own characteristics, however the four activities are not independent of each other, they are interconnected and mutually reinforcing. The relationships between the four different knowledge management activities are shown in Figure 4.1.

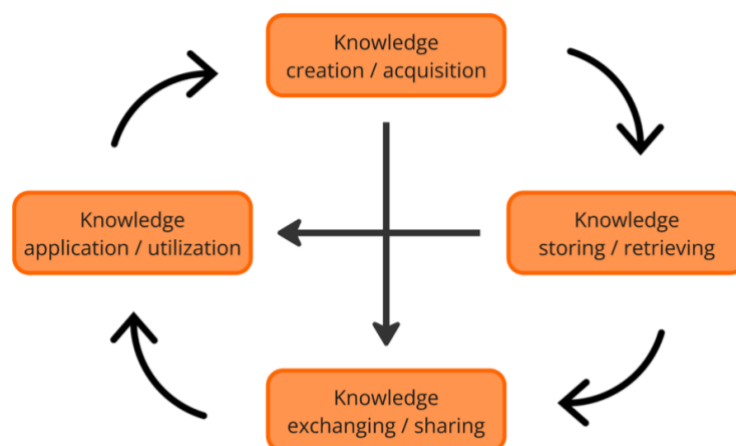


Figure 4.1: Relationships between knowledge management activities (own work, based on Alavi & Leidner (2001); Ayinde et al. (2021); Jarrahi et al. (2023); Ruggles (1997), 2024)

As can be seen in Figure 4.1, the knowledge management activities are in relationship with the next activity in the process. Knowledge creation / acquisition is the foundation for the other activities. Without generating and acquiring new insights, ideas, and knowledge there would be nothing to store, share, or apply. The process of creating or acquiring new knowledge often involves collaboration, which facilitates knowledge exchange. Therefore, there is a direct link between these two activities. Knowledge storing / retrieving ensures that the newly created and acquired knowledge is stored and retrieved in a way that individuals can easily access the knowledge. Knowledge exchanging / sharing is the process of exchanging the newly created, acquired, or the stored knowledge throughout an organization or between individuals and organizations. The final activity, knowledge application / utilization, ensures the application of the stored or exchanged knowledge to improve projects and processes. When knowledge is applied successfully, it can often lead to new insights and experiences, which can contribute to further knowledge creation.

In this research, a project database for university real estate will be created. The goal with this project database is to let the users share knowledge and information that they have about university real estate with other users. Therefore, the focus of the research will be on the concept knowledge exchange. The concept knowledge exchange will be explained in the next paragraph.

4.1.2 Knowledge exchange

Knowledge exchange within organizations is the process through which one unit of an organization (e.g. a department) is influenced by the experiences, information, or expertise of another unit within an organization (Argoto & Ingram, 2000), this is called intra-organizational knowledge exchange. The exchange of knowledge can occur at various levels, such as individual, group, a department, or a division, and involves changes in the knowledge or performance of the recipient unit (Argoto & Ingram, 2000). Therefore, knowledge exchange can be measured by observing the changes in knowledge or performance of the recipient units and it plays a crucial role in enhancing organizational effectiveness and competitive advantages (Argoto & Ingram, 2000).

Knowledge exchange also occurs between two different types of groups, for example between two different organizations. Interorganizational knowledge exchange therefore involves the migration of knowledge between firms (Milagres & Burcharth, 2018). Interorganizational knowledge exchange can be classified into two different approaches: replication and adaption (Williams, 2007). The approach replication involves the attempt to recreate identical activities or processes in two different locations or organizations. It focuses on replicating the knowledge or practices of the source organization without significant modifications. Replication is more straightforward and aims to exchange explicit knowledge that can be easily codified and

transferred (Williams, 2007). The approach of adaption on the other hand involves modifying or combining the practices of the source organization to suit the context or needs of the receiving organization. This approach recognizes that knowledge exchange is not a one-size-fits-all process and that adaptations may be necessary to make the transferred knowledge relevant and effective in the new setting. Adaptation is particularly important when dealing with tacit knowledge or complex knowledge that is context-dependent and requires customization (Williams, 2007).

Tacit knowledge exchange refers to sharing knowledge that is difficult to articulate or pin down. This type of knowledge is often deeply rooted in personal experiences, insights, intuitions, and certain skills that individuals may not be consciously aware of or able to easily communicate to others (Shi & Xie, 2023). Within organizations tacit knowledge is a significant part of the knowledge that organizations acquire (Argoto & Ingram, 2000). In organizations, tacit knowledge exchange can occur through various informal channels such as personal interactions, observation, imitation, and shared experiences. Unlike explicit knowledge, which can be documented and transferred more easily through manuals, training programs, or databases, tacit knowledge is more challenging to formalize and transmit (Milagres & Burcharth, 2018).

A difference can be made between collective and individual knowledge exchange. This refers to the distinction between transferring knowledge at the organizational level (collective) and transferring knowledge at the individual level (Milagres & Burcharth, 2018). Collective knowledge exchange has been explained above. Individual knowledge exchange refers to the transfer of knowledge at personal level, focusing on the skills, and expertise possessed by individuals (Milagres & Burcharth, 2018). While individual knowledge transfer is important for building specific competencies within the organization, collective knowledge transfer is essential for sustaining organizational capabilities and competitive advantage over the long term (Milagres & Burcharth, 2018).

In the context of this research, the focus is on interorganizational knowledge exchange, in this case between universities. Interorganizational knowledge exchange involves the exchange of knowledge between different organizations. While the concept of knowledge exchange shows the potential for sharing valuable information and knowledge, the process is not without challenges. Identifying the factors that enable, and hinder knowledge exchange is important to ensure its effectiveness. Therefore, the next chapter delves into the barriers and drivers of knowledge exchange.

4.1.3 Knowledge exchange barriers and drivers

Understanding the barriers and drivers of knowledge exchange is critical to develop a knowledge database, therefore in this chapter the sub question: '*What are the knowledge exchange barriers and drivers?*' will be answered. This paragraph elaborates on the important barriers and drivers found in the literature. The barriers found in the literature are shown in table 4.2-4.4, and the drivers found in the literature are shown in table 4.5-4.7.

4.1.3.1 Barriers

Barriers are obstacles that can hinder knowledge exchange (Rego et al., 2009). In the research of Rego et al. (2009), three main domains are considered, individual level, socio-organizational level, and technological level. These three domains will be used in this research to categorize the barriers and drivers. Tables 4.2-4.4 show the knowledge exchange barriers according to the literature.

Table 4.2: Barriers on an individual level

Barrier	Explanation	Literature
Lack of trust	When people do not trust each other, they do not want to share knowledge. When a source is not trustworthy, people do not easily exchange knowledge	Birdi et al. (2020); Asrar-ul-Huq & Anwar (2016); Rego et al. (2009)
Lack of motivation	Knowledge will not be exchanged when people do not have the motivation, because they can see it as extra work.	Birdi et al. (2020); Asrar-ul-Huq & Anwar (2016); Rego et al. (2009)
Lack of time	People feel that they do not have the time to share knowledge effectively or they may not prioritize knowledge exchange	Rego et al. (2009); Bjorvatn & Wald (2020); Santos et al., (2012); Cvitanovic et al., (2014)
Poor communication	The way that (new) knowledge is communicated has an impact on the acceptance of the receivers. Different languages also prevent effective knowledge exchange	Rego et al. (2009)
Fear	Fear that the sharing of knowledge may jeopardize people's job security	Rego et al. (2009)
Heavy workload	When the workload is too heavy, people do not have time to exchange knowledge	Asrar-ul-Huq & Anwar (2016)

Variability of people	The variability of people poses challenges, because people are highlighted as challenging factors for knowledge exchange	Argate & Ingram (2000); Aslam et al. (2023)
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Table 4.2: Knowledge exchange barriers on an individual level (own work, 2024)

Table 4.3: Barriers on a socio-organizational level

Barrier	Explanation	Literature
Cultural differences	Differences in cultural values and traditions can affect how knowledge is perceived and exchanged. The company's culture may not support the exchange of knowledge	Asrar-ul-Huq & Anwar (2016); Rego et al. (2009); Tzavides et al. (2020)
Organizational and management structure	Each organization may have different procedures and processes, which can complicate communication and collaboration	Asrar-ul-Huq & Anwar (2016); Tzavides et al. (2020); Rego et al. (2009)
Lack of incentives and rewards	Without incentives to exchange knowledge, people do not have the motivation, or they may not prioritize knowledge exchange, especially when weighed against other responsibilities	Rego et al. (2009); Birdi et al. (2020); Asrar-ul-Huq & Anwar (2016)
Leadership	Poor leadership can be a hinderance for the exchange of knowledge	Birdi et al. (2020); Rego et al. (2009)
Organizational silos	Occurs when individuals or department do not have the means to share knowledge with each other	Asrar-ul-Huq & Anwar (2016); Rego et al. (2009)
Shortage of formal and informal spaces	The shortage of formal and informal spaces to share, reflect, and generate knowledge	Rego et al. (2009)
Diverse agendas, goals, and processes	Not having the same agendas, goals, and processes prevents the exchange of knowledge	Borg & Von Knorring (2019)
Unclear integration of KM practices	When the integration of knowledge management practices into the organization's goals and strategy is unclear it can lead to ineffective knowledge exchange	Tzavides et al. (2020); Rego et al. (2009)

Table 4.3: Knowledge exchange barriers on a socio-organizational level (own work, 2024)

Table 4.4: Barriers on a technological level

Barrier	Explanation	Literature
Lack of shared databases and repositories	Without shared databases and repositories, it is difficult to distribute knowledge to others	Birdi et al. (2020); Tzavides et al. (2020); Rego et al. (2009); Bektas et al. (2015)
Lack of training	When people do not understand the technology, they will not use it	Birdi et al. (2020); Rego et al. (2009)
Unnecessary information	When there is too much information, it can be difficult to identify the useful information, and it takes up too much time	Rego et al. (2009)
Unrealistic expectations	People can have unrealistic expectations as to what technology can and cannot do	Rego et al. (2009)

Table 4.4: Knowledge exchange barriers on a technological level (own work, 2024)

4.1.3.2 Drivers

The drivers for the exchange of knowledge, also known as facilitators or enablers, promote the flow of knowledge, (Rego et al. (2009) states “Facilitators are individual, socio-organizational, or technological aspects that improve, stimulate, or promote the flow of knowledge” (p. 34). Tables X-X show the knowledge exchange drivers, based on the three domains, according to the literature.

Table 4.5: Drivers on an individual level

Driver	Explanation	Literature
Willingness to exchange knowledge	If people do not want to share knowledge, then no knowledge will be shared	Nassuora (2011); Rego et al. (2009)
Willingness to learn	The willingness to learn stimulates because people will share information to gain information	Rego et al. (2009)
Trust	A high level of trust in other people can stimulate the exchange of knowledge	Birdi et al. (2020); Asrar-ul-Huq & Anwar (2016); Al-Gharibeh (2011)
Collaboration	People working together on a shared goal can stimulate the exchange of knowledge	Nassuora (2011); Al-Gharibeh (2011)
Help-seeking	Help-seeking behaviour stimulates other people to exchange knowledge	Rego et al. (2009)

Table 4.5: Knowledge exchange drivers on an individual level (own work, 2024)

Table 4.6: Drivers on a socio-organizational level

Driver	Explanation	Literature
Collaborative culture	A collaborative knowledge exchange environment within an organization that values openness, respect, and a shared vision	Asrar-ul-Huq & Anwar (2016); Rego et al. (2009); Al-Kurdi et al. (2018); Nassuora (2011)
Leadership	Leaders can be drivers for the effective exchange of knowledge	Al-Gharibeh (2011); Nassuora (2011); Rego et al. (2009)
Incentives and rewards	Incentives and rewards can motivate people to share knowledge	Asrar-ul-Huq & Anwar (2016); Rego et al. (2009);
Centralization	Having control over decision-making and improved decision-making	Al-Gharibeh (2011); Nassuora (2011); Rego et al. (2009)
Integrating KM	Integration of knowledge management with the organization's mission and vision	Al-Kurdi et al. (2018); Rego et al. (2009)
Face-to-face communication	Knowledge is easier exchange when people communicate face-to-face	Rego et al. (2009)

*Table 4.6: Knowledge exchange drivers on a socio-organizational level (own work, 2024)***Table 4.7:** Drivers on a technological level

Driver	Explanation	Literature
Utilization of technology	Effective utilization of technology can stimulate the exchange of knowledge by supporting collaboration and communication. The same technology that can be used by everybody makes the sharing of knowledge easier	Asrar-ul-Huq & Anwar (2016); Rego et al. (2009); Al-Gharibeh (2011); Al-Kurdi et al. (2018); Nassuora (2011); Tzavides et al. (2020)
Centralized knowledge repository	Knowledge exchange repositories (databases) to connect individual informational systems and facilitate collecting of knowledge	Rego et al. (2009)

Table 4.7: Knowledge exchange drivers on a technological level (own work, 2024)

When the drivers and barriers are compared, it can be seen that many of the barriers stated in the literature can become drivers if the barrier can be overcome by the individuals participating in the knowledge exchange activities.

This chapter has answered the sub question: '*What are the knowledge exchange barriers and drivers?*'. The barriers and drivers are divided into the three domains stated by Rego et al. (2009). Within this research, mainly the barriers and drivers on a technological level will be utilized. The barrier is lack of shared databases and repositories, and the drivers are utilization of technology and centralized knowledge repository. The goal is that through the development of a project database, the drivers, utilization of technology and centralized knowledge repository, will be further enabled and the barriers on the technological level will be overcome. By creating such a database, individuals all work with the same type of technology which should stimulate the exchange of knowledge (Asrar-ul-Huq & Anwar, 2016; Rego et al., 2009; Al-Gharibeh, 2011; Al-Kurdi et al., 2018; Nassuora, 2011; Tzavides et al., 2020).

There are already existing project databases about university real estate, these are discussed in paragraph 4.3.2 Existing project database. However, these databases are no longer up to date or incomplete. Therefore, an updated project database about university real estate is necessary to overcome and further enable the barriers and drivers.

A project database by itself does not directly enhance the exchange of knowledge, but it can be seen as an important facilitator for more efficient knowledge exchange (Rego et al., 2009). Campus managers or other related stakeholders can use a project database as a stepping stool to access, retrieve, and exchange knowledge. The type of knowledge in a database is mainly explicit, because explicit knowledge can be easily documented and transferred (Milagres & Burcharth, 2018; Williams, 2007). When users are looking for tacit knowledge, they can use the database as a stepping stool to see who to contact about a certain university building to exchange the tacit knowledge about that building.

One of the most frequently mentioned barriers by the literature is the lack of time that individuals encounter when sharing knowledge (Rego et al., 2009; Bjorvatn & Wald, 2020; Santos et al., 2012; Cvitanovic et al., 2014). Through the creation of a centralized database where knowledge is easily accessible, retrievable, and exchangeable, users can save time when looking for knowledge. So, again in this way a project database can be a facilitator to overcome the knowledge exchange barrier lack of time.

The project database that will help overcome the knowledge exchange barriers will be created with the help of Artificial Intelligence, this will be explained in the next chapter.

4.2 Artificial Intelligence (AI)

Artificial Intelligence has emerged as a cornerstone technology into day-to-day life, with the potential to transform the way knowledge is created, managed, and shared across and between various disciplines. This paragraph delves into the concept of AI, what is Artificial Intelligence. After that, the language model ChatGPT, which will be used for the creation of a knowledge database in this research, will be discussed. It further examines the development of tailored Generative Pre-trained Transformers (GPTs), which are customized language models trained to meet specific user needs in a specific domain. Lastly, prompt engineering, an essential aspect of working with AI language models, will be discussed.

4.2.1 What is Artificial Intelligence

Artificial Intelligence seems like a rather new concept, but the birth of Artificial Intelligence already dates back to the 1950s. In 1950, Alan Turing published his work 'Computer Machinery and Intelligence'. Turing suggested that humans use available information as well as reason to solve problems and make decisions, so why can machines not do the same thing (Turing, 1950). In his research Turing (1950) states the question 'can machines think?'. To give an answer to this question Turing proposes a test called The Imitation Game, which eventually became The Turing Test, which experts now use to measure computer intelligence. The first time the word Artificial Intelligence was used was during the Dartmouth Summer Research Project on Artificial Intelligence hosted by John McCarthy and Marvin Minsky in 1956 (Moor, 2006). This event is seen as the catalyst for AI in the next twenty years. Since the birth of AI, a lot of research has been done. According to several studies (Rossini, 2000; Kaplan, 2016), the definition of Artificial Intelligence is the ability to perform the intelligent functions of the human brain by machines, in particular certain forms of reasoning, learning, and the ability to improve over time.

The implementation of AI over the last decade has led to project and organizational success, as organizations are gradually embracing the benefits of AI (Olan et al., 2022). Therefore, AI has emerged within a broad spectrum of industries, also within the real estate industry. The real estate industry has experienced some of the most remarkable innovations fueled by AI (Seagraves, 2023). However, within the real estate industry, the concept 'Smart' is often used instead of Artificial Intelligence. Smart concepts have grown rapidly in recent years and examples of smart concepts are smart buildings or smart tools. Smart buildings are intelligent buildings but with additional, integrated aspects of adaptable control, enterprise and materials and construction, thus offering additional control strategies based on improved occupant interaction (Buckman et al., 2014). Another research on the concept of 'Smart' is the research of Valks (2021), which is a study on smart campus tools. He defines smart campus tools as: "A smart campus tool is a service or product that measures space use real-time in order to support students and employees in making better use of spaces on campus today, whilst also supporting campus managers in making better decisions on the future campus." (Valks, 2021,

p. 127). So, a smart tool can be seen as a service or product that measures a certain domain to optimize processes and improve experiences. Smart tools can also leverage technical solutions, such as machine learning, and computer vision, to perform tasks intelligently and autonomously. These tools use algorithms to analyze data, learn from patterns and interactions, and make predictions or decisions without explicit human intervention. This is something that AI can do as well. So, the concept smart can be seen as a different name for Artificial Intelligence.

In the context of real estate, AI tools can include chatbots, virtual assistants, predictive analytics platforms, and automated data processing systems that enhance efficiency, accuracy, and effectiveness in tasks such as property recommendations, market analysis, customer service, and workflow automation. They enable stakeholders in the real estate industry to access valuable insights, streamline processes, and make informed decisions, ultimately driving innovation and improving outcomes.

4.2.2 ChatGPT

ChatGPT, Generative Pre-trained Transformer, is a natural language processing model that generates humanlike responses from users that launched in 2022. The AI model ChatGPT is created by OpenAI, which is an AI research laboratory. The goal of OpenAI is to develop a safe and beneficial Artificial General Intelligence (AGI), by which they mean a highly autonomous systems that outperform humans at most economically valuable work (OpenAI, n.d.). The way that ChatGPT can generate human-like responses is because it is an autoregressive language model that uses deep learning to produce those responses. The AI model is a computational system designed to generate sequences of words, code, or other data, starting from a source input, called a natural language prompt (Floridi & Chiriatti, 2020; Welsby & Cheung, 2023). The way that ChatGPT has been trained was by using rankings, weighted algorithms, constructed by humans based on massive datasets of diverse texts, including books, articles, scientific papers, Wikipedia, websites, and news media (Floridi & Chiriatti, 2020; Welsby & Cheung, 2023). With its easy accessibility and astonishing abilities, ChatGPT has become widely adopted across multiple sectors, transforming task and reshaping the expectations of AI models (De Angelis et al., 2023).

The key development that has led to the rise of ChatGPT is the use of transformer architectures (Kasneci et al., 2023). This development has improved the ability of natural language models to handle long-range dependencies in natural-language texts. The transformer architecture uses self-attention mechanisms to determine the relevance of different parts of the input when generating predictions. This allows the AI model to better understand the relationships between words in a sentence, regardless of their position (Kasneci et al., 2023). This

architecture enabled significant improvements over earlier models, which relied on limited contextual understanding.

4.2.2.1 How does it work?

The heart of ChatGPT is a Large Language Model (LLM), which are models that are primarily built on transformer architectures (Naveed et al., 2023; OpenAI, 2023a). The current LLM for ChatGPT is GPT-4 (OpenAI, 2023a). A LLM is a type of neural network-based model, see figure 4.2. The LLM, as explained before, is trained on massive amounts of text data to understand and generate human language (Floridi & Chiriatti, 2020; Welsby & Cheung, 2023). The model uses the training data to learn the statistical patterns and relationships between words in the language and then utilizes this knowledge to predict the subsequent words, one word at a time (OpenAI, 2023a).

A LLM is often characterized by its size and the number of parameters it contains. GPT-4 has more than 1.5 trillion parameters spread across 96 layers in the neural network, making it one of the largest deep learning models ever created (Emmanuel, 2023).

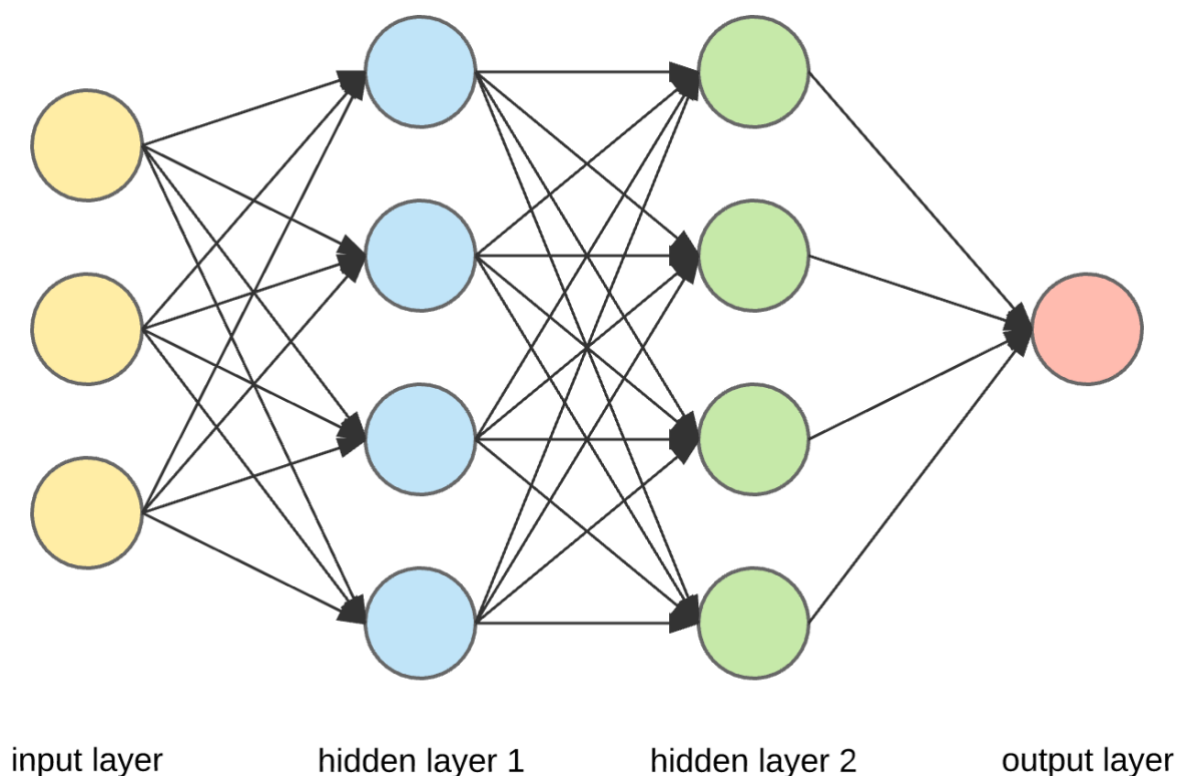



Figure 4.2: Neural network-based model (Dertat, 2022)

The input and output of the model are organized by tokens as shown in figure 4.3. Tokens are numerical representations of words; they can be seen as the vocabulary of the LLM. Numbers are used for tokens rather than words because they can be processed more efficiently (Robinson et al., 2024).

Text: 

Token IDs: [3666, 4004, 3124, 318, 2266, 13]

Figure 4.3: Tokens; numerical representations of words (own work, based on Dertat (2022), 2024)

GPT-4 was trained on a large chunk of internet data as well as licensed data (OpenAI, 2023a). The data used for training contains over 500 billion tokens. So, the model was trained on hundreds of billions of words. The model is trained to predict the next token given a sequence of input tokens, so trained to predict the next word in a document (OpenAI, 2023a). The model is able to generate text that is structured in a way that is grammatically correct and similar to the internet data it was trained on. The data that has been used to train the model included correct and incorrect solutions, weak and strong reasoning, self-contradicting and consistent statements, and represented a great variety of ideologies and ideas (OpenAI, 2023a). This has been done so that when the model is prompted with a question, the model can respond in a wide variety of ways that might be far from the user's intent. To align the response with the user's intent, the model's behavior has been fine-tuned using Reinforcement Learning with Human Feedback (RLHF) (OpenAI, 2023a). GPT-4 is fine-tuned with RLHF by gathering feedback from people, creating a reward model based on their preferences, and then improving the model's performance using Proximal Policy Optimization (PPO). This allows GPT-4 to generate better responses tailored to specific user requests. But without the right guidance, the model can also generate outputs that are untruthful, toxic, or reflect harmful sentiments. Even with that severe downside, the model is already useful, but in a very structured way. It could be taught to perform natural language tasks using carefully engineered text prompts. This is where the new field "prompt engineering" came from. This will be explained in the next paragraph.

4.2.2.2 Benefits

The use of ChatGPT and other similar Large Language Models can offer benefits across multiple domains. In the educational sector, ChatGPT has shown potential to enhance teaching and learning, by providing support and making information more accessible to students (Stahl & Eke, 2024). With the help of ChatGPT it is easier to find all kinds of information and knowledge

about all kinds of topics. ChatGPT has also increased the competition in internet search. It stimulates competition which can potentially lead to better services for users (Stahl & Eke, 2024). From an economic perspective, ChatGPT has the potential to drive economic growth by transforming existing industries. The integration of ChatGPT can stimulate the emergence of AI driven startups, improve the efficiency of existing companies, and create new opportunities in the tech sector. This growth also benefits the societal well-being, as it can contribute to job creation and economic stability (Stahl & Eke, 2024).

ChatGPT can improve the efficiency of tasks. It can automate conversations, saving time and resources by eliminating the need for manual interactions. It can provide additional intelligence to organizations, which allows organizations to optimize workflows, enhance productivity, and because of that human resources can focus on higher-level tasks that require specialized knowledge and critical thinking. This can lead to more efficient operations and innovative solutions within various sectors (Deng & Lin, 2023; Stahl & Eke, 2024). While the benefits of ChatGPT and other Large Language Models highlight their potential, it is important to address the ethical and societal considerations that accompany their use.

4.2.2.3 Ethical considerations

ChatGPT and other similar Large Language Models also raise important ethical and societal considerations. Among the primary challenges is the problem of alignment, which involves the difficulty of ensuring that the behavior of ChatGPT is aligned with human values and ethical principles (De Angelis et al., 2023). Addressing this problem is an ongoing area of research and for this problem OpenAI developed a moderation system, trained to detect a broad set of categories of undesired content. Together with the RLHF, OpenAI tries to tackle this problem. Despite these advancements, aligning ChatGPT with diverse human expectations is complex and therefore sometimes lead to potential ethical misalignments (De Angelis et al., 2023).

The environmental impact of ChatGPT, like other Large Language Models, has become a significant concern due to the high energy requirements associated with training and running these models (Stahl & Eke, 2024). Training a large-scale LLM, like ChatGPT, involves processing vast amounts of data across numerous of computational units. This process requires substantial energy, contributing to a large carbon and water footprint and therefore raising concerns about the sustainability of AI technologies (Li et al., 2023). For the training of GPT-3 in the Microsoft data center, 700.000 liters of fresh water has been used, that is equal to the amount of water needed to produce 350 cars. Estimates show that the water withdrawal of global AI can reach 4.2 – 6.6 billion cubic meters in 2027, which is more than the annual water withdrawal of 4 to 6 times Denmark or half of the United Kingdom (Li et al., 2023).

The impact of ChatGPT on job displacement and potential bias in decision-making are societal considerations (Welsby & Cheung, 2023). AI models can perform the human labor in tasks

involving information processing, content creation, and customer service, which can result in an increased risk of job displacement. Additionally, biases within the training of the GPT can alter the outputs, maintaining stereotypes and making biased decisions.

The spreading of misinformation and disinformation are also significant ethical issues due to ChatGPT's ability to produce large volumes of text rapidly. This capability could potentially lead to harmful outcomes (De Angelis et al., 2023; Stahl & Eke, 2024). Relatedly, the lack of true understanding in the fast generated texts can be an issue. ChatGPT does not possess a genuine understanding, it generates text based on patterns in data rather than comprehension, which therefore raises questions about the reliability of the outputs. While ChatGPT can assist, human oversight is necessary for quality assurance and ethical accountability (Floridi & Chiriatti, 2020; Stahl & Eke, 2024).

4.2.3 Prompt engineering

Prompt engineering is an increasingly important skillset needed to optimize the performance of Large Language Models, such as ChatGPT. Through prompt engineering it is possible to converse with LLMs. A prompt is a set of instructions or query that you provide to a LLM to guide its behavior and generate desired outputs (Giray, 2023) and prompt engineering is how LLMs are programmed via prompts (White et al., 2023).

There are six building blocks that make up a good prompt to consistently generate high quality outputs. These building blocks are, in order of importance (Giray, 2023; Su, 2023):

1. Task (mandatory)
2. Context (important)
3. Exemplar (important)
4. Persona (nice-to-haves)
5. Format (nice-to-haves)
6. Tone (nice-to-haves)

It is not necessary to use all six building blocks in every prompt to have a good output. However, a task is mandatory, and context and exemplar are important to add in a prompt to get a good output. The six building blocks are explained below.

Task

As mentioned before, a task is necessary in every prompt, because the task is what guides the model to the desired output (Giray, 2023). It is important to always start the task sentence with a verb, such as generate, write, give, etc. and clearly describe what the end goal is (Su, 2023).

Context

This is external information or additional context that can be added to the prompt to provide background knowledge to the model, helping the model to generate more accurate and relevant responses (Giray, 2023). Giving the right context to a prompt can be difficult because technically there is an infinite amount of information that can be added to the prompt, but the goal is to limit the endless possibilities, by giving just enough information (Su, 2023).

Exemplar

Within a prompt, adding examples can drastically improve the quality of the output (Su, 2023). It is not necessary to add exemplar in every prompt, but including a relevant example can improve the quality of the output, and therefore they are important.

Persona

The persona component is about who you want the AI model to be. This component introduces a specific role, voice, or perspective for the AI model to adopt. Adding a component can enhance the engagement and relevance of the response, but it is not always necessary to add one (Su, 2023).

Format

This component specifies the type or format of the desired output. It helps to shape the response by defining whether the response should be for example a short answer, a paragraph, or another specific format (Giray, 2023). With the format it is therefore possible to explain how exactly the output should be.

Tone

This component defines the style or emotional quality of the response. With the component tone it is possible to let the response be formal, funny, empathetic, etc. (Su, 2023). Tone is not mandatory, but it can play a role in adjusting the AI model's response to match the users' preferences.

4.2.4 Tailored GPT

Tailored Generative Pre-training Transformers (GPT) are customized versions of ChatGPT, designed to perform specific task or purposes (OpenAI, 2023b). Within these GPTs it is possible to integrate instruction, knowledge, guides, and possibilities, to enhance the model's utility in specific contexts. Tailored GPTs can be created and shared by anyone, and no coding is necessary to make a tailored GPT. The tailored GPTs undergo additional training with industry specific data to make sure that the GPT can provide answers that are relevant to the industry.

The primary benefits of tailored GPTs include their accuracy and relevance, due to their specialized training (Rouse, 2024). They also promote efficiency, by automating routine tasks tailored GPTs allow for organizations to allocate human resources to more complex issues, and therefore improving the overall efficiency (Rouse, 2024). This increased automation can, over time, significantly reduce operational costs by automating data intensive tasks, which makes tailored GPTs cost-effective (Rouse, 2024).

However, implementing tailored GPTs also presents challenges and considerations. In sensitive sectors data privacy and security can become a challenge (Rouse, 2024). However, it is possible to not make the GPT public when working with sensitive data. Moreover, the same ethical considerations as with ChatGPT can occur with tailored GPTs.

4.2.5 AI facilitating knowledge exchange

Tools that can facilitate knowledge exchange are technologies that can enhance and enable knowledge exchange (Ruggles, 1997). Although, the importance of knowledge activities, AI tools, and organizational performance has been discussed by Argote & Fahrenkopf (2016); Argote & Ingram (2000); Lombardi (2019); Jaharri et al. (2023) respectively, Olan et al. (2022) states that there is a limited direct relationship between these individual research areas. However, they have been able to derive a logical relationship between knowledge exchange, AI tools, and the improvement of organizational performance because of the improved knowledge activities (Olan et al., 2022). They have done that by employing a set-theoretic comparative approach that simultaneously tested the complementary factors of AI, knowledge exchange, and organizational performance. Through this approach, the researchers were able to demonstrate the relationship between the three concepts, highlighting how the integration of AI tools with knowledge exchange initiatives can contribute to improved performance. The logical assumption that AI tools can improve knowledge exchange is the starting point for this paragraph.

As discussed in the knowledge exchange barrier paragraph, barriers on the technological level are the lack of shared databases and repositories as well as the utilization of technology (Asrar-ul-Huq & Anwar, 2016; Rego et al., 2009; Al-Gharibeh, 2011; Al-Kurdi et al., 2018; Nassuora, 2011; Tzavides et al., 2020). These limitations hinder the efficient exchange of knowledge and collaboration between organizations. The explanation of the concept Artificial Intelligence (AI) and in particular the development of Tailored GPTs can offer a solution to overcome the barriers on the technological level. With the use of AI, a shared database can be developed, both in the form of a project database and a Tailored GPT. Because AI has the ability to access, retrieve, and produce large volumes of data and knowledge. With this data and knowledge that was previously scattered or inaccessible an AI-generated shared database about university real

estate can be created. Through that the driver utilization of technology is also employed, which further enhances and facilitates the exchange of knowledge.

A Tailored GPT, as explained in the previous paragraph can be developed for university real estate projects. By creating such a shared Tailored GPT, universities can address the technological barriers effectively. The project database and Tailored GPT together can serve as a centralized database where information is easily shared, retrieved, and utilized, therefore transforming the knowledge exchange barriers into drivers.

This section has answered the sub question: *“How can Artificial Intelligence (AI) facilitate knowledge exchange?”* by demonstrating how AI can overcome the knowledge exchange barriers on a technological level and can become an enabler of effective knowledge exchange and collaboration among universities, by developing an AI-generated shared database and a Tailored GPT model.

4.3 University real estate

In the Netherlands, there are fourteen research universities, between which collaboration is important. The universities want to pool resources and knowledge and, through collaboration, strengthen each other complementarily (Den Heijer et al., 2016). Universities typically manage large and diverse real estate portfolios, including academic buildings, student housing, and recreational facilities. The thirteen universities campuses – excluding the Open University, which does not have a campus – collectively contain an estimated 1200 buildings (Den Heijer, 2011). Although that number is already very large, more buildings will be added in the coming years as universities continue to grow (Den Heijer, 2011).

Each university has its own specialized knowledge and expertise in managing the existing portfolios and in developing new buildings for the campus. However, this process could be significantly improved with better exchange of knowledge of the existing building stock of universities. As explained before AI could play a beneficial role in enhancing the exchange of knowledge between universities to improve the campus of the future, by creating a knowledge database. However, even though the universities consider mutual collaboration important, they remain stand-alone organizations, which means that they also manage their assets and projects to maximize financial return and operational efficiency. Therefore, while AI could present an opportunity to improve knowledge exchange, it is important to consider these institutional constraints when implementing collaborative solutions.

The thirteen universities in the Netherlands, as well as universities in other countries in the world, all have portfolios with many buildings. To make good strategic decision for the campus of the future, it is necessary to be able to value the performance of university real estate. Den

Heijer (2011) states that “the relationship between real estate and performance is the most important foundation for real estate management” (p. 103). To value the performance of higher education real estate, De Vries (2007) created the Corporate Real Estate Management (CREM) theory. Corporate Real Estate Management is the management of real estate by parties that are both the owners and occupiers of the real estate (Den Heijer, 2011). CREM focusses on matching the supply of real estate to the demand of real estate (De Vries, 2007; Den Heijer, 2011). The CREM theory will be explained in the next paragraph.

4.3.1 Corporate real estate management

To evaluate the performance of university real estate, Den Heijer (2011) has made an improved CREM theory model as shown in figure 4.4. This model shows how adding value is connected to the four CREM stakeholders shown in figure 4.5, which are policy makers, technical managers, users, and controllers, and linked to the four main performance criteria of university buildings: profitability, productivity, competitive advantage, and sustainable development (Den Heijer, 2011).

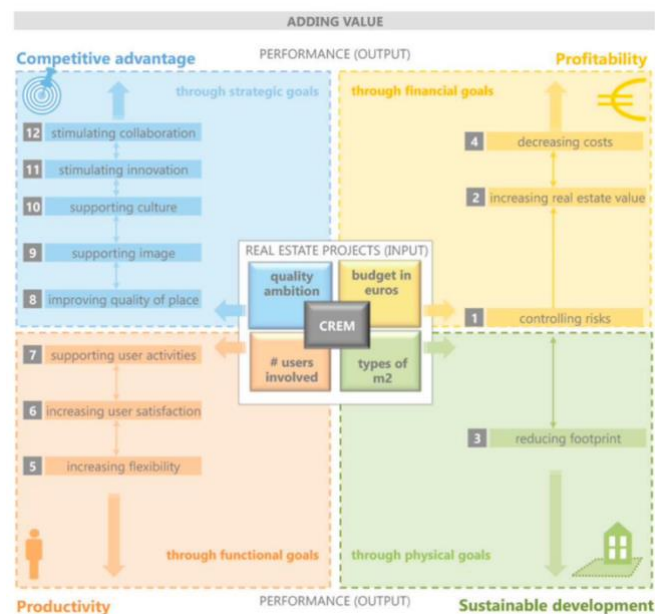


Figure 4.4: The Corporate Real Estate Management (CREM) theory (Den Heijer, 2011)

Figure 4.4 shows the process of value creation from input throughout output. The CREM model shows that real estate decision is linked to performance criteria through real estate goals that are connected to different stakeholders. This model can be used either before a real estate decision is made to make a business case, or after a real estate decision has been implemented to make a post-occupancy evaluation (Den Heijer, 2011). The four Key Performance Indicators (KPIs) to measure a university's building performance with the twelve ways to add value will be explained below:

Profitability

The first KPI, profitability, is about examining the costs of campus investments, the allocation of resources that are spent on maintaining and developing real estate, and the financial value that the campus represents (Den Heijer, 2011). The three ways to add value for this KPI is controlling risks, increasing real estate value, and decreasing costs, as shown in figure 4.4. The stakeholders for this KPI are the controllers as shown in figure 4.5.

Productivity

This KPI productivity assesses the number and types of users that the real estate and the campus is required to accommodate. Key indicators are occupancy rates and frequency rates of space occupation, and the user satisfaction of the campus (Den Heijer, 2011). The three ways of adding value, as shown in figure 4.4, are increasing flexibility, increasing user satisfaction, and supporting user activities. The stakeholders for this KPI are the users as shown in figure 4.5.

Competitive advantage

The KPI competitive advantage assesses how and to what extent the institutional goals on research, education, human resources, and valuation of knowledge are supported, achieved, or obstructed with the real estate portfolio (Den Heijer, 2011). For this KPI there are five ways to add value, shown in figure 4.4. These ways are improving quality of place, supporting image, supporting culture, stimulating innovation, stimulating collaboration. The stakeholders for this KPI are the policy makers as shown in figure 4.5.

Sustainable development

The last KPI, sustainable development, addresses the environmental performance of campus real estate. This perspective also addresses the quantity and quality of the current and future campus real estate, including the characteristics of the location, types of spaces, condition of the buildings, and the age of the buildings (Den Heijer, 2011). The ways to add value for this KPI is by reducing the footprint, as shown in figure 4.4. The stakeholders for this KPI are the technical managers as shown in figure 4.5.

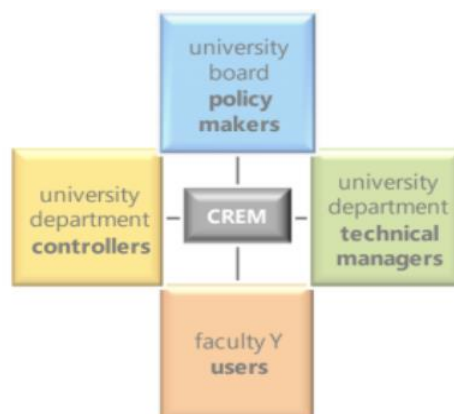


Figure 4.5: The four CREM stakeholders (Den Heijer, 2011)

The management of the university campus, similar as with the CREM theory, integrates four perspectives (Den Heijer, 2011). These four perspectives are: strategic, financial, functional, and physical. The four perspectives can be matched with the CREM theory and the four CREM stakeholders, this is shown in the figure 4.6. The policy makers align with the strategic perspective, the controllers align with the financial perspective, the users align with the functional perspective, and finally, the technical managers align with the physical perspective (Den Heijer, 2011). This framework, figure 4.6, is the basis for the required management information for campus decisions. The management of the campus is about involving the four stakeholders and connect their perspectives in both the management process and management decisions (Den Heijer, 2011). Therefore, the campus management framework was the basis for the project database created by Den Heijer (2011), which will be explained in the next paragraph.

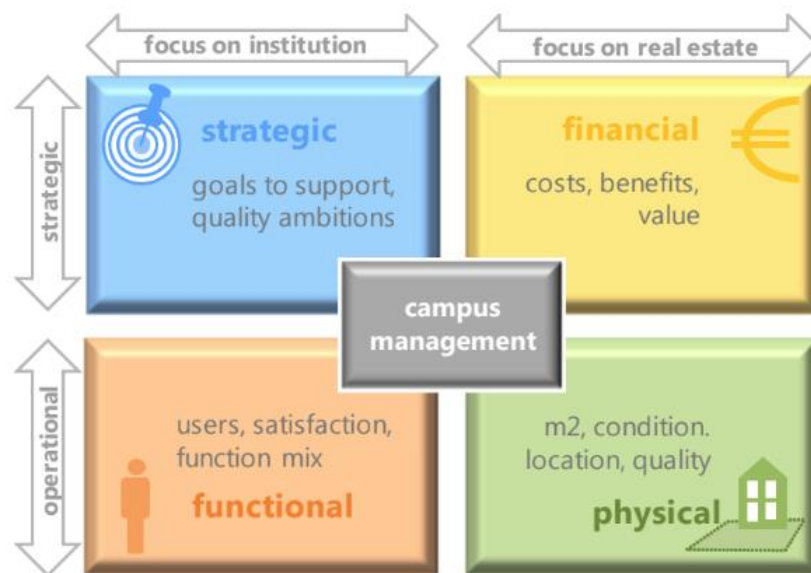


Figure 4.6: Campus management framework (Den Heijer, 2011)

4.3.2 Existing project database

Den Heijer (2011) developed a project database which will be the first starting point for the project database that will be created in this research. An example of a project from this database can be seen in figure 4.7. The database created by Den Heijer (2011) consists of thirty-nine university buildings from the thirteen universities in the Netherlands. Each building overview in the database is structured into three sections, as illustrated in figure 4.7.

The first section highlights the location, the location of the building on the campus map, the type of project, the year of construction, the main functions and the database shows an image of the project. The second section of the database contains a general description of the building. The third section presents the project profile in which the campus management framework is used to summarize the data from the four different perspectives. The strategic

data shows an indication of the quality ambition and what the goals are for the project. The financial data provides an overview of the investment costs, construction costs, and operating expenses. The functional data shows for whom the project is intended, so who are the users and how many students and staff fit in the building. Lastly, the physical data shows the space utilization and the spatial data of the project. This is demonstrated with the gross and usable floor area.

All data in the database was provided by the campus managers and their staff over a period of four years. In the empirical part of this research, it is examined if the process of creating a project database can be faster with the use of Artificial Intelligence. In this research, a similar overview per project will be used to develop the project database to maintain consistency and to be able to compare outcomes. So, the new database will consist of the same three sections as in the existing database by Den Heijer (2011).



Figure 4.7: Project from project database: J Building – Erasmus University Rotterdam (Den Heijer, 2011)

The second starting point for the development of a project database is the Campus of the Future FAIR Dataset created by Altinkaya Genel et al. (2023). This digital database is part of the output of the Campus of the Future project. This project proposes to develop evidence based decision-making strategies to match supply and demand for the future campus (Altinkaya Genel et al., 2023). The dataset provides decision-makers and researchers with the most relevant campus management data. A section from this project database can be seen in figure 4.8.

campus_no	project_name	link	area	year	location	architects	dominant_campus_theme	dominant_campus_theme_name	secondary_campus_theme_1	secondary_campus_theme_2	secondary_campus_theme_3	secondary_campus_theme_4	secondary_campus_theme_5	secondary_campus_theme_6	secondary_campus_theme_7	secondary_campus_theme_8	secondary_campus_theme_9	secondary_campus_theme_10	secondary_campus_theme_11	secondary_campus_theme_12	secondary_campus_theme_13	campus_theme	secondary_campus_theme_name
1	Department of Mechanical & Manufacturing Engineering / Grafton Architects	www.archdaily.com/875404	850	2002	Ireland	Grafton Architects	3	Academic mixed use		1		1				1							Learning environment, Laboratories, Circulation space
2	Politechnic School / Itaiqui Carreras	www.archdaily.com/631567		2002	Madrid, Spain	Itaiqui Carreras	2	Learning environment	1							1							Working environment, Circulation space
3	Lee School of Stochastic University / ARTS Group	www.archdaily.com/150861	150861	2003	Suzhou, China	ARTS Group	3	Academic mixed use								1							Circulation space
4	Chemical and Biological Library / Giuseppe Rebecchini	www.archdaily.com/1022260	1508	2003	Ferrara, Italy	Giuseppe Rebecchini	2	Learning environment					1					1	1				Heritage, Silence, Storage
5	Waterloo School of Architecture / Levitt Goodman Architects	www.archdaily.com/433771	7897	2004	Cambridge, Canada	Levitt Goodman Architects	3	Academic mixed use		1		1						1	1				Learning environment, Non-academic functions, Silence, Storage
6	AD Classics Stockman Gallery / O'Donnell + Tuomey	www.archdaily.com/795443	2300	2005	Cork, Ireland	O'Donnell + Tuomey Architects	5	Non-academic functions		1					1						1		Learning environment, Circulation space, Showroom
7	Central Library of the PUC Campinas / Piratininga Arquitetos Associados	www.archdaily.com/600007	5200	2005	Campinas, Brazil	Piratininga Arquitetos Associados	2	Learning environment										1	1				Silence, Storage
8	Free University's Philology Library / Foster + Partners	www.archdaily.com/648405		2005	Berlin, Germany	Foster + Partners	2	Learning environment										1	1				Silence, Storage
9	Paichai University Appenzeller Memorial Hall / IARC Architects	www.archdaily.com/119050	9883	2005	South Korea	IARC Architects	5	Non-academic functions		1													Learning environment
10	Markham Davis Center for Childhood Diabetes / Anderson Mason Dale Architects	www.archdaily.com/115412	110000	2005	Aurora, United States	Anderson Mason Dale Architects	4	Laboratories	1														Working environment
11	Sino-Italian Ecological and Energy Efficient Building / Mario Cucinella Architects	www.archdaily.com/880371	20000	2006	Haizhen Qi, China	Mario Cucinella Architects	3	Academic mixed use					1					1					Heritage, Sustainability
12	Faculty of Economics Ghent University / Kaveer De Geyter Architects + Stéphane Beel Architects	www.archdaily.com/430177	7241	2006	Ghent, Belgium	Stéphane Beel Architects, KOGA - Kaveer De Geyter	3	Academic mixed use		1								1					Learning environment, Sustainability
13	Homage to Architects / Atelier Serap	www.archdaily.com/207970	2006	2006	Lille, France	Atelier Serap	3	Academic mixed use															
14	Carroll A. Campbell Jr. Graduate Engineering Center at Clemson University / Mack Scogin Merrill Elam Architects	www.archdaily.com/128600	7897	2006	Greenville, United States	Mack Scogin Merrill Elam Architects	3	Academic mixed use	1	1		1	1						1	1			Working environment, Learning environment, Laboratories, Non-academic functions, Silence, Storage
15	University of New South Wales Law Building / Lyons	www.archdaily.com/101895	12000	2006	Sydney, Australia	Lyons	3	Academic mixed use	1	1										1	1		Working environment, Learning environment, Silence, Storage

Figure 4.8: Campus of the Future FAIR Dataset (Altinkaya Genel et al., 2023)

The dataset contains of 780 university campus buildings from universities over the world constructed between 2002 and 2022. The dataset highlights the project name, area, construction year, location, and the architects in the grey columns. The orange columns show the campus themes, which are the university buildings typologies (Altinkaya Genel et al., 2023). The campus themes are divided into the dominant theme and the secondary themes. The dominant theme is used to assign a function to each project and the secondary theme includes all the sub-functions of the projects.

By demonstrating 780 university buildings from all over the world, the database shows a diverse overview of university buildings. However, from a Dutch perspective, which is the focus of this research, the database by Altinkaya Genel et al. (2023) is incomplete. The database does not show all Dutch university buildings that have been constructed between 2002-2022. For example, for the year 2020 no Dutch university buildings have been incorporated in the dataset, while in this year the Aletta Jacobshal at University of Groningen, Tapijnkazerne at Maastricht University, and Plus Ultra II at Wageningen University & Research have been completed. Therefore, the database that will be developed for this research builds upon the existing two databases by further incorporating all Dutch university buildings that have been completed after 2010, because the database by Den Heijer (2011) includes buildings constructed till 2010.

Both the database from Den Heijer (2011) and Altinkaya Genel et al. (2023) will be included in the knowledge base of the Tailored GPT model to further strengthen the usefulness, robustness and relevance of this model through incorporating diverse university buildings.

One of the identified knowledge exchange barriers is the lack of shared databases and repositories (Birdi et al., 2020; Tzavides et al., 2020; Rego et al., 2009; Bektas et al., 2015). However, as explained in this paragraph, there are existing shared project databases about university real estate in the Netherlands and the rest of the world, one by Den Heijer (2011) and one by Altinkaya Genel et al. (2023). However, the database by Den Heijer (2011) only consisted of buildings up to 2010, making the database no longer up to date. And in the database by Altinkaya Genel et al. (2023) are not all Dutch university buildings included, making the database less relevant for people working at Dutch universities, which is mainly the scope of this research. Therefore, there is not necessarily a lack of shared databases and repositories but a lack of updated and relevant shared databases and repositories. Keeping a database up to date can also be done without the use of AI, however this is time consuming. Lack of time is already one of the most cited barriers to knowledge exchange (Rego et al. 2009; Bjorvatn & Wald 2020; Santos et al., 2012; Cvitanovic et al., 2014). Therefore, with the use of AI it is more time-efficient and therefore easier to keep the database up to date. This is the main barrier that will be tried to overcome in this research.

EMPIRICAL RESEARCH



5. Empirical research

This chapter entails the empirical research conducted to explore the role of Artificial Intelligence (AI) in enhancing knowledge exchange about university real estate buildings. It explores how AI can be utilized to create a knowledge database for university buildings. The chapter is structured according to the four steps outlined in the methodology: finding, collecting, creating an overview, and analyzing and identifying. The (AI) tool utilized for this research is ChatGPT, developed by OpenAI.

5.1 Finding

The first step in creating the knowledge database about university real estate buildings is: *“Using AI to **find** university buildings in open project databases and websites”*. Traditionally, finding university buildings requires a manual search of numerous websites, databases, and other documents. This process is subject to human error and can be time consuming. Artificial Intelligence (AI) can significantly improve this process by searching on multiple websites, databases, and documents at once, and by extending the reach of queries to a wide range of sources, including those that may be difficult to discover using traditional methods.

5.1.1 Data sources

To use AI effectively, it is important to target the right sources. AI can search these sources on its own or, if required, it is possible to target specific sources by asking AI to search from that source. These sources can include:

- Open project databases: Databases such as ArchDaily, Architect, Architizer, etc. are open databases that share information about all types of projects. The database consists of projects that are newly developed, under-development, or years old.
- Websites: Architectural, educational, and general news and media websites cover building developments and provide all kinds of information about these buildings.
- Institutional data: Publicly available datasets from government agencies or educational institutions can provide information on university construction, expansion, or renovation.
- Research databases: Research organizations, especially those focused on architecture and engineering, often publish case studies or reports on university campuses and their development.

5.1.2 Execution

To use AI to **find** university buildings, the right prompt should be made. This paragraph shows the steps taken to create the right prompt to quick and easily find university buildings. The results from the AI model are copied from ChatGPT without altering them to show how AI responds to the given prompts. The responses given by the AI model are checked for correctness, accuracy, and completeness.

As explained in the literature review on page 37, through prompt engineering it is possible to converse with Large Language Models (LLMs), such as ChatGPT. Prompt engineering is needed to optimize the performance of LLMs. According to Giray (2023) and Su (2023), there are six building blocks to make up a good prompt to consistently generate high quality outputs. These six buildings blocks, in order of importance, are:

1. Task (mandatory)
2. Context (important)
3. Exemplar (important)
4. Persona (nice-to-haves)
5. Format (nice-to-haves)
6. Tone (nice-to-haves)

The six buildings blocks are explained in paragraph 4.2.3 Prompt engineering. When generating prompts for the finding of university buildings, it is necessary to incorporate at least a task, context, and exemplar to create a prompt that generates high quality outputs. In the prompt engineering in this paragraph the building blocks will be used.

Prompt: 'find all university buildings built in 2022 in the Netherlands'

AI result:

1. **Langeveld Building at Erasmus University Rotterdam:** Opened in November 2022, this highly sustainable education building on the Woudestein campus is recognized for its focus on biophilic design and energy efficiency. With its innovative ventilation system and use of recycled materials, the building has achieved a BREEAM-Outstanding certification, making it one of the greenest educational buildings in the country.
2. **Echo Building at TU Delft:** Completed in July 2022, the Echo building is an interfaculty, energy-generating structure designed to support flexible learning spaces. It features 1,200 solar panels and advanced sustainable systems, enabling the building to generate more energy than it consumes.

Feedback:

This result that comes out of this prompt is correct. The two buildings given are the two buildings that are completed in 2022. Within this prompt, task is the only building block that is used. It would be useful to get the results in tabular form, this can be achieved with the format building block.

Prompt: 'find all university buildings built in 2023 in the Netherlands'

AI result:

1. **Matrix ONE** (Amsterdam Science Park) – This cutting-edge building opened in 2023 and is part of the Matrix Innovation Center. It was designed to promote sustainable innovation, housing various companies and facilitating collaboration between businesses and university research facilities. Matrix ONE emphasizes circular design, energy efficiency, and nearly 100% recyclability.
2. **Langeveld Building** (Erasmus University Rotterdam) – Completed in 2023, this multifunctional building was designed for flexibility and sustainability, accommodating the university's growing student population. It is BREEAM-Outstanding certified, meaning it meets the highest standards for sustainability, using natural ventilation, solar energy, and recycled materials. The building is part of the university's broader plan to develop a sustainable campus.

Feedback:

The result that comes out of this prompt is incorrect. The AI model again shows the Langeveld Building but this time it says that it is built in 2023, even though it has been built in 2022. The misunderstanding lies in the word 'built'. With this word, it is unclear whether it means that the building has been realized or that the building is still being built. Therefore, in the next prompts the words 'completed' and 'finished' are used.

Prompt: *'find all university real estate built and completed in the Netherlands between 2020 and 2024 and put it in a table'*

AI result:

	Building Name	University	Completion Year	Key Features
1	Echo Building	TU Delft	2022	Energy-generating, flexible learning spaces, sustainable design with 1,200 solar
2	Jakoba Mulderhuis	Amsterdam University of Applied Sciences	2022	Mass timber structure, circular economy principles, sustainability-focu
3	Langeveld Building	Erasmus University Rotterdam	2023	BREEAM Outstanding, energy-neutral, biophilic design
4	Marga Klompé Building	Tilburg University	2023	First mass timber lecture hall in Europe, circular design, energy efficiency

Table 5.1: University real estate built and completed between 2020 and 2024.

Feedback:

The result that comes out of this prompt is partly correct, because the AI model still misses a building. By adding the word '*completed*' into the prompt the result shows what the completion year for the buildings is. This almost tackles the misunderstanding of whether a building is still being built or if it is finished in a particular year. By adding 'put in a table' into the prompt the AI model makes a table of the results, which makes it easier to read, store, organize, and categorize.

Prompt: *'Find all university buildings completed in the Netherlands between 2020 and 2024 and put it in a table'*

AI result:

	Building Name	University	Completion Year	Key Features
1	New University Building	Vrije Universiteit Amsterdam	2021	Energy-efficient systems, sustainable design, future flexibility
2	Echo Building	TU Delft	2022	Energy-generating, flexible learning spaces, sustainable design with 1,200 solar
3	Jakoba Mulderhuis	Amsterdam University of Applied Sciences	2022	Mass timber structure, circular economy principles, sustainability-focus
4	Langeveld Building	Erasmus University Rotterdam	2023	BREEAM Outstanding, energy-neutral, biophilic design
5	Marga Klompé Building	Tilburg University	2023	First mass timber lecture hall in Europe, circular design, energy efficiency

Table 5.2: University buildings completed between 2020 and 2024.

Feedback:

The result that comes out of this prompt is correct. By removing the word ‘*built*’ the misunderstanding about whether a building is still being built or if it is completed in a particular year.

The result in table 5.2 was presented to the CampusNL campus contacts to verify, among other things, the completeness of the university building table compiled by the AI model. In this meeting the campus contacts were asked to let it be known if the AI model had forgotten any university buildings completed between 2020 and 2024. The campus contacts identified several projects completed between 2020 and 2024 that the AI model had overlooked. The missing projects according to the campus contacts are the following:

- Rölling Building, University of Groningen
 - Renovation project
 - Completed in 2023

- Logistics & Environment, Delft University of Technology
 - New built project
 - Completed in 2024
 - Not an educational building
- Gorlaeus Building 2a, Leiden University
 - New built project
 - First part was completed in 2016, and the second part was completed in 2024
- Neuron, Eindhoven University of Technology
 - Renovation project
 - Completed in 2023
- Aletta Jacobshal, University of Groningen
 - Expansion project
 - Completed in 2020
- Duboisdomein 30, Maastricht University
 - Transformation project
 - Completed in 2022
- Qubit: Eindhoven University of Technology
 - New built project
 - Completed in 2023

With the prompt: *‘Find all university buildings completed in the Netherlands between 2020 and 2024 and put it in a table’* the AI model was restricted to only look at newly built projects. As a result, projects involving renovations, expansions, and transformations were not included. Many of the projects mentioned by the campus contacts were not new built projects but were renovation, expansion, and transformation projects. That is why with this prompt the AI model has missed the buildings Rölling Building, Neuron, Aletta Jacobshal, and Duboisdomein 30.

In addition to overlooking renovations, expansions and transformations, the AI model also missed some newly built university projects completed between 2020 and 2024. This oversight is likely due to the specificity and scope of the sources accessed by the model, as well as potential gaps in open-access project databases. The Logistics & Environment building at the Delft University of Technology is not an educational building, for the AI model to also find this building it should broaden the scope to all campus real estate. The prompt was designed to retrieve data on completed university buildings and therefore relied heavily on the availability and categorization of projects in online databases with the labels completed university buildings. The other new-build projects, Gorlaeus Building 2a, Leiden University and Qubit, Eindhoven University of Technology, may not have been listed in accessible, or may have been categorized under broader project headings that did not clearly identify them as *‘completed’* or *‘university buildings’*. By better implementing the building blocks in the prompt, the buildings missed according to the campus contacts can also be found.

Prompt:

I am building a knowledge database about university real estate and therefore I need to find all university real estate built in the Netherlands to fill the database.

Find all university real estate completed in the Netherlands between 2020 and 2024.

The results should be put in a table and the table should contain of the building name, the university, the location, the year of completion, and a few key features.

AI result

Building name	University	Location	Year of completion	Key features
Echo Building	Delft University of Technology	Delft	2022	Energy-generating, flexible learning spaces, sustainable design with 1,200 solar
Langeveld Building	Erasmus University Rotterdam	Rotterdam	2022	BREEAM outstanding, energy-neutral, biophilic design
Marga Klompé Building	Tilburg University	Tilburg	2023	First mass timber lecture hall in Europe, circular design, energy efficiency
Herta Mohr Building	Leiden University	Leiden	2024	Circular renovation and extension with 11,400 m ² of space, lecture theatres, and libraries.

Table 5.3: University real estate completed between 2020 and 2024.

Feedback:

With this prompt, the building blocks have been incorporated. The context in this prompt is *‘I am building a knowledge database about university real estate and therefore I need to find all university real estate built in the Netherlands to fill the database’*. The task is *‘Find all university real estate completed in the Netherlands between 2020 and 2024’*. The format is *‘The results should be put in a table’*, and finally the exemplar is *‘the table should contain of the building name, the university, the location, the year of completion, and a few key features’*.

In this prompt it is not clear if it should be only new built projects or if it should also be renovation and transformation projects, therefore there are still projects that are missed, such as the Gorlaeus Building 2a. The year of completion is a point that the AI model struggles with. To counter this challenge, the next prompt asks for the buildings completed in a single year and the realized will be used instead of completed to make sure that the results should be realized buildings.

Prompt:

I am building a knowledge database about university real estate and therefore I need to find all university real estate built in the Netherlands to fill the database.

Find all university real estate realized in the Netherlands in 2024, encompassing new construction, renovation, and transformation buildings.

The results should be put in a table and the table should contain of the building name, the university, the location, the year of realization, and a few key features.

AI result:

Building name	University	Location	Year of realization	Key features
Utecht Science Park Expansion	Utrecht University	Utrecht	2024	Addition of state-of-the-art research facilities, sustainable design with energy-efficient systems, and expanded student housing to accommodate growing enrollment.
Erasmus University Medical Center Renovation	Erasmus University Rotterdam	Rotterdam	2024	Comprehensive modernization of medical research labs, integration of advanced healthcare technologies, and improved patient care facilities.
University of Groningen Library Transformation	University of Groningen	Groningen	2024	Conversion of historic library into a modern learning hub, featuring collaborative study spaces, digital resources, and preservation of architectural heritage
Delft University of Technology Sustainable Engineering Building	Delft University of Technology	Delft	2024	New construction focused on sustainable engineering practices, equipped with green roofs, solar panels, and rainwater harvesting systems
Maastricht University Campus expansion	Maastricht University	Maastricht	2024	Development of new academic buildings with flexible learning environments, emphasis on interdisciplinary research, and enhanced student amenities

Table 5.4: University real estate completed in 2024.

Feedback:

The results from this prompt are incorrect. The results are not university buildings, it seems that the focus is on expansion, renovation, and transformation areas. To counter this problem, the next prompt will use the word university buildings instead of university real estate.

Prompt:

I am building a knowledge database about university real estate and therefore I need to find all university real estate built in the Netherlands to fill the database.

Find all university buildings realized in the Netherlands in 2024, encompassing new construction, renovation, and transformation buildings.

The results should be put in a table and the table should contain of the building name, the university, the location, the year of realization, and a few key features.

AI result:

Building name	University	Location	Year of realization	Key features
Herta Mohr building	Leiden University	Leiden	2024	Circular renovation and extension with 11,400 m ² of space, lecture theatres, and libraries.
Gorlaeus Building (Phase 2)	Leiden University	Leiden	2024	New main entrance, advanced research and educational spaces, sustainable design elements.
Feringa Building	University of Groningen	Groningen	2024	New construction providing 64,000 m ² of space, state-of-the-art research facilities, lecture halls, and offices.

Table 5.5: University buildings completed in 2024.

Feedback:

To improve the accuracy of the AI results, the research found that searching for university buildings by specific year results in more accurate outcomes. For example, when the prompt focused solely on university buildings realized in 2024, the AI model correctly identified the three university buildings constructed during that year. When asking for multiple years at once, the AI model failed to identify all buildings realized in those years. Therefore, this approach will be applied for identifying university buildings realized in other years to ensure more accurate findings.

With the correct prompt, it has been possible to generate a list of university real estate buildings in the Netherlands. The list of Dutch university buildings has been verified through the campus managers and online availability of the university buildings per university. After the verification, the list has proven to be reliable, which means that with this prompt all university real estate buildings can be found. Therefore, the same prompt has been used to find university real estate buildings in the rest of Europe.

An effort has also been made to generate a list of university real estate buildings from the rest of the world. However, due to the vast number of universities and therefore university buildings in the world, compiling such a comprehensive list is even for AI too challenging. Therefore, a list with all university real estate buildings from all over the world has not been able to be quickly generated by AI.

5.2 Collecting

The second step in developing the project database about university real estate is: “Using AI to **collect** information about university real estate building”. This database builds upon the project database created by Den Heijer (2011), as explained in paragraph 4.3.2 of the Literature review chapter. This chapter explores how the new project database builds upon the existing project database and identifies what types of data are necessary in a project database. By doing so, this chapter answers the sub question: “*What knowledge do the campus managers need in a project database?*”.

5.2.1 Verifying reliability

Before collecting data about the university real estate, it is essential to ensure the reliability of the AI model in terms of data collection. To verify the reliability, a comparative analysis will be conducted using three projects from the project database by Den Heijer (2011) and one random university building not incorporated in the existing database. Using AI, data will be collected about the four projects to compare the results with the existing project database. This comparison aims to assess whether the AI model can collect data in way that aligns with the existing database and information and knowledge online and in documents.

By selecting three representative projects from Den Heijer’s (2011) database, each from a different university and another year of construction, the AI model will be tested. The key aspects that are evaluated are:

- Accuracy: is the AI model able to collect accurate and complete data that aligns with the existing data
- Relevance: is the AI model able to collect the most relevant data that aligns with the existing data

The four buildings that have been selected for the comparison are:

- the T Building at Erasmus University Rotterdam
- the Huygens Building at Radboud University Nijmegen
- the Bernoulliborg at University of Groningen
- Blind test: Building O at University of Antwerp

It should be considered that Den Heijer's (2011) database was created in 2011 and therefore the buildings included in the database are relatively older. As a result, there may be less information on these buildings available, which may affect the outcome of the comparison. After verifying the reliability of the data collection capabilities of the AI model, it is possible the collect data from the university buildings that have been listed in the previous step.

T Building at Erasmus University Rotterdam



Figure 5.1: T Building (Den Heijer, 2011)

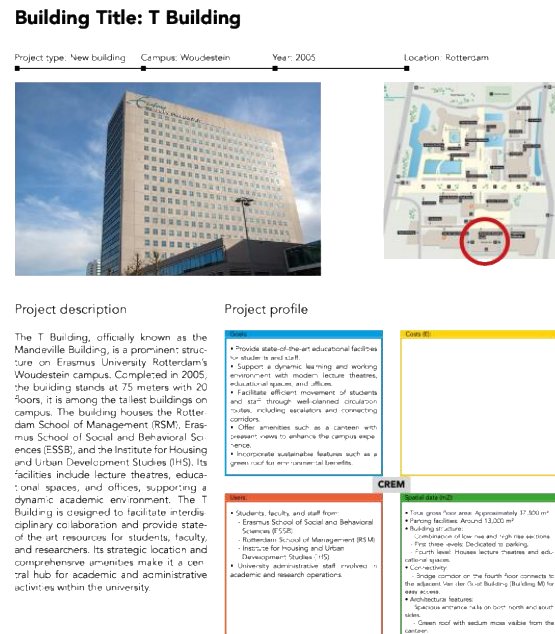


Figure 5.2: T Building (own work, 2025)

The first building selected for comparison is the T Building at the Erasmus University Rotterdam. The comparison highlights the similarities and the differences between the data from the existing database and data collected by the AI model in the updated database.

Comparing the two project overviews shows that the general building information, such as, location, year of construction, project type, facilities, architectural features, and the project description closely align between the two sources. The AI model demonstrates that it is capable to accurately identify the goals of the building and its users.

However, challenges arise when it comes to providing numerical data. For example, the existing database shows that the building's gross floor area (gfa) 46,100 m² is, while the AI model reports a total of 50,500 m² gfa. This difference could be attributed to the AI model retrieving its data from contemporary references, whereas the existing database uses sources from 2011 and older. Similarly, while the existing database includes exact numbers for the number of users and other spatial data, the AI model struggles to retrieve these specific numbers, because they are not stated online or in public databases.

Additionally, the AI model is unable to provide data about the costs of the building. Building costs is usually information that is not publicly accessible, which makes it difficult for the AI model to retrieve this data. As a result, the cost quadrant in the AI-generated overview remains empty.

Huygens Building at Radboud University Nijmegen

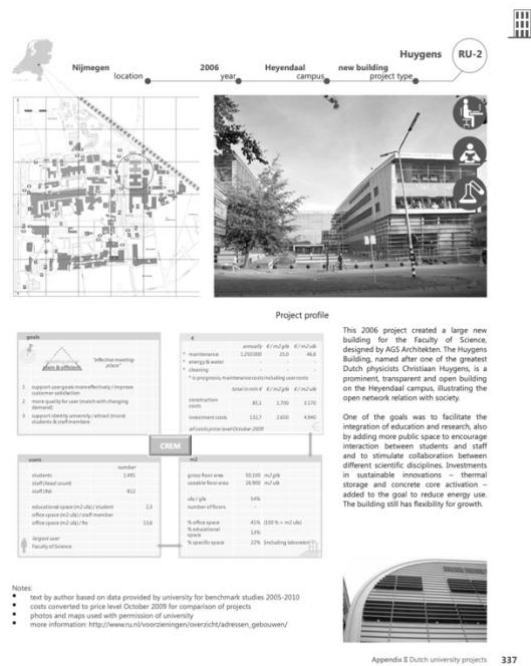


Figure 5.3: Huygens Building (Den Heijer, 2011)

Building Title: Huygens Building

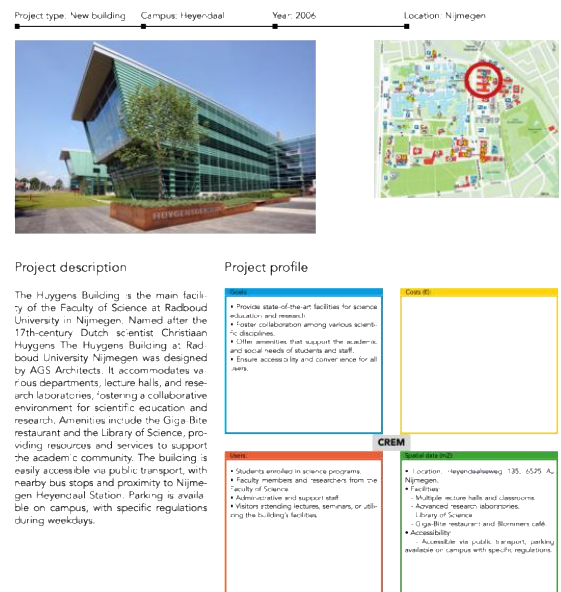


Figure 5.4: Huygens Building (own work, 2025)

The second building selected for comparison is the Huygens Building at the Radboud University in Nijmegen. Similar observations apply for this comparison as with the T Building. The general information collected by the AI model align closely with the existing database. The AI model successfully identifies the goals and the types of users of the building. But, again, it struggles with retrieving exact numerical data.

For instance, while the existing database provides exact numbers for the users and spatial data, the AI model in this case is not able to find any numerical data. Additionally, like with the T Building, the AI model is unable to retrieve cost related data due to its limited access to such information.

Despite these limitations, the AI model shows that it is capable in retrieving relevant general building information and understanding the purpose of the building, while keeping in mind that these buildings are older and therefore there is less information and data available for these buildings.

Bernoulliborg at University of Groningen



Figure 5.5: Bernoulliborg (Den Heijer, 2011)

Building Title: Bernoulliborg



Figure 5.6: Bernoulliborg (own work, 2025)

The third building selected for the comparison is the Bernoulliborg at the University of Groningen. This the newest building of the three building, with a construction year of 2007.

As with the previous comparisons, the AI model is able to retrieve data about the general building information that aligns with the existing database. Additionally, the AI model successfully identifies the goals and functions of the building.

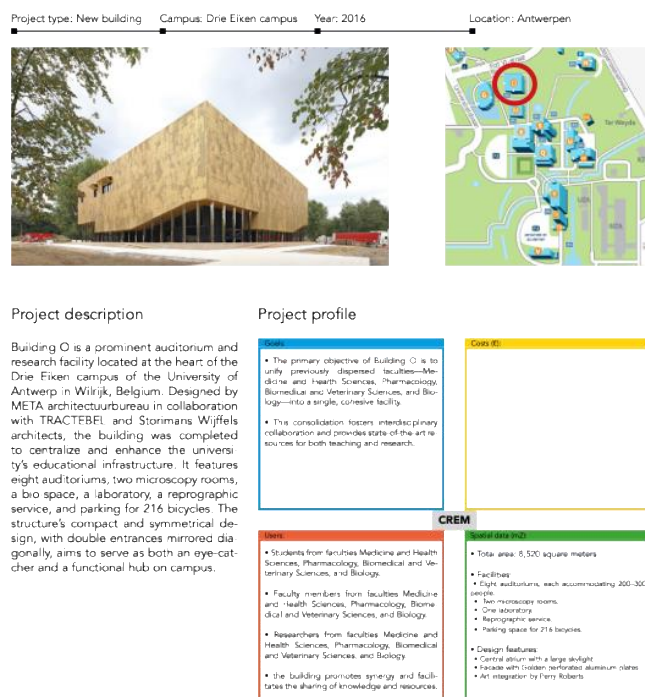
In this case, the AI model was able to retrieve numerical data about the building. The number of students and staff using the building, 500 and 307 respectively, closely matches the numbers from the existing database, which are 537 students and 248 staff members. Besides the numerical data for the users, the AI model also retrieved numerical spatial data. The stated data by the AI model, a gross floor area (gfa) of over 10,000 m², closely aligns with the gfa described in the existing database, which is a gfa of 12,000 m². Furthermore, the AI model successfully identifies and retrieves numerical data about facilities that are in the building, such as lecture halls, classrooms, computer labs, and a restaurant.

However, as observed in the previous comparisons, the AI model still struggles to retrieve cost related data. This limitation shows an ongoing challenge for the data collection with an AI model.

Blind test: Building O at University of Antwerp

The final step to verify the reliability of the AI data collection is the blind test. In this verification test, it looks at whether the AI-model can collect data from a random university building that has not been incorporated in the database by Den Heijer (2011) and Altinkaya Genel et al. (2023). This helps determine whether the AI model can find and collect accurate data independently, without relying on data from the existing databases. The university building used for this verification test is Building O at the University of Antwerp. The results from the AI data collection can be seen in figure 5.7.

Building Title: Building O



The verification of building O has been done on the same six variables as with the other three comparisons. So, the comparison has been done on the general building information, project description, strategic data, financial data, functional data, and physical data.

The data collected by the AI-model as shown in the figure 5.7 has been compared to information available online, in reports, and in documents about Building O.

Figure 5.7: Building O (own work, 2025)

All data collected by the AI-model is correct and aligns with the information and knowledge found online and in documents about Building O. In this case, the spatial data has also been retrieved. The numerical data given, such as the total area (8520 m²), the number of facilities, and number of bicycle parking spaces (216), are all accurate. This shows that when these types of knowledge are available, the AI-model is capable of retrieving it. However, as with the other three comparisons, the AI-model was unable to retrieve data about the costs of the building. The financial information is, as with the other three buildings, not available online and therefore not retrievable. However, the collected data demonstrates that the AI-model is capable of retrieving information about a random university building, showing relevant explicit knowledge.

In conclusion, the comparison demonstrates that out of the six variables in the existing database: general building information, project description, strategic data, financial data, functional data, and physical data, the AI-model is capable of successfully retrieving four variables: general building information, project description, strategic data, and functional data, as demonstrated in table 5.6. With the physical data as knowledge that is sometimes retrievable. In all three the comparisons, the AI-generated data aligns closely with the existing database by Den Heijer (2011) and in the blind test all collected data is accurate. This shows that the AI model is capable in retrieving such data for the creation of a project database.

However, difficulties arise in retrieving the numerical data. The AI model struggles with collecting numerical data about the users and the spatial data, while the existing database does show these types of data. The AI model is capable of providing some numbers for spatial and occupancy data, as with the Bernoulliborg and Building O, but the accuracy varies, this is likely because of differences in sources and availability of sources. The biggest limitation is that the AI model is unable to retrieve financial information, while the existing database does show information about the maintenance and construction costs. The reason for this limitation is that data about costs and finances are typically not publicly accessible.

These findings show that the AI model is capable of collecting data about university real estate. Additionally, it is likely that more recent buildings will have more data available, which could improve the accuracy of the numerical data retrieval. With the model's incapability of finding financial data, this type of data will have to be retrieved from the universities or campus managers if it is required in the database.

	T Building	Huygens Building	Bernoulliborg	Building O
General building information				
Project description				
Strategic data				
Financial data				
Functional data				
Physical data				

Table 5.6: Comparison existing and new database and blind test (own work, 2025)

5.2.2 Collecting by means of the existing database

Now that it has been established that the AI model is reliable in collecting data and that it becomes more reliable as the buildings get younger, the data about university real estate can be collected. The project database by Den Heijer (2011) contains buildings constructed up to 2010. Therefore, the new database will consist of buildings constructed between 2011 and 2024.

Since the new project database builds upon the project database created by Den Heijer (2011), as explained in paragraph 4.3.2 of the Literature review chapter, the structure and types of information and knowledge that will be collected is similar. This entails that the updated database will consist of the same three sections as in the existing database, so general building information, general building description, and the project profile containing the campus management framework summarizing the data from the four different perspectives: strategic, financial, functional, and physical. In addition to these types of knowledge and information, the updated database will also incorporate relevant data identified by campus managers. This will be explained in the next paragraph.

5.2.3 Necessary knowledge

Since campus managers are the intended users for the project database, their expertise is essential in determining the most relevant knowledge for the database. Therefore, the new database will incorporate both the types of data from the existing database and additional types of data identified by the campus managers. This paragraph explores which knowledge is relevant in a project database according to campus managers. By doing so, this paragraph answers the sub question: *“What knowledge do the campus managers need in a project database?”*.

Interviews

The interviewees that were interviewed for the research are all working in campus management and participate in the Campus NL research project. Seven people have been interviewed for this research. The functions of the interviewees vary between manager development, policy officer, project leader real estate, account manager campus facilities, and chief consultancy & projects but they are all concerned with university real estate. The function per interviewee and whether a database is beneficial for their work is shown in table 5.7.

After accepting the invite for the interviews, the interviewees received information about the research, the interview, and the informed consent, see Appendix II: Informed consent. In this document it is made clear what the research is about, how the interview is structured, and what questions they can expect during the interview. In addition, in the informed consent form information is given that participation is voluntarily, and how the data from the interview is processed and publicized.

The interviews were recorded by using audio devices and the audio was used to transcribe the interviews. With the transcription, the data from the interviews was processed. The transcripts are analyzed on five components. These components are:

- Knowledge exchange barriers on technological level
- Knowledge exchange drivers on technological level
- Additional knowledge exchange barriers and drivers
- The existing database by Den Heijer (2011)
- Necessary knowledge for in the database

Results

The results from the interviews are summarized in Table 5.8. This table shows the five components and shows whether the interviewees discussed the topics related to each component. By analyzing the data, insides can be gathered to understand how knowledge is exchanged within the university of the campus managers, which barriers and drivers on a technological level they encounter, additional knowledge exchange barriers and drivers they encounter, their familiarity about the database developed by Den Heijer (2011), and the types of knowledge the campus managers consider necessary in a project database.

Interviewee	Function	Database is beneficial for work
I-1	Policy officer	Yes
I-2	Project leader real estate	Yes
I-3	Manager development	Not directly, but could be beneficial
I-4	Chief consultancy & projects	Yes
I-5	Policy officer	Not directly, but could be beneficial
I-6	Manager development	Yes
I-7	Account manager campus facilities	Yes

Table 5.7: Function interviewees and beneficially of database for their work (own work, 2025)

Table 5.7 shows whether a database would be beneficial for the work of the interviewee. It can be seen that, except for interviewee-3 and -5, the interviewees deem a database beneficial for their work. Interviewee-3 and -5 both mentioned that they do not directly work with real estate projects, but in the case of interviewee-3 the use of the buildings and in the case of interviewee-5 the policy. However, they both mentioned that it could be interesting and useful to see how other universities approach certain topics. In that way a database could also be beneficial for their work.

	I-1	I-2	I-3	I-4	I-5	I-6	I-7
Knowledge exchange barriers on technological level							
Lack of shared databases and repositories							
Lack of training							
Unnecessary information							
Unrealistic expectations							
Knowledge exchange drivers on technological level							
Utilization of technology							
Centralized knowledge repository							
Additional knowledge exchange barriers & drivers							
Collaboration (driver)							
Lack of motivation and time (barrier)							
Different processes (barrier)							
Existing database by Den Heijer (2011)							
Familiarity with existing database							
Active use of the existing database							
Necessary knowledge for in the database							
Energy performance of the building							
Architect & Constructor of the building							
Facilities in the building							
Timeline of the building process							
Search function							
Innovations in the building							
Building manager							
Dos and don'ts							
Comparing buildings							
Building costs							
General building information							
Building function							
Function division							
Spatial data							
Project image							
Comment function							

Table 5.8: Barriers, drivers, and knowledge mentioned by interviewees (own work, 2025)

Knowledge exchange barriers on technological level

As discussed in the literature review, the focus of this research is on the barriers and drivers on a technological level as identified by Rego et al. (2009). Therefore, it is examined whether barriers on a technological level are encountered by the campus managers. The interview results indicate that, out of the four barriers on technological level identified in the literature, only one has been mentioned by the interviewees. The barrier, mentioned by three interviewees, is the lack of shared databases and repositories. For example, Interviewee-3 explained that when they were instructed to create pumping rooms on the campus, they missed a shared database in which they would have been able to retrieve information. Such a database would have allowed them to review how other universities have developed similar rooms and what elements are important when creating such rooms.

Additionally, interviewee-1 mentioned that the lack of shared databases is further complicated by the lack of flexibility in organizing the information in the database. Interviewee-1 stated that if there are insights that a user is looking for that are not included in a database or if the insights are compared in a different way, it can become difficult to retrieve relevant information. Therefore, for a project database to be beneficial for a campus manager, it should be well structured and made sure that the right information is included in a project database.

The findings suggest that the campus managers do not encounter many of the barriers on the technological level, but the barrier that they encounter is the lack of shared databases and repositories. This limitation hinders their ability to access relevant information from other universities. A well-structured database could help address this barrier and further enhance the exchange of knowledge.

Knowledge exchange drivers on technological level

The literature review identified two drivers on a technological level, utilization of technology and centralized knowledge repository. Both drivers have been mentioned in the interviews. Regarding the driver utilization of technology, Artificial Intelligence can play a role as a driving factor for knowledge exchange. Interviewee-7 emphasized the benefits of a closed AI-model where universities can collectively input and access relevant data.

“it would be nice if you had one of those closed AI-models where you just insert data which could be interesting for other universities. I do think you have to have a good authorization protocol to clarify who is authorized to use the model and with what purpose.”

- Interviewee-7

Similarly, interviewee-3 mentioned the potential of AI as a driving factor for knowledge exchange but also pointed out the importance of addressing security and ethical considerations of an AI-model.

“In an ideal world, if we leave security and ethical considerations out of it, then we could feed AI everything we have and then AI could offer a lot of opportunities. For example, what I said about the pumping rooms, AI could tell all about it and what it should look like.”

- Interviewee-3

The second driver for knowledge exchange, a centralized knowledge repository, has only been mentioned once during the interviews. Interviewee-2 mentioned that their organization can be quite conservative in a way that they keep working with their own databases and systematics, while the campus managers does recognize the benefit of exchanging knowledge and that a shared database can be a driving factor for the exchange of knowledge among universities.

Additional knowledge exchange barriers and drivers

In addition to the barriers and drivers on technological level, a few other barriers and drivers for knowledge exchange have been identified by the interviewees. The other barriers mentioned by the interviewees are lack of motivation and time, and different processes. Interviewee-2 questioned to what extent people are willing to share knowledge and that different systematics make the exchanging of knowledge difficult. The other driver mentioned during the interviews was collaboration. Several interviewees mentioned that the universities in the Netherland already engage in collaboration, especially through initiatives such as the Campus NL research project. This existing collaboration provides a strong foundation for the enhancing of the knowledge exchange among the universities.

Existing database by Den Heijer (2011)

During the interviews, the participants have been asked if they are familiar with the existing project database developed by Den Heijer (2011) and if they are familiar with the database, whether they actively use the database. While some of the interviewees stated that there is a lack of shared databases and repositories for the exchange of knowledge and others stated that centralized knowledge repositories can enhance the exchange of knowledge, only one interviewee actively uses the existing project database. The results indicate that only three interviewees are familiar with the database, which may explain why the database is not much used. However, interviewee-2 mentioned that he does not actively use the database, but that the database can be useful when looking for a certain project or a reference project.

“It is useful that if you are looking for a particular project or a particular reference that the database exists. It can give a good comparison. Therefore, it is good that with the new Campus NL research it will be updated again.”

- Interviewee-2

These findings suggest that, with the knowledge that five out of the seven participants agree that with the right utilization of technology and centralized databases the exchange of knowledge can be enhanced, awareness and accessibility of a project database should be increased. This could further enhance its effectiveness in supporting knowledge exchange among campus managers and universities.

Necessary knowledge for in the database

During the interviews, the participants have been asked what knowledge is necessary in a project database. The result can be categorized into three categories, necessary (mentioned five to seven times), important (mentioned three to four times), and supportive (mentioned once or twice). The categorized types of knowledge can be seen in table 5.8.

Necessary (5 to 7)	Important (3 to 4)	Supportive (1 to 2)
Energy performance of the building	Architect & Constructor of the building	Timeline of the building process
Facilities in the building	Spatial data	Search function
Comparing buildings		Innovations in the building
Building costs		Dos and don'ts
General building information		Function division
Building function		Project image
		Comment function
		Building manager

Table 5.9: Categorization of the types of knowledge (own work, 2025)

Energy performance of the building

The necessary knowledge is mentioned by at least five of the seven participants. Therefore, these types of knowledge should be included in a project database. The first necessary type of knowledge is the energy performance of the building.

“The energy performance is something that is becoming more and more important in buildings. What kind of energy label do they have? Is the building BREEAM certified or developed in accordance with BREEAM? Is the building BENG or ENG?”

- Interviewee-2

Since the energy performance of buildings is becoming more and more important, it is highlighted as a necessary type of knowledge according to the interviewees. Every building should be as energy efficient as possible and therefore, it can be beneficial if it is possible to see what the energy performance of another university building is. Interviewee-7 mentioned that everybody needs to show, monitor, and report more and more about the energy performance. By sharing insights into building energy efficient, universities can learn from each other and implement best practices for the development of sustainable and energy-efficient

buildings. Generally, a lot is written about the energy performance of university buildings, therefore it should be no problem for the AI-model to find this type of knowledge. The energy performance of the building is not highlighted in the existing database by Den Heijer (2011) therefore this type of knowledge can be classified as additional knowledge for the updated database.

Facilities in the building

The second necessary type of knowledge are the facilities that are in the building. This type of knowledge has been mentioned by six of the seven participants. Interviewee-4 stated that understanding which facilities are inside a building is relevant for gaining insights into the function and purpose of a building, so to understand what kind of building it is. According to interviewee-7, universities must make considerable cost savings. By analysing the facilities in other buildings and learning how different universities manage their spaces, universities can identify opportunities to reduce costs per building and improve space efficiency. In the existing database, the facilities of the building are not highlighted. Therefore, this type of knowledge is classified as additional knowledge.

Comparing buildings

The third necessary type of knowledge, which has been mentioned five times, is the ability to compare buildings within a project database. The comparison of buildings is something that is already possible in the existing database developed by Den Heijer (2011). Interviewee-1 emphasized that the primary function of a project database is to find buildings that are comparable to the project that is being developed. However, it is important that the building information in the database is comparable with each other, so the data in the database should be standardized and structured consistently.

“Provided it is information that you can compare, so comparing apples with apples. That would be a great addition.”

- Interviewee-2

Interviewee-7 highlighted that a project database can be very useful for benchmarking, allowing universities to see how another university developed something or how they solved a certain problem. He suggested that, rather than searching for a specific project, it could be beneficial to compare what the building characteristics are, examining what features other buildings have and how they align with the current project. Comparing buildings becomes easier with a well-structured database, since all relevant information is accessible in a single platform, therefore further enhancing knowledge exchange.

One of the main advantages of the AI-generated database is that the AI-model can efficiently extract data about university buildings from around the world. This capability increases the

chance of identifying relevant reference projects, making it easier to find suitable comparisons for campus development.

“With AI you can pass by any University in the world to find similar projects, yourself you would only look at the well-known universities, while the most suitable reference project might be from a very unknown University.”

- Interviewee-5

Building costs

The fourth necessary type of knowledge, mentioned by five participants, is the building costs. In the existing project database by Den Heijer (2011), information about the maintenance and construction costs is included. However, as discussed in paragraph 5.2.1 Verifying reliability, the AI-model is unable to extract financial data about university buildings. Therefore, in the project database created by the AI-model there will be no financial data. According to interviewee-1, the building costs is something that could be an interesting addition to a project database. However, showing the costs, such as investment costs, is not so easy. The main challenge lies in the differences in definitions and systematics used to calculate costs, making comparisons difficult. For a project database to include financial data, it is essential to establish a standardized approach that all universities follow to ensure consistency and comparability.

General building information

The fifth necessary type of knowledge is the general building information. This type of knowledge is about the location, year of construction, project type, facilities, architectural features, and the project description. Since this type of knowledge is already included in the existing project database and is mentioned by five participants, it remains included in the updated database. The AI-model is effective at retrieving this type of knowledge. As a result, the updated database will maintain the same structure as the existing database, regarding the general building information.

Building function

The last necessary type of knowledge, mentioned by six participants, is the building function. The portfolio of universities consists of a wide range of building types. Each of these building types have specific design needs, these different needs can influence the spatial layout, sustainability requirements, and the user capacity. Therefore, by highlighting what the function of the building is, campus managers can more effectively compare buildings with similar functions.

“How is the building used? What functions are in the building, so is it educational, research, meeting, offices? In order to benchmark.”

- Interviewee-4

Including what the function of a building is improves the usability of the database. Users can filter and search for buildings that align with their project needs. Since this type of knowledge is already included in the existing database, it will also be incorporated in the updated database.

Important knowledge

The second category for the knowledge mentioned by the participants is important knowledge. These are types of knowledge that have been mentioned by three to four interviewees. The types of knowledge in this category are the architect and constructor of the building and the spatial data of the building.

The architect and constructor are not systematically mentioned in the existing database, so it is classified as additional knowledge, but this type of data can easily be collected by the AI-model, therefore this type of knowledge will be included in the updated database. According to interviewee-2, knowing who worked on a building can help with issues they often face during the development of their own project.

“It can be useful to know who was present at a project, so who was the manager, the architect, or the installation consultant? Those are questions we often have, because you are often looking for something in a specific way that only they know.”

- Interviewee-2

The spatial data, static information, includes measurements such as gross floor area, useable floor area, and functional division. This data is important for understanding and comparing buildings according to interviewee-4. It can help campus managers assess space efficiency and identify potential space optimizations. This type of knowledge is included in the existing database but has been proven to be difficult to collect by the AI-model. However, if the AI-model successfully collects the spatial data then it will be incorporated in the updated database.

“In general, I think that static information can be stored in a database just fine, but dynamic information I find more difficult because it is usually outdated at the time of writing.”

- Interviewee-6

Supportive knowledge

The supportive knowledge, as shown in table 5.7, were mentioned by only one or two interviewees, making these types of knowledge less relevant for inclusion of the updated database. Out of the supportive types of knowledge the timeline of the building process, search function, innovations in the building, dos and don'ts, and building are additional knowledge, so these are not included in the existing database.

This paragraph has answered the sub question: “*What knowledge do the campus managers need in a project database?*”. The types of knowledge that the campus managers need can be seen in table 5.7. Nine of those types of knowledge are additional knowledge, so not already included in the existing database. These types of knowledge will be validated with eleven campus managers in the next paragraph.

5.2.4 Additional knowledge

The nine additional types of knowledge have been validated with eleven campus managers from eleven different universities in the Netherlands during a Campus NL campus contact meeting. The campus managers were asked to identify which of the additional types of knowledge they considered important in a project database. The results can be seen in figure 5.7.

The findings indicate that the energy performance, facilities, and comparing buildings are among the types of knowledge that are deemed most important in the project database. These types of knowledge were also categorized as necessary knowledge in the interviews. Remarkably, however, is that innovations in the building, initially classified as supportive knowledge based on the interview results, were deemed important by the campus managers. As a result, innovations in buildings will also be included in the updated database.

The types of knowledge that have been chosen by a maximum of five campus managers will not be incorporated in the updated database, except for the architect and constructor of the building. Despite receiving fewer endorsements by the campus managers, this type of knowledge was categorized as important knowledge in the interview results, and therefore, will be included in the updated database.

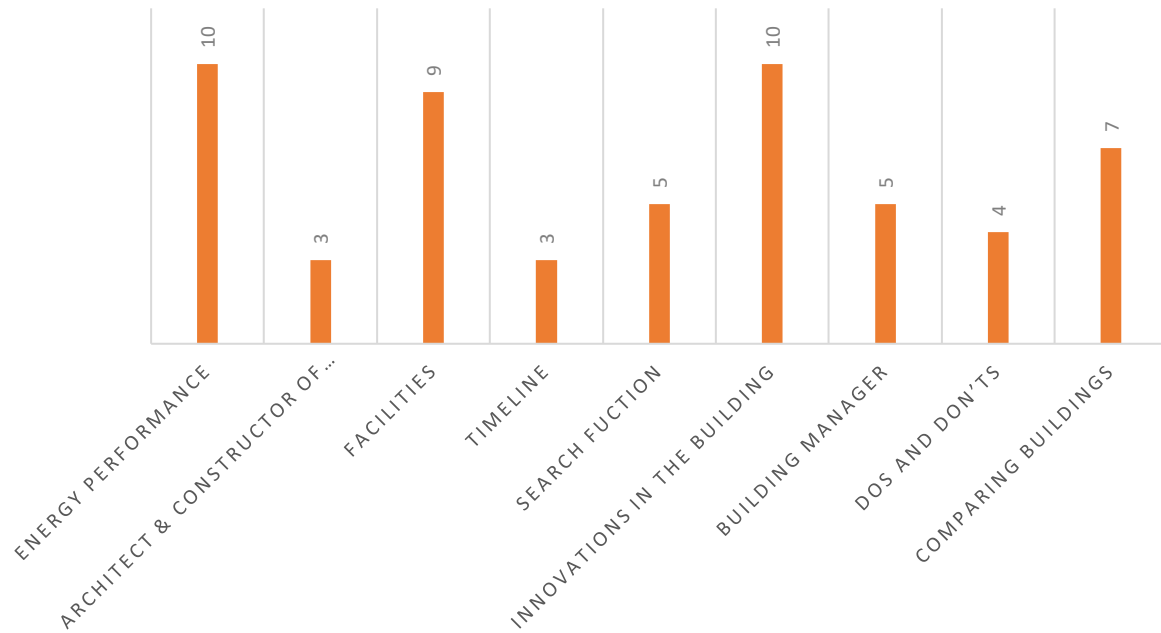


Figure 5.7: Validation of the nine additional types of knowledge (own work, 2025)

Now that the AI-model has been validated for its reliability in collecting data and which knowledge should be included in the updated database, the data can be collected. The updated database will consist of the types of knowledge from the existing database, including general building information, building function, project description, project goals, users, and the spatial data. Additionally, it will incorporate the additional knowledge that has been identified during the interviews and campus contact meeting: energy performance, facilities, innovations, and the architect and constructor of the building. In the next step, an overview per building will be created using the data collected in this step.

5.3 Creating an overview

The third step in developing the project database about university real estate is: *“Using AI to create an **overview** per building”*. With the results from the two previous steps an overview per building can be created. The data identified in the second step has been collected about the Dutch university real estate that has been found in the first step of the development of a project database.

“I think it is already beneficial to see what you can find online and bring that together. I think that would be a very nice first step in the right direction, and it could open doors to go a step further together and cross that threshold of whether or not to share certain information.”

- Interviewee-2

The AI-model is capable to perform the first to steps for the development of a project database. However, the AI-model is unable to directly create an overview per building based on the existing database by Den Heijer (2011). This means that while all the data is generated by the AI-model, the overview is made by hand. All the overviews of the Dutch university real estate buildings together form the project database, the database can be seen in Appendix VII: Project database. The updated database consists of 39 Dutch university buildings constructed between 2011 and 2024. The database by Den Heijer (2011) consisted of buildings realized up to 2010, so the updated database builds upon the existing database by adding the buildings realized after 2010. Table 5.9 shows how many university buildings are included in the database by Altinkaya Genel et al. (2023) and the updated database.

Year	Database Altinkaya Genel et al. (2023)	Updated database
2011	1 Building	1 Building
2012	2 Buildings	2 Buildings
2013	2 Buildings	2 Buildings
2014	2 Buildings	2 Buildings
2015	2 Buildings	4 Buildings
2016	2 Buildings	3 Buildings
2017	1 Buildings	1 Building
2018	1 Building	1 Building
2019	1 Building	1 Building
2020	0 Buildings	5 Buildings
2021	0 Buildings	0 Buildings
2022	0 Buildings	5 Buildings
2023	0 Buildings	5 Buildings
2024	0 Buildings	7 Buildings

Table 5.10: Comparison database Altinkaya Genel et al. (2023) and updated database (own work, 2025)

In the database by Altinkaya Genel et al. (2023), a total of 25 Dutch educational buildings were included. Out of these 25 educational buildings, 14 buildings are university buildings and constructed after 2010, these are shown in table 5.9. These 14 buildings have been incorporated in the updated database. In addition, all Dutch university buildings that were not included in the database by Altinkaya Genel et al. (2023) have been incorporated in the updated database to make the database more accurate and relevant. In table 5.9 it can be seen how many extra buildings per year of construction are included in the updated database.

Using AI, the updated database has been developed within a week. The database by Den Heijer (2011) was created in five years. This shows the time-efficiency of using AI. With the use of AI, it is easier to keep the database up to date, because it does not take a lot of time to update the database. A database that is up to date is more accurate, useful, and relevant for the users.

Now that the first three steps have been completed for university real estate buildings in the Netherlands, the same process can be executed for university real estate in the rest of Europe. This has resulted in 103 European university buildings. Expanding the dataset with information from European university buildings will enhance the knowledge base for the Tailored GPT, which will be developed in the next chapter. By collecting data about university buildings from the rest of Europe, the knowledge base of the Tailored GPT will be more extensive, thus resulting in more comprehensive and diverse knowledge for the campus managers using the Tailored GPT.

5.4 Analyzing and identifying

The fourth step in creating the knowledge database about university real estate is: *“Use AI to **analyze** and **identify** patterns, trends and innovations in university real estate buildings”*. The AI model created to analyze and identify the patterns, trends, and innovations is a Tailored GPT model called ‘University Real Estate Project Database’. The Tailored GPT can answer a variety of questions about university real estate, because the data that forms the knowledge base of the Tailored GPT is the data that has been found and collected in the previous steps. This chapter answers the fourth sub question: *“How can a Tailored GPT be developed to serve as a knowledge database about university real estate buildings?”*.

Campus managers or other stakeholders related to managing the university campus can use this Tailored GPT to ask many different types of questions they have about university real estate. With this Tailored GPT they can easily find reference projects, information about energy specifications, information about building functionalities, building costs, the building’s architect and constructor, etc. The Tailored GPT is evaluated in the next paragraph, where the model is tested on five subjects, in which multiple example questions are asked.

The Tailored GPT does not just provide the user with straightforward answers but first analyzes its knowledge base to provide accurate and valuable answers. The model can identify patterns, such as the shared features of energy-efficient buildings, it can identify trends, such as the increasing use of renewable energy on university campuses, and finally, it can identify innovations, such as new energy generating technologies used in university buildings.

By using this model, campus managers can easily gain knowledge about university buildings from different universities in the Netherlands and the rest of the world. When all universities utilize this GPT model, then the knowledge exchange barrier ‘Lack of shared databases and repositories’ can be overcome, resulting in the knowledge exchange drivers ‘Utilization of technology’ and ‘Centralized knowledge repositories’.

5.4.1 Tailored GPT evaluation

This paragraph delves into the evaluation of the tailored GPT model. The model will be evaluated and tested on five subjects, these subjects are: task-specific performance, domain expertise, contextual understanding, factual accuracy and reliability, and user experience.

5.4.1.1 Tailored GPT configuration

This section explains the configuration of the Tailored GPT model. It describes what the model is designed to do and provides guidelines on how it should behave and respond to questions. Additionally, it outlines the documents that have been used as the knowledge base for the model.

Name: University Real Estate Project Database

Description: This GPT is project database for university real estate. The purpose of this GPT is to assist campus managers in managing their portfolios. With this GPT, knowledge about university real estate can easily be exchanged.

Instructions: The campus manager using this GPT is the expert, but you are their assistant. Therefore, your primary role is to assist campus managers with their questions about university real estate. You should be able to answer question about university real estate such as the year of construction, the energy performance, features and functionalities of the buildings, building costs, building specifications, the building's architect and constructor, and dos and don'ts. You should provide clear and helpful answers to question and tasks asked about the projects. It is important that your answers are correct and that before providing an answer, you first analyze the datasets thoroughly to try to find the answer in the datasets. Whenever answers are found online cite the website used to ensure transparency and traceability in reporting.

Conversation starters:

-

Knowledge (.pdf):

- Building list Dutch university real estate
- Building list EU university real estate
- Building list World university real estate (FAIR Dataset Altinkaya Genel al. (2023))
- Dutch university real estate
- EU university real estate
- List of all Dutch university real estate

Capabilities:

- | | |
|--------------------------------------|-----|
| - Internet search | ON |
| - Canvas | OFF |
| - DALL·E-image generation | ON |
| - Code interpreter and data analysis | OFF |

5.4.1.2 Evaluation of the Tailored GPT model

1. Task-specific performance

The first area in which the model will be trained and tested are the task-specific performances. This includes accuracy, completeness, and relevance. Accuracy measures how well the model performs the tasks it was designed for and whether it provides correct answers to the questions. Completeness checks if the model provides comprehensive answers without leaving out important details. Finally, relevance ensures the model stays on topic, answering domain-specific questions without veering into unrelated information.

Accuracy:

In what year is the Echo Building built?



The Echo Building at TU Delft was completed in May 2022.

Who was the architect of the Echo Building?



The architect of the Echo Building at TU Delft is **UNStudio**.

Can you tell me something about the users of the Echo Building?



The Echo Building at TU Delft is designed to serve a diverse group of users, including the following:

1. **Students:**

- Echo provides over 300 study spaces for group work and self-study.
- The building features seven teaching rooms with flexible layouts, including a 700-seat lecture hall that can be divided into three separate rooms.

2. **Faculty Members:**

- Instructors utilize the flexible teaching rooms for delivering lectures, facilitating group discussions, and conducting project-based teaching.

3. **Administrative Staff:**

- The building includes office spaces for staff involved in the coordination and support of educational activities, ensuring the efficient operation of academic programs.

4. **Visitors and External Partners:**

- The transparent design of the building encourages engagement with the broader community, hosting debates, seminars, and collaborative events that attract visitors and industry partners.

This user-focused design fosters collaboration, education, and community engagement.

The model provided three correct answers, demonstrating the model's ability to verify information from the documents used as the knowledge base and deliver accurate responses. This result highlights the model's capability to cross-reference data effectively, ensuring consistency with the source material.

Completeness:

Can you list all university buildings that were built in Tilburg after 2010?



Here are the university buildings built in Tilburg after 2010:

1. **Faculty Club (2011):** A multipurpose pavilion for academic staff and guests, designed by Shift Architecture Urbanism. It includes a restaurant, meeting spaces, and views of the Oude Warande forest.
2. **CUBE (2018):** An education and self-study center designed by KAAN Architecten. It spans 11,000 square meters and includes a central indoor study plaza, lecture halls, and group study areas.
3. **Marga Klompé Building (2024):** Europe's first academic building constructed entirely from solid wood. It features lecture halls, self-study spaces, and nearly energy-neutral operations, designed by Powerhouse Company.

The answer is correct, these are the three university buildings constructed Tilburg after 2010. This demonstrates the model's ability to identify information accurately, ensuring a complete answer and not missing information in the answer.

Relevance: (correct)

What are the most common sustainability certifications for university buildings, and how do these certifications influence decision-making?



Common Sustainability Certifications for University Buildings:

1. **BREEAM (Building Research Establishment Environmental Assessment Method):**
 - Focus: Environmental performance, energy use, materials, waste, and occupant well-being.
 - Common in Europe and worldwide; ratings include "Good," "Very Good," "Excellent," and "Outstanding."
2. **LEED (Leadership in Energy and Environmental Design):**
 - Focus: Energy efficiency, water conservation, materials, and indoor air quality.
 - Globally recognized, with levels ranging from Certified to Platinum.
3. **WELL Building Standard:**
 - Focus: Health and well-being of occupants, including air quality, water, light, fitness, comfort, and mental health.

Influence of Certifications on Decision-Making:

1. **Design and Construction Choices:**
 - Certifications guide the selection of sustainable materials, energy-efficient systems, and designs that optimize natural light and ventilation.
 - Decisions aim to meet specific criteria for certifications, driving early integration of sustainability in design.
2. **Cost-Benefit Analysis:**
 - Helps assess the long-term savings from energy and water efficiency versus upfront costs of sustainable systems and materials.
 - Certifications like LEED and BREEAM can demonstrate return on investment (ROI) through operational savings.

When asked multiple questions in a single prompt, the GPT model stays focused and does not veer off into unrelated topics. The model stays focused on answering the specific questions within the domain.

2. Domain expertise

The second area in which the Tailored GPT model will be trained and tested is domain expertise, this entails terminology use and knowledge depth. Terminology use evaluates whether the model understands and applies domain-specific terminology correctly and whether it can answer questions about these terms accurately. Knowledge depth examines how well the model handles specific prompts, testing its ability to analyze and discuss patterns, trends, and innovations in detail.

Terminology use:

Can you explain the term 'gross floor area' and give me the GFA of the Echo Building?



What is Gross Floor Area (GFA)?

Gross Floor Area (GFA) refers to the total floor area of a building, including all spaces within its external walls. This measurement encompasses all usable and non-usable spaces, such as:

- Hallways
- Staircases
- Walls
- Mechanical rooms
- Restrooms

GFA is used to assess the overall size of a building for planning, construction, and compliance purposes, and it plays a crucial role in determining building costs, energy use, and functional capacity.

GFA of the Echo Building:

The Gross Floor Area (GFA) of the Echo Building at TU Delft is **8,844 square meters**.

To evaluate whether the model understands domain-specific terminology and can answer questions about those terms, it was asked about the term 'gross floor area'. The response shows that the model understands the concept and is able to explain it clearly. Therefore, this shows that the model is capable of handling domain-specific terminology effectively.

Knowledge depth:

What are some recent innovations in energy generating technologies in university real estate, and in which buildings has this been applied?



Recent Innovations in Energy-Generating University Real Estate

1. **Energy Academy Europe (EAE), University of Groningen:**
 - **Features:** The building is energy-positive, producing more energy than it consumes. Key innovations include:
 - A **solar chimney** for natural ventilation.
 - A **thermal labyrinth** for air pre-conditioning and energy storage.
 - A large roof covered with approximately 2,000 solar panels.
 - **Recognition:** Achieved BREEAM 'Outstanding' certification.
2. **Echo Building, TU Delft:**
 - **Features:**
 - Incorporates **1,200 solar panels**, effective insulation, and a thermal energy storage system.
 - The building produces surplus energy, including for user-related activities like lighting and laptop use.
 - **Purpose:** Supports the goal of creating a CO2-neutral and circular campus by 2030.
3. **Langeveld Building, Erasmus University Rotterdam:**
 - **Features:**
 - Operates energy-neutrally through a combination of solar panels, heat pumps, and underground thermal energy storage.
 - Features an innovative **Earth, Wind & Fire ventilation system** powered by natural elements.
 - **Recognition:** BREEAM 'Outstanding' certification.

These innovations highlight the commitment of universities to integrating advanced energy solutions into their real estate projects, driving sustainability while setting examples for eco-friendly construction.

To evaluate the model's depth of knowledge about university real estate, it was asked about recent innovations in energy generating technologies. The model effectively identified and explained the recent innovations in energy generating technologies while also cross-referencing these innovations with the university buildings included in the model's database. This demonstrates the model's capability to analyze and identify patterns, trends, and innovations relevant to the buildings it has information on. This shows that the GPT model can perform step 4 in the knowledge database development process: *"Use AI to **analyze** and **identify** patterns, trends and innovations in university real estate buildings"*. By meeting this requirement, the model proves to be a valuable tool for the creation of a knowledge database.

3. Contextual understanding

The third area of evaluation for the Tailored GPT model is contextual understanding. This area focuses on the model's ability to maintain coherence in the dialogues and the model's adaptability to variations in phrasing and framing of the prompts. Coherence in dialogues ensures that the model understands long or complex prompts, while continuing context throughout the conversation to provide accurate and relevant responses. Adaptability tests how the model responds to prompts framed in different ways or different languages. The GPT model should respond correctly and consistently, regardless of how the prompt has been phrased or framed.

Coherence in dialogues: (incorrect)

First, list the buildings that were built in Delft after 2010, then list the buildings that were built in Eindhoven after 2010. Finally, explain which sustainability certifications those buildings have.



University Buildings Built in Delft After 2010:

1. Echo Building (2022):

- An energy-generating, interfaculty education building at TU Delft.
- Includes solar panels, thermal storage, and a flexible teaching layout.
- Building** (2024):
- A modular, sustainable building for laboratory supplies at TU Delft, featuring solar panels and green roofs.

Buildings Built in Eindhoven After 2010:

1. Atlas Building (Renovated in 2019):

- A transformation of a 1960s building at Eindhoven University of Technology (TU/e).
- Features advanced sustainable technologies, including a high-performance climate façade and geothermal energy.

2. **Qubit Building - A facility for quantum technology research at TU/e, including vibration-free underground labs and adaptable design.

Sustainability Certifications:

Building** (Delft):

- Emphasizes sustainability but does not specify a certification. It contributes to TU Delft's CO2-neutral campus goal.

2. Logistics & Environment Building (Delft): renewable materials and biodiversity enhancement but lacks mention of a formal certification.

3. Atlas Building (Eindhoven):

- Achieved **BREEAM 'Outwith a score of 96.01%, making it one of the most sustainable educational buildings globally.

4. Qubit Building (Eindhoven):

- While emphasizing sustainability, certification is mentioned.

5. MetaForum (Eindhoven):

- Features sustainable construction methods but does not specify a certification.

These projects reflect strong commitments to environmental responsibility, with certifications signaling world-class sustainability standards.

In the prompt the model was asked three related questions in a row to evaluate if the model can answer long and complex prompts. However, the response shows that the model struggled with this prompt. It made grammatical errors and incorrectly identified the university buildings built in Delft and Eindhoven after 2010.

Coherence in dialogues: (incorrect)

I want you to first list the building that were built in Delft after 2010, then list the buildings that were built in Eindhoven after 2010. Finally, I want you to explain which sustainability certifications those buildings have



Buildings Built in Delft After 2010:

1. **Echo Building (2022):**
 - Interfaculty educational building designed for sustainability with solar panels, thermal energy storage, and energy-positive operations.
2. **Logistics & Environment Building (2024):**
 - A modular building at TU Delft, integrating sustainable elements such as solar panels and green roofs.

Buildings Built in Eindhoven After 2010:

1. **Atlas Building (Renovated in 2019):**
 - A major renovation transforming the 1960s main building into a state-of-the-art sustainable facility at Eindhoven University of Technology (TU/e).
2. **Qubit Building (2023):**
 - A cutting-edge research facility for quantum technology at TU/e, featuring advanced sustainability and adaptability.
3. **MetaForum (2012):**

Sustainability Certifications of the Buildings:

1. **Echo Building (Delft):**
 - While focused on energy generation and CO2 neutrality, no formal sustainability certification is explicitly mentioned.
2. **Logistics & Environment Building (Delft):**
 - Highlights sustainable practices and biodiversity enhancement but lacks a specific certification.
3. **Atlas Building (Eindhoven):**
 - Achieved **BREEAM 'Outstanding'** certification with a score of 96.01%, setting a global benchmark for sustainable educational buildings.
4. **Qubit Building (Eindhoven):**
 - Emphasizes sustainability in design, but no explicit certification is mentioned.
5. **MetaForum (Eindhoven):**
 - Incorporates sustainable upgrades and adaptive reuse but does not cite a specific certification.

In a follow-up test, the model does not make grammatical errors and it correctly lists the buildings built in Delft. However, it still failed to provide all the buildings built in Eindhoven after 2010. These results indicate that while the GPT model performs well in certain areas, such as

identifying the sustainability certifications of the listed buildings, it is not capable to handle complex and long prompts correct and effectively.

Adaptability: Variations in how questions are framed

What are the goals for the Echo Building?



The Echo Building at TU Delft has several key goals:

1. **Accommodate Growing Student Numbers:** It provides additional educational spaces to meet increasing demand, including seven teaching rooms with flexible layouts and a 700-seat lecture hall that can be divided into three separate rooms.
2. **Enhance Educational Flexibility:** The building supports various teaching methods and study styles with over 300 study places for group work and self-study, fostering a dynamic learning environment.
3. **Achieve Sustainability Goals:** Echo is an energy-generating building, aligned with TU Delft's ambition to operate a CO2-neutral and circular campus by 2030. It incorporates solar panels, effective insulation, and a thermal storage system, producing more energy than it consumes.
4. **Promote Interfaculty Collaboration:** It serves as an interfaculty educational building, providing spaces for education, debates, self-study, and offices to enhance interdisciplinary interaction.
5. **Create an Open and Inviting Environment:** The transparent design allows visibility of educational activities, fostering community and engagement among students, staff, and visitors.

Can you provide insights into the goals of the Echo Building at the TU Delft?



The Echo Building at TU Delft is a groundbreaking facility that reflects the university's commitment to sustainability, innovation, and educational excellence. Its goals include:

1. **Supporting Growth in Student Numbers:**
 - Accommodates the increasing demand for educational spaces with seven teaching rooms and a versatile 700-seat lecture hall that can be divided into three separate spaces.
 - Includes over 300 study places, fostering environments for group work and self-study.
2. **Enhancing Educational Flexibility:**
 - The building is designed to support diverse teaching methods, from lectures to project-based learning and self-study.
3. **Achieving Sustainability:**
 - Echo is an energy-producing building, utilizing solar panels, effective insulation, and a thermal storage system. It generates more energy than it consumes, including energy for user-related needs like laptops, lighting, and catering.
 - This contributes to TU Delft's goal of becoming a CO2-neutral and circular campus by 2030.
4. **Facilitating Interfaculty Collaboration:**
 - As an interfaculty education facility, it fosters interaction and cooperation among different departments through shared spaces for education, debates, and collaborative projects.
5. **Creating a Community-Oriented Space:**
 - The building's transparent and open design emphasizes visibility and accessibility, encouraging a sense of community and engagement among students, staff, and visitors.

To test adaptability, the same questions were asked in different ways. The model's responses were similar, showing it can handle variations in how questions are framed. This ability makes it a reliable tool for answering questions in different styles and phrasings.

Adaptability: Different language

In welk jaar is het Echo gebouw gebouwd?



Het Echo-gebouw van de TU Delft is gebouwd in **2022**.

Additionally, the model was tested with questions in a different language, in this case Dutch since the campus managers are Dutch. The model correctly interpreted the question and answered in Dutch. The multilingual adaptability of the model further enhances its usability.

4. Factual accuracy and Reliability

The fourth area of evaluation for the Tailored GPT model is factual accuracy and reliability. This area ensures that the model provides information that is trustworthy and correct. The aspect that is tested in this area is misinformation. A reliable model must not only deliver accurate information but must also identify and correct misinformation provided by the user. Identifying information ensures that the model's responses are valuable and credible.

Misinformation:

how many lecture halls does the Herta Mohr Building at TU Delft have?



The Herta Mohr Building is not located at TU Delft; it is part of Leiden University's Humanities Campus. It features **two large lecture halls**, among other facilities.

I heard that the Feringa Building covers around 70,000 square meters, and that sustainability is central but the building still uses gas to heat the building can you give me more information about that?



The Feringa Building at the University of Groningen covers approximately **64,000 square meters**, not 70,000 square meters as suggested. It is specifically designed to support cutting-edge research and education in fields such as chemistry, nanotechnology, and materials science.

Sustainability Features:

1. **Fully Gas-Free:** Contrary to the claim about using gas, the Feringa Building is entirely gas-free, aligning with modern sustainability standards.
2. **Solar Panels:** The building incorporates **900 square meters of solar panels** to harness renewable energy.
3. **Efficient Climate Control:** Advanced climate control systems have been implemented to maintain energy efficiency.
4. **BREEAM Certification:** It aims for a BREEAM-NL 'Very Good' certification, which reflects its strong commitment to environmental responsibility.

When there is information in the question that is incorrect, the model does not assume that what the users' states is correct, but it bases its knowledge on the documents that have been provided to the model. The model corrects the misinformation stated in the questions.

5. User experience

The final area of evaluation for the Tailored GPT model is the user experience, which ensures that the interactions between the users and the model is effective and smooth. The three factors that are evaluated are clarity, responsiveness, consistency, and image generation. Clarity ensures that the responses of the model are easy to understand and free of unnecessary complexity, especially for non-expert users. Responsiveness measures how quickly and appropriately the model responds to the users prompts. Slow and vague responses can have a negative effect on the user experience. Consistency evaluates whether the model stays consistent when asked follow-up questions. In addition to textual answers, the model's ability to generate relevant and accurate images will be tested. This ability can enhance the user experience by making information visual.

Clarity:

I am looking for a reference project for a building made of wood, can you give me all university buildings constructed from wood



The **Marga Klompé Building** at Tilburg University in the Netherlands is a notable reference project for a university building made entirely of wood:

- **Material:** It is Europe's first academic building constructed entirely from solid wood, using a wooden load-bearing framework. This aligns with circular construction principles, enabling disassembly and reuse of materials.
- **Sustainability:** The building operates nearly energy-neutrally, supported by solar panels, heat recovery systems, and underground thermal energy storage. It aims for a **BREEAM-Outstanding certification**.
- **Size and Functionality:** The facility spans multiple spaces, including 13 lecture halls and self-study areas, accommodating around 1,000 students daily.

If you'd like more details about this or similar projects, feel free to ask!

The clarity of responses is tested in every prompt the model answers. For this prompt, the clarity of the response is evaluated by asking for a reference project for a building made of wood, the model responded clearly. It identified a wooden university building and included details about its sustainability, size, and functionality. This shows that the model can provide clear and easy to understand answers.

Responsiveness:

I need a summary of two of the most energy-efficient university buildings in the Netherlands. Can you provide it?



Here is a summary of two of the most energy-efficient university buildings in the Netherlands:

1. Atlas Building (Eindhoven University of Technology)

- **Completion Year:** 2019
- **Energy Efficiency:**
 - Achieved a **BREEAM Outstanding certification** with a remarkable score of 96.01%.
 - Features a high-performance climate façade that regulates temperature and lighting intelligently.
 - Reduces **CO2 emissions by 80%**, exemplifying a commitment to sustainability.
- **Key Features:**
 - Intelligent lighting systems and energy-efficient ventilation.
 - Serves as a central hub for education and research, blending functionality with ecological responsibility.

2. Energy Academy Europe (University of Groningen)

- **Completion Year:** 2016
- **Energy Efficiency:**
 - Earned a **BREEAM Outstanding certification** with a score of 89.62%.
 - Fully energy-positive, generating more energy than it consumes through innovative design.
- **Key Features:**
 - Solar chimney for natural ventilation and a thermal labyrinth for efficient energy storage.
 - Designed to serve as a hub for energy research and education, focusing on sustainability at its core.

These buildings set benchmarks for sustainable architecture and operational efficiency in academic facilities, demonstrating the potential of modern design to address environmental challenges effectively. Let me know if you need more details!

The responsiveness of the model has also been tested in all interactions so far. It consistently provides quick and appropriate responses to the questions asked. For this specific responsiveness evaluation, the model was asked to provide two of the most energy-efficient university buildings in the Netherlands. The model provided the accurate answer within approximately eight seconds, demonstrating its ability to deliver quick and reliable information.

Consistency:

What is the role of 'adaptive reuse' in university real estate development?



Adaptive reuse plays a significant role in university real estate development by repurposing existing buildings for new functions, which aligns with sustainability goals, preserves cultural heritage, and supports evolving academic needs. Below are the primary roles of adaptive reuse in university real estate:

1. Sustainability and Environmental Impact

- **Reduced Resource Consumption:** Reusing existing structures minimizes the demand for raw materials and energy required for new construction.
- **Lower Carbon Footprint:** By retaining the building's core structure, adaptive reuse often produces fewer greenhouse gas emissions compared to demolition and new builds.
- **Circular Economy:** It embodies principles of circular design by extending the lifecycle of existing assets.

2. Preservation of Heritage

- **Cultural Continuity:** Many universities operate in historical buildings. Adaptive reuse allows for the preservation of architectural heritage while modernizing spaces for current use.
- **Identity and Branding:** Renovated heritage buildings can enhance the university's image by linking tradition with innovation.

3. Cost-Effectiveness

- **Budget-Friendly Development:** Adaptive reuse can be more cost-effective than constructing entirely new facilities, especially when factoring in demolition and material disposal costs.
- **Grants and Incentives:** Many governments offer financial incentives for sustainable development, including adaptive reuse projects.

4. Flexibility in Academic Space Planning

- **Meeting Modern Needs:** Buildings are often adapted to accommodate new teaching methodologies, advanced technologies, or interdisciplinary collaborations.
- **Dynamic Spaces:** Adapted structures often provide flexible spaces, such as multipurpose lecture halls, labs, or community hubs, to cater to evolving needs.

5. Community and Urban Integration

- **Revitalizing Urban Areas:** Repurposed university buildings can contribute to the regeneration of urban spaces, fostering closer ties between universities and their surrounding communities.
- **Improved Accessibility:** Adaptive reuse projects often integrate accessibility upgrades, aligning with inclusivity goals.

Can you give two reference projects in which adaptive reuse has been applied, one in the Netherlands and one outside the Netherlands?



Here are two reference projects highlighting **adaptive reuse**, one in the Netherlands and one outside:

1. Atlas Building (Eindhoven University of Technology, Netherlands)

- **Completion Year:** 2019
- **Adaptive Reuse Highlights:**
 - Transformed a 1960s-era university building into a sustainable and innovative educational hub.
 - Achieved **BREEAM Outstanding certification** with a score of 96.01%, significantly improving energy efficiency and reducing CO2 emissions by 80%.
 - Incorporates advanced technologies like a high-performance climate façade and intelligent lighting systems.
- **Usage:** Serves as a central education and research facility, showcasing how older buildings can meet modern academic and sustainability needs.

2. Mylly Building (University of the Arts Helsinki, Finland)

- **Completion Year:** 2021
- **Adaptive Reuse Highlights:**
 - Repurposed a historic industrial building into a state-of-the-art art and design education facility.
 - Retained elements of the original structure, including exposed brickwork and industrial features, while integrating modern studios and lecture spaces.
 - Focuses on blending historical character with cutting-edge facilities for creative disciplines.
- **Usage:** A vibrant academic space that respects its industrial heritage while supporting contemporary educational practices.

These projects demonstrate how adaptive reuse can preserve history while meeting the demands of modern university environments, with a strong focus on sustainability and innovation. Let me know if you need more information!

To evaluate whether the model maintains consistency, a follow-up question about adaptive reuse in university real estate was asked. With the first prompt, the model explained the concept of adaptive reuse, providing a clear definition. With the second prompt, it was assessed if the model could stay consistent in its explanation and apply the concept to relevant reference projects. The results shows that the model was able to use its initial explanation and apply it on example projects.

Image generation:

can you give an image of the marga klompé building?



Here is an illustration of the Marga Klompé Building at Tilburg University, showcasing its sustainable and innovative wooden architecture. Let me know if there's anything else you'd like to explore!

This is not an image of the Marga Klompé Building, can you give me a real image of the Marga Klompé Building?



The Marga Klompé Building at Tilburg University is Europe's first academic building constructed entirely from solid wood. This nearly energy-neutral facility spans 5,000 square meters and includes a foyer, auditorium, 13 lecture halls, and self-study spaces for approximately 1,000 students. Its design pays homage to the campus's modernist architecture, particularly the iconic Cobbenhagen Building, while emphasizing sustainability and circular construction principles.

ARCHDAILY

For more information and images, you can visit the following sources:

- Powerhouse Company's official project page: [POWERHOUSE COMPANY](#)
- ArchDaily's feature on the Marga Klompé Building: [ARCHDAILY](#)
- Tilburg University's official page: [TILBURG UNIVERSITY](#)

To evaluate the model's ability to generate accurate images, it was asked to give an image of the Marga Klompé Building. The first image that the model provided was an image that is generated by the model itself. While this demonstrates the model's capability to create images, it did not answer the question. After clarifying that the image should be an actual image of the Marga Klompé Building, the model gives the real image of the building, and it includes the references from where the information was retrieved.

5.4.2 Benefits

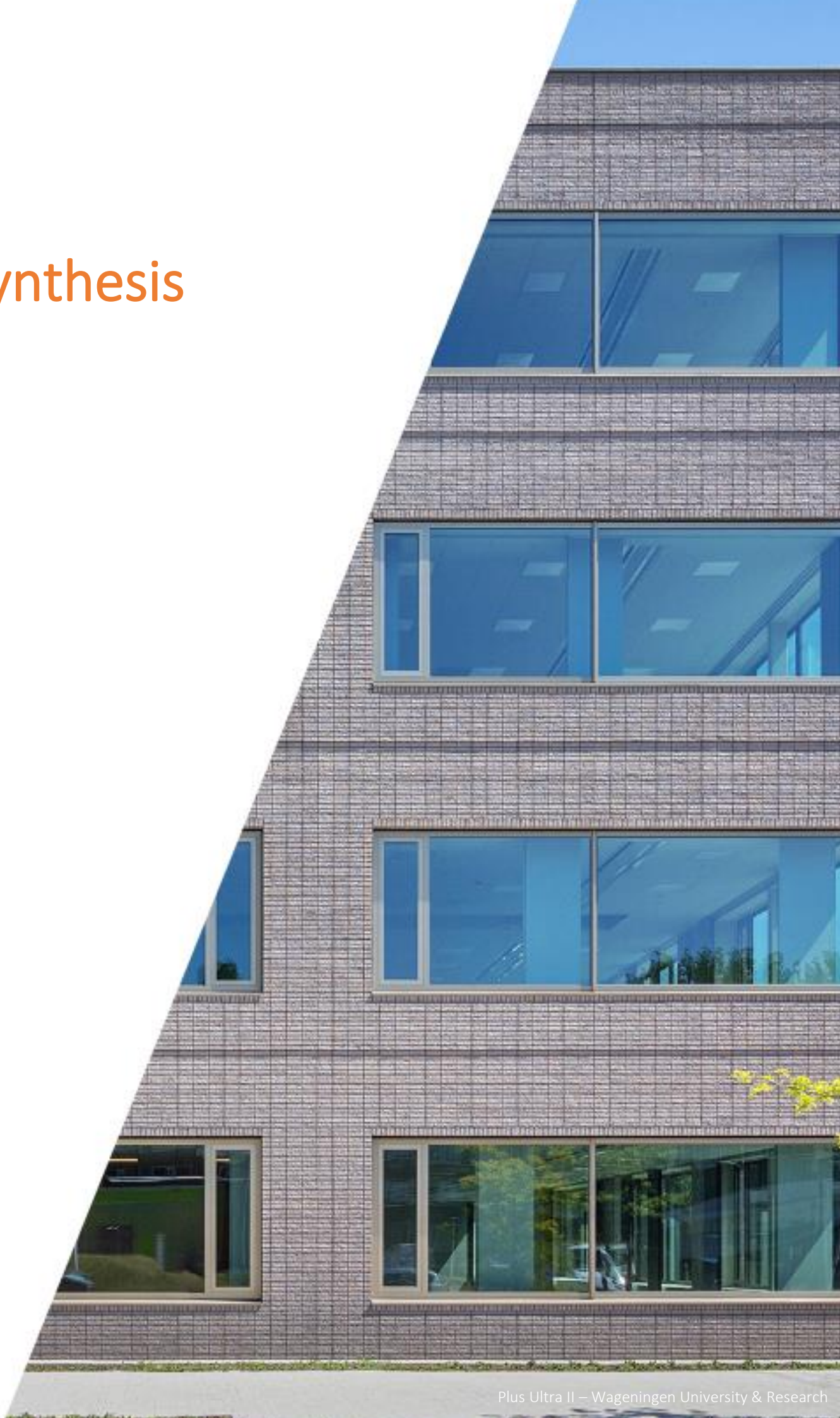
In the evaluation of the Tailored GPT it is demonstrated that the knowledge about university real estate is easily accessible, retrievable, and that the model is capable of analyzing the data. However, the question arises if this could not also be achieved through other tools without the use of AI, for example through the creation of a database in Excel in which searching for specific knowledge is also possible. This paragraph explores how the Tailored GPT model is beneficial compared to other tools that do not incorporate AI. As an example, Excel is used for this comparison.

One of the most frequently mentioned barriers to knowledge exchange by the literature is the lack of time (Rego et al., 2009; Bjorvatn & Wald, 2020; Santos et al., 2012; Cvitanovic et al., 2014). This shows that people do not have the time or do not allocate time for exchange of knowledge. While Excel is a useful tool for data structuring, it requires significant human input to fill, compile, and organize information. According to the literature, time-consuming processes discourage knowledge sharing (Rego et al., 2009). Therefore, for individuals to share knowledge it should be as easily accessible and retrievable as possible. This is one of the benefits of a tool that incorporates AI, such as the Tailored GPT. Instead of users manually searching through a database, the AI model can easily extract and collect relevant knowledge from large datasets using a single prompt. This reduces the effort required from users, making the exchange of knowledge more efficient and faster which could help the lack of time barrier.

When both Excel and a Tailored GPT are filled with the same data, users can retrieve and access knowledge from either tool. However, an advantage of the Tailored GPT is that it can generate human-like responses. Users can interact with the model using prompts, enabling easier access to information, but also the possibility to ask the model to further analyze the knowledge or identify innovations and trends, as demonstrated in the evaluation. In contrast, Excel relies on structured data inputs and formulas, and it does not interpret or respond to human like prompts or language in a contextual manner. Finding the right formula to extract the necessary knowledge from an Excel file can time consuming, while the Tailored GPT can respond within a minute to a question asked by a user.

Despite the advantages of AI, Excel remains superior in numerical data processing. The Tailored GPT model struggles with complex calculations and numerical accuracy, whereas Excel is designed for processing numerical data, computations, and numerical data analysis. Therefore, when dealing with large volumes of numerical data, Excel remains the preferred tool. However, for knowledge retrieval, identifying trends, analyzing data, the Tailored GPT provides significant advantages.

Synthesis



6. Synthesis

The goal of this research is to investigate how the exchange of knowledge between Dutch universities can be improved through the creation of a shared project database about university real estate projects. Further building upon the databases by Den Heijer (2011) and Altinkaya Genel et al. (2023), but through AI data collection improving time-efficiency, making it easier to update the database so that it remains complete and relevant. With this the research aims to further overcome the knowledge exchange barriers on a technological level and with that enable better collaboration and knowledge exchange among universities in managing their campuses.

Following the four steps that were set up for the development of the knowledge database, the project database and the Tailored GPT have been developed in the Chapter 5: Empirical research. The developed database has been evaluated and the Tailored GPT has been tested by five experts from universities in the Netherlands. The five individuals that evaluated and tested both tools are all working in the real estate department of a university in the Netherlands. They are all concerned with real estate on the university campus and are therefore potential users for both tools. Due to the confidentiality of the five individuals, they referred to as experts.

This chapter synthesizes the findings from the evaluation of the project database and the Tailored GPT model by the campus managers. The purpose of this expert panel was to assess the usefulness, accuracy, relevance, completeness, and limitations of these tools. After the results from the expert evaluations have been analyzed, recommendations for improving both the project database and the Tailored GPT model will be implemented. These improvements will focus on enhancing the criteria both tools have been evaluated on to further enhance and facilitate the exchange of knowledge of university real estate.

6.1 Evaluation of the project database

To evaluate the project database, the experts were asked to review a university building from their own university in the project database. They were asked to verify whether the information that was collected by the AI-model is correct, complete, and useful. The key criteria for evaluation included:

- Accuracy: Is the data about the building correct (general building information, project description, functions, project profile, and architect & constructor)?
- Completeness: Is the information complete or is there any missing or incorrect information that needs to be added or amended?
- Relevance: Does the database contain aspects and data that are relevant or is there data that would be relevant?

6.1.1 Results

The results on the three evaluating criteria for the project database are presented in this paragraph. The improvements for the project database mentioned in the results are discussed in the next paragraph.

Accuracy

The experts had varied feedback about the accuracy of the project database. Overall, most of the information and knowledge of the projects evaluated by the experts in the database are correct. Expert-5 confirmed that all data about of the building from their university is correct and that they could not identify any errors in the data.

However, expert-1 pointed out that the data on energy performance for their building is incorrect. In the database it is stated that the building is BREEAM certified, but according to the expert, they did not work with a BREEAM certification. However, they noted that they have also found this information themselves as well on the website of their project manager, AT Osborne. This suggest that two different sources, both involved in the construction process of the building, provided conflicting information and knowledge about the building, which the AI model then incorporated into the database.

Expert-2 also confirmed that the data about their building is correct, but they suggested that the way the data is presented could be improved. For example, data such as the gross floor area could be more clearly defined. Finally, expert-4 suggested that with using more precise definitions the clarity and accuracy of the database could be improved. Standardizing terms can help ensure consistency and with that improve that usability of the database.

Completeness

The experts acknowledged that the database is already quite complete, but they pointed out that the database mainly provides static information. The reason for this is because these are the types of knowledge that an AI-model is capable of retrieving. As explored in the empirical research, it is difficult for an AI-model to find dynamic data, such as numerical data, occupancy rates, real-time building performances, since this data usually not publicly available online.

“The data in the project database now feels quite static and the portfolio data could be more comprehensive.”

- Expert-2

While the project database already contains useful knowledge, further enhancing its scope by including more comprehensive data sets could make the database more valuable for the

campus managers to retrieve more knowledge. By integrating additional sources of data, such as direct input from universities and campus managers, the database could offer a more complete knowledge base. However, that is not the goal of this research, which is the development of an AI-generated database for the exchange of knowledge.

Relevance

The information that has been included in the database proves to be relevant according to the experts. However, expert-5 suggested that the database could be even more relevant if there would be more numerical data incorporated in the database. Again, this has been proven to be difficult by the AI-model and can therefore not be easily incorporated into the project database.

“As far as I am concerned, the information included is relevant and I would say the more information the better you can work with it.”

- Expert-5

Additionally, expert-2 mentioned that for improved usefulness and better decision-making capabilities the database should incorporate more real-time data. This would make data in the project database more detailed for portfolio management. This feedback further highlights the potential for future research in which alternative methods are explored for incorporating dynamic data into the project database, such as through direct input from the universities and the campus managers.

6.1.2 Improvements

The experts identified incorrect knowledge related to specific buildings from their university during the evaluations. These inaccuracies have been reviewed and have been corrected to ensure that the database is accurate and reliable.

According to the experts, the database could be improved by standardizing terminology across all buildings. When the terminology of all the buildings in the database is similar, then comparing the buildings will be more effective. While achieving complete uniformity in terminology is challenging due to the different terminologies used by different universities, an effort has been made to align the terms as closely as possible to facilitate an improved comparability of buildings.

Based on the expert feedback, one of the improvements that must be made is that the knowledge presented in the database is not always easily readable or clearly defined. Experts suggested that some information was not easily accessible due to its structure. To address this, adjustments have been made to ensure that the project database is more clearly structured, visually organized, and therefore easier to use. This has been done by more clearly categorizing

the types of knowledge and further standardizing the terminology and format. In addition, a reader's guide has been created for the users to understand how the project database is structured.

6.2 Testing of the Tailored GPT model

To evaluate the Tailored GPT model, the experts were asked to test and review the Tailored GPT model. They were asked to explore the functionalities and, by asking relevant questions, assess the quality and usefulness of the answers generated by the model. The experts evaluated the model on the following criteria:

- Clarity: Are the responses generated by the model easy to understand and well-structured?
- Usefulness: Are the responses useful and do they offer valuable insights?
- Accuracy: Are the responses and the information provided by the model correct and relevant?
- Limitations: Does the model provide inconsistencies or incorrect results? Or are there other limitations to the model?

6.2.1 Results

The results on the four evaluating criteria for the Tailored GPT model are presented in this paragraph. The improvements for the GPT model mentioned in the results are discussed in the next paragraph.

Clarity

The experts agreed that the responses generated by the GPT model are easy to understand and well-structured. Expert-5 highlighted that clarity is one of the biggest strengths of ChatGPT, the structured format of the responses allows the users to quickly understand the key points.

"This is, in my opinion, ChatGPT's greatest strength. Despite the fact that what is said is not always correct, ChatGPT manages to bring it well-structured."

- Expert-5

However, while the clarity is a strong point, expert-2 and expert-4 noted that the model does not always indicate which knowledge it has and which it does not have. It would be an improvement if the model would specify when it is unsure about certain information. For example, expert-2 asked the model about wheelchair accessibility, the model provided an answer without acknowledging its uncertainty about the topic and therefore providing wrong knowledge.

Usefulness

Most experts found the tool useful for gathering insights about a certain topic and gathering knowledge about university buildings from other universities. During the interviews expert-1 mentioned that at their university they are working on pumping rooms in the buildings. With the evaluation of the GPT model, expert-1 asked the model about pumping rooms at other universities in the Netherlands. The model was able to share knowledge on how pumping rooms have been developed at four other universities in the Netherlands. This response provided expert-1 a starting point for the development of pumping rooms at their university.

Expert-3 used the model to generate insights on the lessons learned about one of their university buildings. They aimed to apply those lessons learned to the planning and construction of a similar building at their campus. This shows that the GPT model is able to analyze and evaluate the building processes and identify areas for improvement, offering campus managers guidance and knowledge for future building projects.

Expert-4 stated that with this GPT model, finding the right knowledge certainly saves time. But expert-4 also wondered how often the data in the model is updated, for the model to stay relevant. For example, when buildings are renovated, the data should be updated otherwise the GPT model shares the wrong knowledge about a certain building. Therefore, updating the data and knowledge is important for the usefulness of the model.

Accuracy

The experts had mixed experiences with the accuracy of the responses by the GPT model. Expert-5 conducted two separate tests with model, resulting in two different outcomes. In the first conversation with the GPT model, almost none of the response were correct. During this conversation, mainly questions about numerical data were asked. Processing numerical data is something ChatGPT is not good at, which was also highlighted in paragraph 5.2.1 Verifying reliability. The responses in the second conversation were mostly correct and relevant.

“The model can generate static information, such as FNO data, well. Dynamic information, on the other hand, is more difficult for the model.”

- Expert-2

During expert-1's testing of the model, the GPT provided a few incorrect answers when asked about what additional university buildings the model knows from expert-1's university that are not including the projects database due to being built before 2011. This again demonstrates that instead of indicating that the model does not have the necessary knowledge, the model generates and shares the wrong knowledge with the user. This again highlights a key limitation of the GPT model, its drive to provide an answer even when lacking the right knowledge, rather

than indicating uncertainty or that it does not have the right knowledge. Addressing this issue is essential for the model's usefulness and accuracy.

On the other hand, expert-3 stated that they have not come across any wrong information or knowledge provided by the model during the testing of the GPT. Expert-3 did not ask any numerical data, which has been identified as a challenge for the model. This feedback demonstrates that the GPT model is effective in generating accurate responses when handling general knowledge and qualitative data.

Limitations

Through the expert evaluations, several limitations have been identified in the previous steps. The two major limitations are the model's inability to process numerical data and its tendency to provide an answer even though it does not possess the right knowledge. Furthermore, expert-2 and expert-4 pointed out that the model primarily relies on reports as the main source of information, but that certain data can also be retrieved from other systems, such as Topdesk. This might lead to inconsistencies and variations in the retrieved information. However, for the GPT model it is not possible to retrieve information from management systems of an organization. Additionally, some responses included irrelevant details, such as listing architects in building overviews where this knowledge was not necessary. This highlights the need for refining the model's ability to prioritize relevant knowledge and not provide unnecessary details.

The next paragraph will discuss the improvements that will be made to the GPT model to overcome the limitations.

6.2.2 Improvements

One major limitation is that the model does not indicate uncertainty about certain responses or that the model does not indicate when it does not possess the right knowledge, which can lead to misleading answers. This needs to be addressed to enhance the clarity, usefulness, and accuracy of the GPT model. In the configuration of the Tailored GPT, the model can be instructed on how to perform, behave, and what to do and what not to do. In this configuration the following instruction has been added to improve the honesty and transparency of the model:

"When you do not have the right knowledge or data to answer a question, clearly indicate that you are uncertain or that you lack the necessary information. Do this instead of providing a potentially incorrect response."

This adjustment ensures that the users receive more reliable responses and understand when the model is unable to answer. Showing when the users need for additional verification or alternative sources.

Another concern is that some experts asked how often the data for the model is updated. For the Tailored GPT to remain relevant it is important to update the knowledge base periodically to incorporate newly constructed or renovated buildings in the knowledge base.

Updating the knowledge base can be effectively done by following the four-step process outlined in this research. However, there needs to be an individual or research group, such as Campus NL, that is responsible for carrying out these updates. Given that the real estate industry evolves at a relatively slow pace, the knowledge base should be updated once or twice a year to maintain that the model is relevant. If a researcher from Campus NL or another dedicated individual or group takes on this role, the GPT model can remain a valuable tool for campus managers to use.

Another significant limitation is the GPT model's inability to process numerical data and response to questions regarding numerical data. Unlike other limitations that can be addressed through the configuration of the Tailored GPT, this issue lies within the AI model itself. Since AI is still in its infancy, processing numerical data is not yet possible. However, with the huge growth of AI in recent years, it cannot be ruled out that processing numerical data might not be possible in the near future.

USE OF AI IN RESEARCH



7. The use of AI in this research

The title of this research is: *“AI enhancing knowledge exchange about university buildings”*, this already indicates that Artificial Intelligence plays a fundamental role in this research. Throughout the research Artificial Intelligence has been explored. Because of this fundamental role, it is important to discuss the use of AI in this research. Therefore, this chapter explores how AI has been applied throughout the research process, highlighting how it was used for data collection, data processing, and assisting with writing. Finally, it discusses the ethical consideration of using AI.

7.1 Data collection

The goal of this research is enhancing the exchange of knowledge between Dutch universities by the quick and effortless creation of a shared AI-generated knowledge database about university real estate buildings. To achieve this, AI, specifically ChatGPT, has been used for the development of the database. This has been outlined in the four steps that were created for the development of the database:

1. Using AI to **find** university real estate buildings in open project databases and websites.
2. Using AI to **collect** information about university real estate building.
3. Using AI to create an **overview** per building.
4. Use AI to **analyze** and **identify** patterns, trends and innovations in university real estate buildings.

For the fourth step, ChatGPT was utilized to develop the Tailored GPT. This model is completely AI-driven and uses the knowledge collected in the previous steps as its knowledge base.

7.2 Data processing

In addition to the direct application of AI for the research, AI has also assisted with processing and analyzing data. In the literature review, the AI-model ChatPDF was used to assist with analyzing papers that were relevant for this research. This AI-model is designed to read, analyze, interpret, and extract information from research papers, allowing users to ask questions about the content of the papers. This model has helped with reviewing papers and finding the right and necessary knowledge for the literature review, improving the efficiency of the literature review process.

7.3 Assisting with writing

Finally, throughout the research process AI has been used as a supportive tool for writing and structuring content. ChatGPT was utilized to assist with generating ideas for how to write text, structuring paragraphs and chapters, and improving the overall quality and cohesion of text.

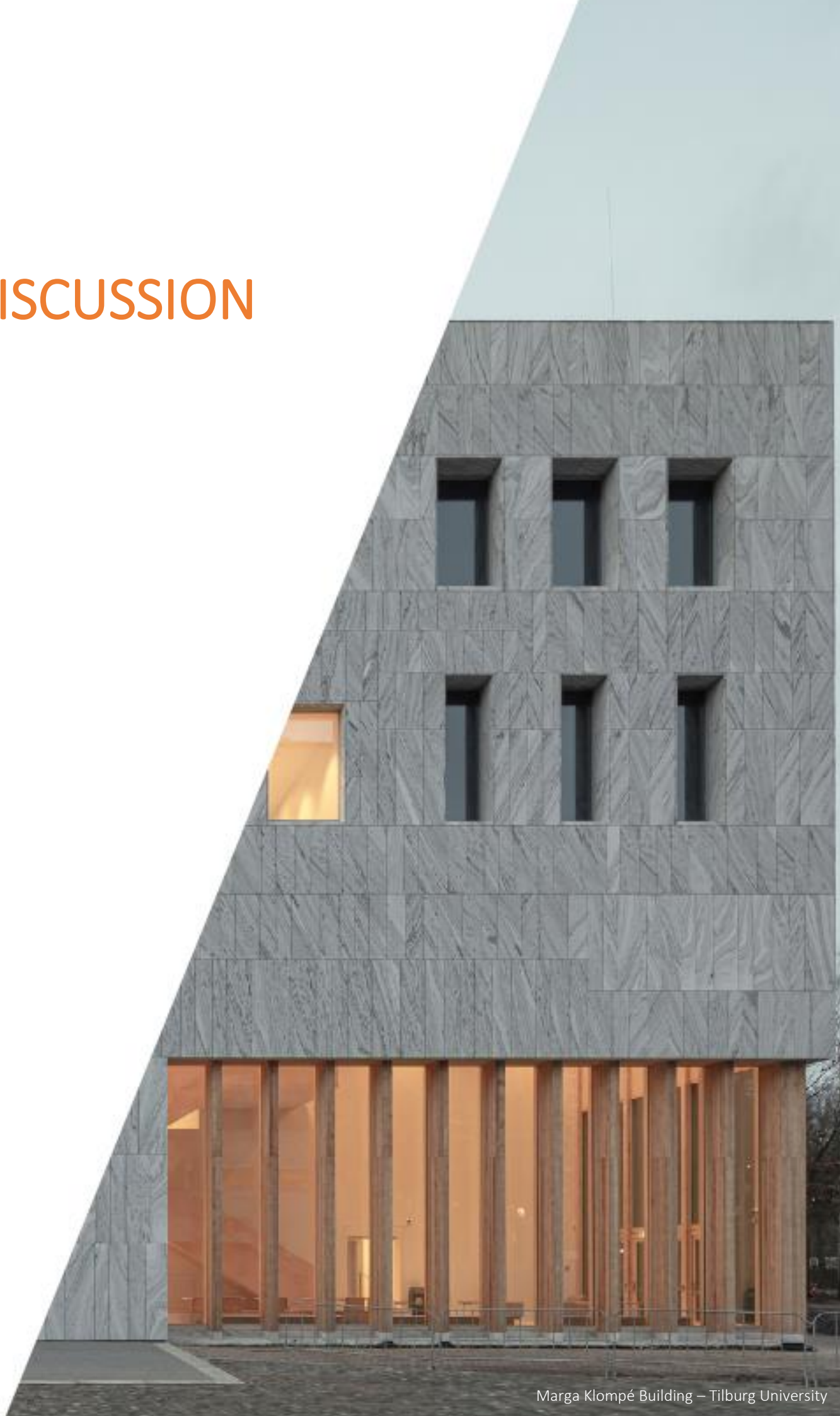
However, no text or ideas generated by ChatGPT have been directly copied into this research. Instead, the AI-generated output has only been used for generating ideas and getting started with writing. All content has been rewritten into the researcher's own words to ensure originality, consistency, and coherence with the research goals. By utilizing AI, particularly ChatGPT, in this way, the writing process became better structured and more efficient.

7.4 Ethical considerations

As discussed in the literature review, the use of AI brings important ethical and societal considerations, which therefore also applies in this research. The environmental impact of AI has become a significant concern (Stahl & Eke, 2024). With the extensive use of AI in this research, it is important to consider that this approach is not entirely sustainable. Another ethical consideration is data privacy and security. The AI model processes and saves all data that will be provided by the users. Therefore, it is important to avoid giving personal, sensitive, or confidential data to an AI-model to ensure that privacy regulations are met. Furthermore, the transparency of AI-generated knowledge is important. Users must be aware that there are possible limitations to the knowledge.

All ethical challenges have been considered in this research. No personal, sensitive, or confidential data was used and throughout this research the role of AI has been made transparent. This chapter further serves to clarify the involvement of AI in this study and to ensure that it has been used responsibly.

DISCUSSION



8. Discussion

This section of the research focusses on the discussion of the findings and results. In addition, the limitations of the research will be discussed and finally the recommendations for further research are described.

8.1 Discussion of findings and results

The goal of this research was to investigate how the exchange of knowledge between Dutch universities can be improved through the creation of a shared project database about university real estate projects. To understand how knowledge exchange could be improved, the barriers and drivers for knowledge exchange were examined. Rego et al. (2009) divided the barriers and drivers into three levels, individual, socio-organizational, and technological. One of the barriers on the technological level is the lack of shared databases and repositories (Birdi et al., 2020; Tzavides et al., 2020; Rego et al., 2009; Bektas et al., 2015). This entailed that more shared databases could improve the exchange of knowledge. However, in contrary to the literature there were already two shared databases about university real estate, one by Den Heijer (2011) and one by Altinkaya Genel et al. (2023). The database by Den Heijer (2011) only consisted of buildings up to 2010, making the database no longer up to date. The database by Altinkaya Genel et al. (2023) did not include all Dutch university buildings, making the database less relevant for people working at Dutch universities. This is in line with what the interviewees mentioned, only three interviewees knew that the databases existed and only one had used the database. The interviewees did mention that a database could be very beneficial provided it is up to date. This showed that there is not necessarily a lack of shared databases and repositories but a lack of updated and relevant shared databases and repositories.

The use of AI has the potential to easily collect data and with that keep a database up to date and relevant. In the literature, it is mentioned that AI has the potential to enhance knowledge exchange (Liebowitz, 2001; Olan et al., 2022; Bolisani & Nakash, 2024; Jarrahi et al., 2023). However, research into its adaption remained limited (Bolisani & Nakash, 2024). Therefore, in this research AI has been utilized to create a shared database about university real estate. The development of the database demonstrated that with the use of AI, a project database can be created to serve as a stepping stool for knowledge exchange for people working in campus management. From the literature and interviews it was clear that there is a lack of updated and relevant shared databases. Keeping a database up to date can also be done without the use of AI, however this is time consuming. Lack of time is already one of the most cited barriers to knowledge exchange (Rego et al. 2009; Bjorvatn & Wald 2020; Santos et al., 2012; Cvitanovic et al., 2014). Therefore, with the use of AI it is more time-efficient and therefore easier to keep the database up to date.

With the project database as the knowledge base, a Tailored GPT model was created to further enable the knowledge exchange drivers; utilization of technology and centralized knowledge repository (Asrar-ul-Huq & Anwar 2016; Rego et al. 2009; Al-Gharibeh 2011; Al-Kurdi et al. 2018; Nassuora 2011; Tzavides et al. 2020).

Both tools were tested and evaluated by people working with university real estate. The expert evaluations confirmed that most of the AI-generated knowledge in the project database and the Tailored GPT is accurate and relevant. But the experts also noted challenges. The results highlight that there are limitations in handling dynamic and numerical data and ensuring real-time updates, which would further enhance the usability of the database and GPT model. The AI-model is not yet capable of processing this kind of knowledge. If the model would be capable, then the robustness, accuracy, and usability of the project database and GPT model would be further enhanced. This demonstrates that the AI generated database and Tailored GPT are mainly suitable for explicit knowledge, which is easier to document and transfer (Milagres & Burcharth, 2018; Williams, 2007). Therefore, the database can be a stepping stool for users in the exchange of knowledge. Explicit knowledge is retrievable from the database and the Tailored GPT. When users want to extract and exchange tacit knowledge, they can use the database and Tailored GPT as a stepping stool to see where they need to go or who they need to contact to exchange tacit knowledge.

In that way this study demonstrated that AI can be utilized to enhance the exchange of knowledge by automating data collection, structure real estate knowledge, and facilitating easy and quick access to valuable knowledge about university real estate. The development of an AI-generated project database and a Tailored GPT model provides campus managers with a centralized knowledge database, overcoming the knowledge exchange barrier of lack of updated and relevant shared databases and further enabling the driver of centralized repositories and utilization of technology.

8.2 Research limitations

Besides the positive impact that this research has on the enhancement of knowledge exchange between universities through the creation of a project database, there are also some limitations to this research. This research has been conducted in a limited time frame, because of this some choices for this research have been made with the limited time frame in mind and not with what is best for the research.

For the interviews seven people were interviewed from only five different universities. Therefore, the results are, except for one university, only based on one perspective from each university. Some of the interviewees mentioned that some of their colleagues also often work with project databases, technology, or other subjects related to this research. If the time frame

would have been even longer, it would have been interesting to speak to those colleagues as well for this study. For the expert panel, ten experts from seven universities were invited. These were the experts who indicated an interest in participating in this research during a Campus NL meeting and those already interviewed. However, only five experts plus an extra colleague of one of the experts participated in the research. Because of this lower-than-expected participation the outcomes of the expert panel are less robust. If all invited experts would have accepted, half of the universities in the Netherlands would have participated in this research. This would have further strengthened the validity of the expert panel.

In this research the focus lies on Dutch university real estate. In addition, university real estate in Europe has been incorporated in this research to provide a broader perspective. The initial goal was to also incorporate university real estate from the rest of the world. Due to lack of time, this has not been possible to achieve. Incorporating university real estate from the rest of the world would have further strengthened the usefulness of the project database. Because then more knowledge from a diverse range of university real estate projects would have been able to be retrieved by the campus managers using the project database. Offering them access to a more extensive and varied set of insights.

AI has played a significant role in this research, but it also presents some limitations. One of the primary challenges of AI is that it does not always generate fully accurate or reliable information and knowledge. Despite the testing and evaluating of the Tailored GPT and the project database, there remains a possibility that some of the AI-generated information and knowledge is incorrect or incomplete.

Since the AI model retrieves its knowledge from open-source databases and websites, the quality of its responses is directly influenced by the reliability of these sources. If incorrect or unverified data is published online, it is possible that the AI model includes and uses this misinformation. Over time, this could lead to a deterioration in the accuracy, usefulness, and reliability of both the project database and the Tailored GPT, affecting the usefulness for knowledge exchange about university real estate.

8.3 Recommendations

While the project database and the Tailored GPT are useful and provide valuable insights, there are still opportunities for further research. This paragraph presents these recommendations for future research.

The focus in this research is on university real estate, similar research could be conducted for other types of real estate, such as office buildings or healthcare facilities. It could be interesting when looking at organizations managing a similar portfolio, such as with university real estate.

For those organizations it could also be beneficial to share knowledge and learn from other organizations in similar way as with this study. It is possible that the needs for other real estate managers are similar, but they could also be very different.

With the primary focus on Dutch university real estate, with inclusion of European university projects, the limitations arose that university real estate data from the rest of the world is not included. For future research real estate data from the rest of the world could be incorporated to further enhance the robustness of a project database and the Tailored GPT. Expanding the database and Tailored GPT would enhance its usefulness and provide a more diverse knowledge base for the campus managers. For other types of real estate, it would also be interesting to incorporate as much real estate from around the world as possible.

One of the limitations of this research is that it is possible that AI generates information and knowledge that is not fully accurate and reliable. For future research, a collaborative platform could be developed where campus managers can contribute by handing in the necessary data from real estate projects from their universities. The downside for this is that a lot of this data is not publicly available, which means that the database that will be developed with that data may also need restricted access, limiting its use and accessibility for campus managers. However, the accuracy and reliability of the data in such a database will be enhanced.

A collaborative platform could also be used to explore how direct input from universities and campus managers could improve a project database. By integrating direct input, more dynamic and numerical data can be incorporated into the database. During the expert panel, the lack of dynamic and numerical data was one of the limitations of the project database. So, future research on how to include that and keeping the project database accessible for everybody could be very interesting.

In the literature review, knowledge exchange barriers and drivers on three levels have been identified. In this research the focus is on the barriers and drivers on the technological level. For future studies it could be interesting to research how organizational and individual level barriers can be overcome and how the drivers on these levels can be utilized to enhance the exchange of knowledge between universities or other real estate organizations.

CONCLUSION



9. Conclusion

The goal of this research is to investigate how the exchange of knowledge between Dutch universities can be improved through the creation of a shared project database about university real estate projects. Further building upon the databases by Den Heijer (2011) and Altinkaya Genel et al. (2023), but through AI data collection improving time-efficiency, making it easier to update the database so that it remains complete and relevant. With this the research aims to further overcome the knowledge exchange barriers on a technological level and with that enable better collaboration and knowledge exchange among universities in managing their campuses.

This chapter describes the conclusion of this research. The conclusion will be provided by first answering the sub questions before answering the main research questions.

9.1 Research sub questions

To answer the main research questions, four sub questions were set up to get a better understanding of the themes of the research. By answering the sub questions, the main research question could be answered.

SQ1 – What are the knowledge exchange barriers and drivers?

From the findings in the literature review it can be concluded that there are many barriers and drivers for the exchange of knowledge. In the research by Rego et al. (2009), three domains are considered, individual level, socio-organizational level, and technological level. The most cited knowledge exchange barriers on the three domains are lack of trust, lack of motivation, the variability of people, cultural differences, organizational structure, lack of rewards, lack of shared databases and lack of training. The most cited knowledge exchange drivers on the three domains are trust, collaboration, willingness, collaborative culture, leadership, rewards, and utilization of technology.

However, not all barriers and drivers can be utilized. Therefore, in this research, the barriers and drivers on the technological level have been utilized. There are already two shared databases about university real estate, one by Den Heijer (2011) and one by Altinkaya Genel et al. (2023). These databases however are incomplete and not up to date. Therefore, the main barrier that has been overcome in this research was the lack of updated and relevant shared databases and repositories. In addition, the drivers; utilization of technology and centralized knowledge repository are further enabled.

SQ2 – How can Artificial Intelligence (AI) facilitate knowledge exchange?

Several studies state that there is an important relationship between knowledge exchange and AI (Argote & Fahrenkopf, 2016; Argote & Ingram, 2000; Lombardi, 2019; Jaharri et al., 2023), and that AI has the potential to enhance knowledge exchange (Ruggles, 1997). However, they do not explicitly discuss how AI can facilitate the exchange of knowledge. Therefore, it is explored how AI can deploy the barriers and drivers on technological level.

As discussed, one of the most cited knowledge exchange barriers is the lack of shared databases. With the use of AI such a shared database can be created, both in the form of a project database and a Tailored GPT. AI has the ability to access and produce large volumes of information, allowing it to create an AI-generated shared database about university real estate with data and knowledge that was previously scattered or not accessible. In that way the driver utilization of technology is employed, further enhancing and facilitating the exchange of knowledge.

SQ3 – What knowledge do the campus managers need in a project database?

In the interviews with the campus managers from Dutch universities, they expressed which types of knowledge they deem necessary in a project database. Out of these types of knowledge a division has been made into three categories, necessary knowledge, important knowledge, and supportive knowledge. The types of knowledge mentioned by the campus managers divided into the three categories can be seen in table 9.1.

Necessary (5 to 7)	Important (3 to 4)	Supportive (1 to 2)
Energy performance of the building	Architect & Constructor of the building	Timeline of the building process
Facilities in the building	Spatial data	Search function
Comparing buildings		Innovations in the building
Building costs		Dos and don'ts
General building information		Function division
Building function		Project image
		Comment function
		Building manager

Table 9.1: Categorization of the types of knowledge (own work, 2025)

Out of these types of knowledge, there are nine types that can be classified as additional knowledge, so knowledge that has not been incorporated in the existing database by Den Heijer (2011). The nine additional types of knowledge have been validated with eleven campus managers. The results showed that out of the additional knowledge the energy performance, facilities, innovations, and the architects and constructor are deemed necessary by the campus managers. Therefore, the updated database consists of the types of knowledge from the

existing database, including general building information, building function, project description, project goals, users, and the spatial data, and the necessary additional knowledge.

SQ4 – How can a Tailored GPT be developed to serve as a knowledge database about university real estate buildings?

The results from the first three steps of the four-step process that have been used in this research, form the knowledge base for the Tailored GPT model about university real estate buildings. The Tailored GPT has been evaluated on five subjects: task-specific performance, domain expertise, contextual understanding, factual accuracy, and user experience. The evaluation demonstrated that the model is effective in the evaluation subjects, except for contextual understanding. The GPT is unable in answering long prompts and understanding coherence in dialogues. However, this does not affect the effectiveness of the GPT model.

The Tailored GPT model proves to be effective in enhancing the exchange of knowledge through providing quick and easy access to relevant information that campus managers might be looking for. But there are also challenges regarding the GPT model. The model struggles with numerical data interpretation, which is an issue that lies within the AI-model itself. Additionally, sometimes the model generated responses without acknowledging uncertainty, efforts have been made to prevent this by improving the instructions in the configuration of the GPT model. In conclusion, a Tailored GPT can be developed to be used by campus managers to easily access and retrieve knowledge about university real estate.

9.2 General conclusion

The answers to the sub questions together lead to answering the main research question. The main research question is:

"How can Artificial Intelligence (AI) be utilized to enhance knowledge exchange about university real estate buildings?"

One of the barriers for knowledge exchange on the technological level is the lack of shared databases and centralized repositories (Birdi et al., 2020; Tzavides et al., 2020; Rego et al., 2009; Bektas et al., 2015). There are existing databases, but the existing shared databases by Den Heijer (2011) and Altinkaya Genel et al. (2023) are incomplete and not up to date, which makes them not useful and irrelevant for campus managers. Therefore, the main knowledge exchange barrier is the lack of updated and relevant shared databases and repositories. If this barrier is overcome the exchange of knowledge should be enhanced. In addition, if the drivers; utilization of technology and centralized knowledge repository are further enabled, the exchange of knowledge will be enhanced.

Artificial Intelligence can be used for the creation of such a shared database and centralized repository about university real estate buildings. Through AI-driven data collection, knowledge about university buildings can be centralized, making it easier for campus managers to access, retrieve, and compare relevant knowledge about university buildings. This has been achieved in this research using the four steps that were developed for the creation of an AI-generated database.

The first result of the four steps is a project database about Dutch university real estate buildings. Overall, the AI-generated knowledge presented in this database is accurate and relevant. The knowledge incorporated in the database is mainly explicit knowledge. The knowledge could be more accurate, complete, and relevant if the incorporated data would not only by static data but also dynamic and numerical data. However, an AI-model is not capable of retrieving these types of data because they are usually publicly available online. These types of knowledge could be incorporated by integrating additional sources of data, such as direct input from universities and campus managers. However, this would exceed the goal of this research, which is the development of an AI-generated database for the exchange of knowledge. The database by itself does not directly enhance the exchange of knowledge between universities. But with explicit knowledge, the database is stepping stool for the enhancement of knowledge exchange. The explicit knowledge is retrievable from the database and the Tailored GPT and when the users want to extract and exchange tacit knowledge, they can use the database and Tailored GPT as a stepping stool to see where they need to go or who they need to contact to exchange tacit knowledge.

The barrier lack of updated and relevant shared databases and repositories can be more easily overcome with the use of AI. Keeping a database up to date can also be done without the use of AI, however this is time consuming. Lack of time is already one of the most cited barriers to knowledge exchange (Rego et al. 2009; Bjorvatn & Wald 2020; Santos et al., 2012; Cvitanovic et al., 2014). Therefore, with the use of AI it is more time-efficient and therefore easier to keep the database up to date. A database that is up to date is more relevant and accurate and therefore more useful for people working in campus management.

The second result of the four steps is a Tailored GPT model about university real estate. The results from the first three steps form the knowledge base for this GPT model. This model enables campus managers to quickly and easily access and retrieve knowledge about university buildings throughout the Netherlands and the rest of Europe. However, challenges remain, particularly regarding the accuracy and ability of numerical data and the need for real-time updates. Since the AI-model is not capable of processing numerical data, this will also not be possible only using the GPT. To maximize the effectiveness of the GPT and the database in exchanging knowledge, continuous updates are required to ensure relevancy, usefulness, and reliability.

Overall, this research demonstrates that AI can be utilized to transform knowledge exchange in university real estate management. The AI-generated project database and the Tailored GPT are a stepping stool for the enhancement of knowledge exchange between universities and campus managers. With those tools they can more easily and quickly retrieve knowledge about university real estate, facilitating the overall exchange of knowledge between universities.

REFLECTION



10. Reflection

10.1 Topic

During the master track Management in the Built Environment, the first introduction with portfolio management was during the course Real Estate Management. Initially, I did not think this was the most interesting course of the master track. However, as the course progressed and we learned more and more, I began to develop a strong interest in the subject. I have always been interested in technology and data, and during the presentation by Bart Valks about his research on smart campus tools this interest was further enhanced. This presentation made me realize that it was possible to integrate my passion for data and technology with the real estate industry. At the same time, Artificial Intelligence rapidly emerged into everyday activities, which further enhanced my interest in exploring the combination of technology, AI, and real estate management. Through the theme meetings, my research focus was refined, which eventually led to the development of my research topic.

10.2 Relevance

As I mentioned, during my first year of the master track MBE, Artificial Intelligence emerged into everyday life. The emergence of AI brings with it a lot of changes but also a lot of opportunities. Some of these opportunities are the automation of repetitive tasks, accelerated research, the use of AI in the healthcare and medicine sector, and the creativity of AI in arts and entertainment. In addition, AI can and is going to play an important role in the working industry, in this case the real estate industry. Many researchers have studied the role of AI, however not many studies have been done about how AI can be utilized in the real estate industry.

One of the research missions of the Campus NL research project is that a network of academic experts for knowledge exchange can help the campus managers of the universities (Den Heijer, 2021). In the research of Den Heijer et al., (2016) they state that, the fourteen universities strive for collaboration and effective exchange of knowledge to enhance the management of the campus. By combining the subjects of AI and knowledge exchange for university real estate buildings, this research has tried to find a way to effectively utilize AI to improve the exchange of knowledge about university real estate buildings. Furthermore, this research contributes to the Campus NL research project.

10.3 Product

It took me a while to really form the topic of this research. After the P2 presentation, the research structure, objectives, and outcomes were still too broad and not rightly written down. This led to that I was not directly after the P2 presentation able to continue with the research. I first had to further develop the structure, objectives and outcomes of the research. When those were well established, I could continue with the empirical part of the research and eventually the synthesis and conclusion of the research.

Due to a lack of time, the steps for the development of a project database were not executed for university real estate in the whole world. Those results could have further enhanced the knowledge about university real estate buildings, with that further improving the outcomes of this research.

This research can be used to see demonstrate how an AI-generated project database can easily be created to enhance the exchange of knowledge about university real estate buildings. The outcomes can be used by the campus managers from Dutch universities to easily extract basis knowledge for when they are developing projects on the university campus.

10.4 Method

Since it took some time to define the definite structure, objectives, and outcomes of the research, the methods used for the research also took more shape as the research process progressed. Defining what type of literature review I conducted was a challenge, while we had an idea what its classification is called, we were not able to find the exact name of that type of review, therefore we settled with calling it a narrative literature review. This entailed that when no new information and knowledge was found in papers, the literature review was conducted successfully. For the empirical part it became clear that the four steps set up for the development of the project database had to be executed and at the same time interviews with campus managers had to be conducted to gain the information and knowledge needed for the creation of the project database.

The results from the empirical part were presented to experts for them to test and evaluated those results. Ten experts from seven Dutch universities were asked to help testing and evaluated the results from the empirical research. However, disappointingly only five experts plus an extra colleague of one of the experts were willing to participate. This lower-than-expected participation weakened the robustness and outcomes of the expert panel's conclusion. If all experts were willing to participate, half of universities in the Netherlands would have been represented in this research, further strengthening the validity of the findings.

10.5 Personal reflection

The personal reflection has been divided into two parts: towards P2 and towards P5. The personal reflection towards P2 was written for the P2 presentation and has therefore not been altered.

10.5.1 Towards P2

The graduation lab (AR3MBE100) has been an invaluable experience for me. During this course I have been able to implement all my previous knowledge on writing a research study, but besides that I have also learned a lot about preparing a research proposal. The theme meetings were very useful during the process of this course. These meetings were not only about presenting what we had done, but more about brainstorming about what we could do and how we could further develop the research. This is something that I liked a lot, and I think that it really helped in forming a solid foundation for the research. During the course we kept meeting with the entire theme group, which was valuable, because the graduation process is a highly individual process. Therefore, it is easy to lose track on what your fellow students are working on and in that way, I did not only receive feedback and tips from my tutors but also from my fellow students.

Because of all the freedom, I sometimes found it difficult to put myself to work on my research. Especially when the deadline was far in the future. Only when the deadline approached did I manage to put myself to work on my research. This especially happened after the P1. The first few weeks after the P1, it was difficult to work on the research, also because of other work and study related things that came in between. But if I had divided the workload better, the last weeks before the P2 could have been less stressful, so that is a lesson that I am going to take with me towards P3 and onwards.

During the course, I did sometimes miss a general lecture with explanation on what is expected on for example the Data Management Plan. During RM1, we practiced only once in making a Data Management Plan. Now only during the last meeting we talked about making a data management plan, but an explanation lecture on how to make such a plan could be valuable. It is perhaps also an option to better implement things like this in the RM2 course.

10.5.2 Towards P5

After the structure, objectives, and outcomes of my research were redefined, my research fitted in the Campus NL research project. The collaboration from this research project has really helped my research process with finding the right people for interviews and for the expert panel and positioning my research in a broader perspective. By doing the interviews and processing the results, the feeling of really executing the research arose. I have learned a lot

during this research process. I did enjoy the graduation process from time to time, but it was also very difficult for me every now and then. I struggled a lot with writing and structuring the research in the right way, so that it is understandable for readers. However, as the process progressed, I feel like that I started to understand it more and that I even became better in the writing process.

Overall, I think this was a successful year which introduced me into the field of doing academic research. I learned a lot, but I realized during this graduation process that doing research is not really for me. However, I do look back on a very educational year.

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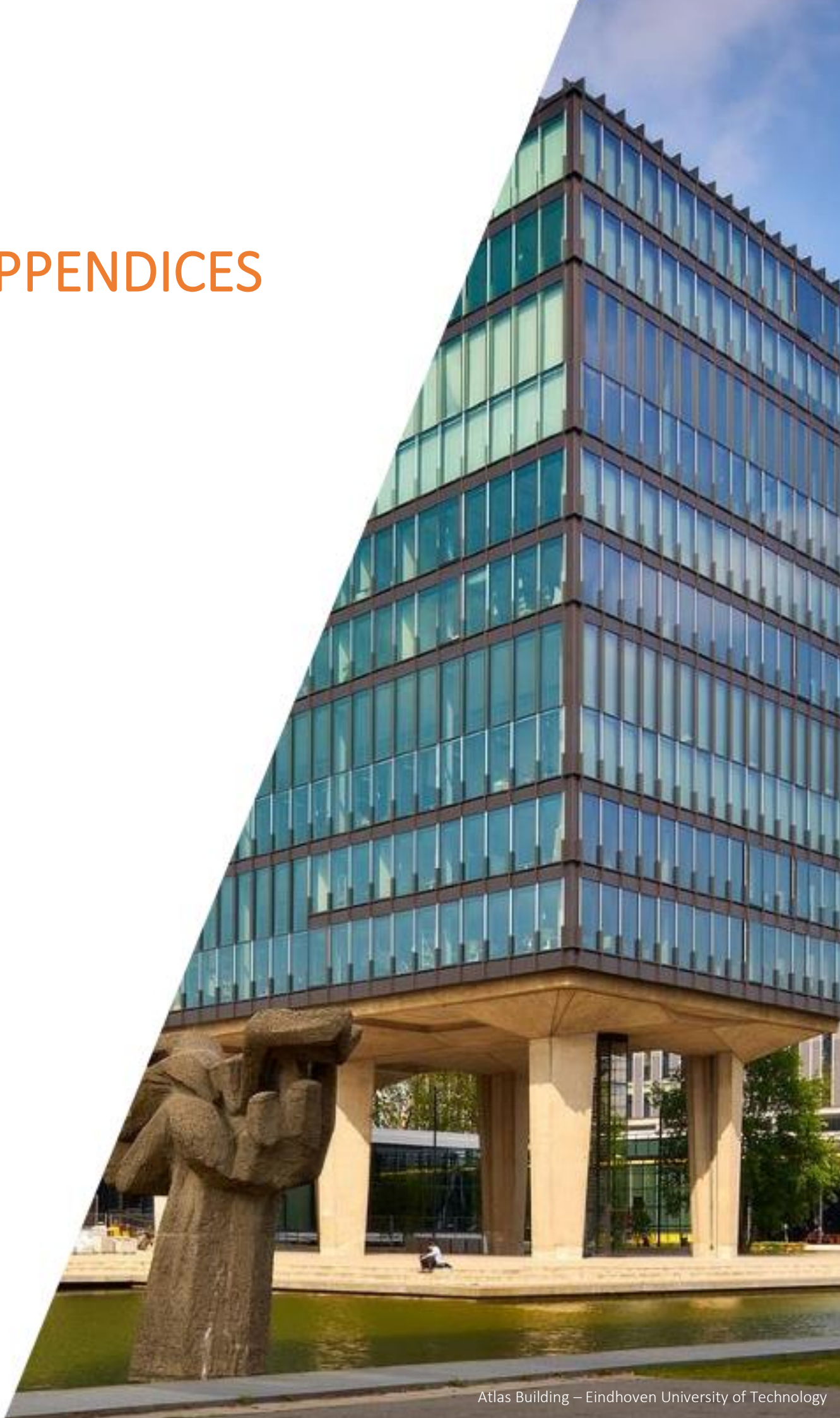
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APPENDICES



Appendix I: Search strategy

The main search engines for the literature review that have been used are Scopus, Google Scholar, and ResearchRabbit.ai. Scopus was the leading search engine, the other search engines have been used to see if there was more literature available on the different concepts.

Scopus search terms:

- Knowledge exchange
- Knowledge management
- Knowledge transfer
- Knowledge sharing
- {Knowledge exchange} AND {real estate}
- {Knowledge management} AND {real estate}
- Artificial intelligence
- {Artificial intelligence} AND {real estate}
- {Artificial intelligence} AND {knowledge exchange}
- {Artificial intelligence} AND {knowledge management}
- {Artificial intelligence} AND {knowledge exchange} AND {real estate}
- {Smart tools} AND {knowledge exchange}
- {Smart tools} AND {knowledge exchange} AND {real estate}
- Campus management
- University real estate

ResearchRabbit.ai has been used to find networks of papers that have been written on the same subject. This has resulted in a lot of useful papers on AI tools for knowledge exchange.

Appendix II: Informed consent

Geachte,

Allereerst wil ik u bedanken voor uw tijd en medewerking aan mijn afstudeeronderzoek. In dit document vindt u het toestemmingsformulier en aanvullende informatie over mijn afstudeeronderzoek en het interview.

U bent uitgenodigd om deel te nemen aan een onderzoek genaamd **AI enhancing knowledge exchange about university buildings**. Dit onderzoek wordt uitgevoerd door M.M.B. (Menno) in 't Veld, als afstudeeronderzoek voor de mastertrack Management in the Built Environment aan de Faculteit Bouwkunde aan de Technische Universiteit Delft. Met behulp van de begeleiders: dr. ir. M.H. (Monique) Arkesteijn, dr. ir. (Michaël) Peeters en J.D.O. (Jasmine) Bacani van de TU Delft.

Toelichting onderzoek

Mijn afstudeeronderzoek gaat over hoe Artificial Intelligence (AI) een rol kan spelen in het verbeteren van de kennisoverdracht over universiteitsgebouwen. Voor dit onderzoek wil ik, met de hulp van AI, een projectendatabase van universitairvastgoed creëren die besluitvorming over toekomstige campussen ondersteunt door inzicht te bieden in trends, patronen en innovaties in universitairvastgoed. Deze database moet kennisdeling vergemakkelijken en barrières overwinnen. De aanleiding van dit onderzoek is complexiteit van campusmanagement, het toenemende gebruik van AI en de cruciale rol van kennisdeling bij besluitvoering.

Het onderzoek bestaat uit vier stappen: met behulp van AI, (1) vinden van universiteitsgebouwen, (2) het verzamelen van relevante informatie en data, (3) het creëren van overzichten van de universiteitsgebouwen en (4) het analyseren en identificeren van patronen, trends en innovaties. Door middel van deze vier stappen kan er een projectendatabase gecreëerd worden.

Wanneer de projectendatabase gecreëerd is, wordt er onderzocht of een op maat gemaakt GPT-model geschikt is als AI-tool om de barrières en uitdagingen van kennisdeling, waaronder inconsistentie in gegevens, barrières tussen belanghebbende, gebrek aan gedeelde databases en ineffectief gebruik van technologie, te overwinnen. Het uiteindelijke doel is om door middel van de projectendatabase kennisdeling over universiteitsvastgoed te stimuleren.

Toelichting interview

Het interview zal maximaal een uur in beslag nemen. Ik heb hiervoor een aantal vragen opgesteld die betrekking hebben op het afstudeeronderzoek. Gedurende het interview zullen we het hebben over het gebruik van bestaande projectendatabases, zal ik vragen stellen over het creëren van een nieuwe projectendatabase en zullen we het hebben over de rol van technologie en Artificial Intelligence (AI).

Uw deelname aan het interview is volledig vrijwillig, en u kunt zich op elk moment terugtrekken zonder een reden op te geven. U bent vrij om vragen niet te beantwoorden of om naderhand toegang te vragen tot het transcript en informatie te wijzigen en of verwijderen.

Het interview zal opgenomen worden door middel van audioapparatuur, zodat ik gebruik kan maken van de informatie die besproken is. Daarnaast het vriendelijke verzoek om het toestemmingsformulier te lezen, eventuele vragen te stellen en deze vervolgens te ondertekenen.

Als u vragen heeft over het onderzoek, het interview of het toestemmingsformulier kunt u contact opnemen via de mail (M.M.B.intVeld@student.tudelft.nl) of telefoon (+31 06 39 87 54 70).

Met vriendelijke groet,

Menno in 't Veld

Gelieve de toepasselijke box aan te vinken	Ja	Nee
A: ALGEMENE OVEREENSTEMMING – ONDERZOEKSDOELEN, DEELNEMERSTAKEN EN VRIJWILLIGE DEELNAME		
1. Ik heb de informatie over het onderzoek gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	<input type="checkbox"/>	<input type="checkbox"/>
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	<input type="checkbox"/>	<input type="checkbox"/>
3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent:	<input type="checkbox"/>	<input type="checkbox"/>
<ul style="list-style-type: none"> Een geluidsopname van het interview via Teams of via een audiorecorder (deze zal na het voltooien van de transcriptie verwijderd worden) Een uitgewerkt transcript van het interview 		
4. Ik begrijp dat de studie 30-04-2025 eindigt.		
B: MOGELIJKE RISICO'S VAN DEELNAME (INCLUSIEF GEGEVENSBESCHERMING)		
5. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk: anonimiseren van transcripten, verwijdering van geluidsopname zodra het transcript verwerkt is, opslag in versleutelde drive, en vernietiging van persoonlijke informatie na het einde van het onderzoek.	<input type="checkbox"/>	<input type="checkbox"/>
6. Ik begrijp dat de persoonlijke informatie die over mij verzameld wordt en mij kan identificeren, zoals (naam, contactgegevens, bedrijfsgevoelige informatie), niet gedeeld worden buiten het studieteam.	<input type="checkbox"/>	<input type="checkbox"/>
7. Ik begrijp dat de persoonlijke data die over mij verzameld wordt, vernietigd wordt op 30-04-2025	<input type="checkbox"/>	<input type="checkbox"/>
C: PUBLICATIE, VERSPREIDING EN TOEPASSING VAN ONDERZOEK		
8. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor het eindrapport.	<input type="checkbox"/>	<input type="checkbox"/>
9. Ik geef toestemming om mijn antwoorden, ideeën of andere bijdrages anoniem te quoten in resulterende producten.	<input type="checkbox"/>	<input type="checkbox"/>

Handtekening

Naam deelnemer

Handtekening

Datum

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

Naam onderzoeker

Handtekening

Datum

Appendix III: Interview protocol

Voorafgaand aan het interview:

- Uitnodiging verzenden
- Informed consent verzenden
- Informed consent getekend
- Teams en opname apparatuur klaarzetten

Start interview:

- De geïnterviewde bedanken voor het meewerken aan het onderzoek
- Controle informed consent
- Wijzen op het opnemen van het interview en toestemming vragen ter controle
- Aanzetten opname en back-up opname apparatuur
- Korte introductie van het onderzoek en het interview

Na het interview:

- Vragen of de geïnterviewde nog iets kwijt wil of nog vragen heeft
- Verdere verloop van het onderzoek kort toelichten
- Aangeven dat de scriptie gedeeld kan worden indien gewenst
- Dank mail sturen met het transcript ter controle

Appendix IV: Interview questions

Huidig gebruik:

1. Hoe krijgt u momenteel toegang tot informatie over universitaire vastgoedprojecten en hoe deelt u die informatie binnen uw team of organisatie?

Bestaande projectendatabase:

De projectendatabase die ik aan het maken ben is gebaseerd op de projectendatabase die Alexandra den Heijer heeft gemaakt in haar proefschrift *Managing the university campus* (2011). Als u niet bekend bent met deze projectendatabase, heb ik een pagina uit de projectendatabase toegevoegd in de bijlage van dit interviewblad. Ik heb ook een pagina uit mijn projectendatabase toegevoegd.

2. Gebruikt u de projectendatabase van Alexandra den Heijer (2011)? Waarom wel of waarom niet? Of
3. Gebruikt u op dit moment een andere projectendatabase of een vergelijkbare tool voor het beheren van universitaire vastgoedinformatie? Zo ja, welke?
4. Als u kijkt naar de informatie en gegevens in de projectendatabase van Alexandra den Heijer of een andere projectendatabase, is er informatie die u mist? Of is er informatie die u niet nodig vindt?

Verbeterde projectendatabase:

5. Hoe zou een ideale projectdatabase er voor u uitzien? Welke belangrijke kenmerken of functionaliteiten zou deze hebben?
6. Welke soorten gegevens of informatie zijn voor u het meest belangrijk in een projectdatabase (bijv. bouwspecificaties, energieprestaties, innovaties)?
7. Zou u baat hebben bij toegang tot patronen, trends of innovaties in vergelijkbare universitaire vastgoedprojecten?
8. Hoe moet een projectdatabase toegankelijk zijn, zodat deze gemakkelijk te gebruiken is door campusmanagers?

Technologie en Artificial Intelligence:

9. Hoe ziet u de rol van technologie en AI evolueren in het beheer van universitaire vastgoedprojecten?
10. Hoe ziet u de rol van technologie en AI in het delen van kennis over universitaire vastgoedprojecten?

11. Heeft u bezwaar tegen het gebruik van AI voor deze database?

Slotvraag:

12. Is er nog iets dat ik volgens u moet weten over uw behoeften met betrekking tot een projectdatabase?

Appendix I

Projectdatabase gemaakt door Alexandra den Heijer in haar proefschrift Managing the university campus (2011).



Figure 1: Dutch university projects (Den Heijer, 2011)

Projectdatabase gemaakt door mij met behulp van AI.

Building Title: Echo Building

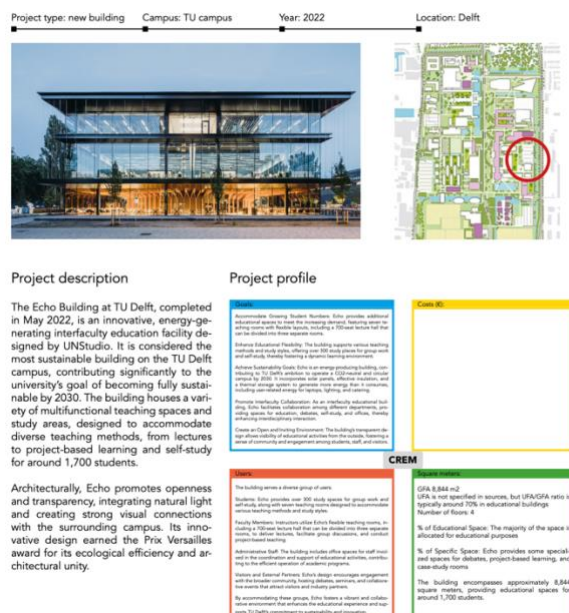


Figure 2: Project database (own work)

Appendix V: Expert panel

Geachte,

Allereerst wil ik u bedanken voor uw tijd en medewerking aan mijn afstudeeronderzoek. In dit document vindt u een toelichting van mijn afstudeeronderzoek en uitleg van het expert panel.

U bent uitgenodigd om deel te nemen aan een onderzoek genaamd **AI enhancing knowledge exchange about university buildings**. Dit onderzoek wordt uitgevoerd door M.M.B. (Menno) in 't Veld, als afstudeeronderzoek voor de mastertrack Management in the Built Environment aan de Faculteit Bouwkunde aan de Technische Universiteit Delft. Met behulp van de begeleiders: dr. ir. M.H. (Monique) Arkesteijn, dr. ir. (Michaël) Peeters en J.D.O. (Jasmine) Bacani van de TU Delft.

Toelichting onderzoek

Mijn afstudeeronderzoek gaat over hoe Artificial Intelligence (AI) een rol kan spelen in het verbeteren van de kennisoverdracht over universiteitsgebouwen. Voor dit onderzoek wil ik, met de hulp van AI, een projectendatabase van universitairvastgoed creëren die besluitvorming over toekomstige campussen ondersteunt door inzicht te bieden in trends, patronen en innovaties in universitairvastgoed. Deze database moet kennisdeling vergemakkelijken en barrières overwinnen. De aanleiding van dit onderzoek is complexiteit van campusmanagement, het toenemende gebruik van AI en de cruciale rol van kennisdeling bij besluitvoering.

Het onderzoek bestaat uit vier stappen: met behulp van AI, (1) vinden van universiteitsgebouwen, (2) het verzamelen van relevante informatie en data, (3) het creëren van overzichten van de universiteitsgebouwen en (4) het analyseren en identificeren van patronen, trends en innovaties. Door middel van de eerste drie stappen kan er een projectendatabase gecreëerd worden, die vervolgens in stap 4 gebruikt kan worden als kennisbasis voor een Tailored GPT. Hier wordt onderzocht of een op maat gemaakt GPT-model geschikt is als AI-tool om naast de projectendatabase de barrières en uitdagingen van kennisdeling, waaronder inconsistentie in gegevens, barrières tussen belanghebbende, gebrek aan gedeelde databases en ineffectief gebruik van technologie, te overwinnen. Het uiteindelijke doel is om door middel van de projectendatabase kennisdeling over universiteitsvastgoed te stimuleren.

Een Tailored GPT model is een op maat gemaakte versie van ChatGPT. Met deze GPTs is het mogelijk om instructies en kennis mee te geven om bruikbaarheid van het model in een specifieke context te vergroten, in dit geval kennis over universitairvastgoed.

Toelichting expert panel

Door middel van onderstaande link krijgt u toegang tot de Tailored GPT. Bijgevoegd als bijlage is de projectdatabase van universiteitsvastgoed in Nederland. Deze database vormt samen met lijsten van universitairvastgoed vanuit de hele wereld en de projectendatabase van universitairvastgoed vanuit de hele wereld de kennisbasis van de Tailored GPT.

Link naar Tailored GPT: <https://chatgpt.com/g/g-cxbREbyZR-university-real-estate-project-database>

Mijn vraag is of u de Tailored GPT wilt testen en feedback hierop wilt geven. Hieronder heb ik een aantal richtlijnen opgesteld voor het testen van de GPT. Het is aan u om de functionaliteiten te verkennen en, door middel van relevante vragen te stellen, de kwaliteit en bruikbaarheid van de antwoorden te beoordelen.

Richtlijnen voor het testen:

- Stel de Tailored GPT vragen over universitairvastgoed in Nederland of het buitenland
- Evalueer de antwoorden op basis van:
 - Duidelijkheid: zijn de antwoorden begrijpelijk en goed gestructureerd
 - Bruikbaarheid: zijn de antwoorden nuttig en bieden ze waardevolle inzichten
 - Nauwkeurigheid: is de informatie correct en relevant
 - Beperkingen: zijn er inconsistenties of onjuiste resultaten

Naast het testen van de Tailored GPT, wil ik u vragen om de projectendatabase te evalueren. Naast de volledige projectendatabase met Nederlandse universiteitsvastgoed heb ik als bijlage een gebouw van uw universiteit toegevoegd. Mijn vraag is of u de informatie die in dit overzicht staat wilt beoordelen op de volgende punten:

- Juistheid: zijn de gegevens over het gebouw correct
- Volledigheid: is er ontbrekende of onjuiste informatie die moet worden toegevoegd of aangepast
- Relevantie: bevat de database aspecten die relevant zijn

*De database is in het Engels omdat mijn studie in het Engels is.

Na het testen en evalueren zou ik uw feedback over de juistheid, prestaties en bruikbaarheid op prijs stellen. Door middel van het laten zien welke vragen u aan het model gesteld heeft kan ik de feedback beter verwerken. Dit kan via een reactie per mail of een korte online nabespreking. Uw feedback en input zullen helpen om de projectendatabase en het GPT-model te verfijnen, zodat het een effectiever hulpmiddel wordt voor kennisuitwisseling.

Als u vragen heeft over het onderzoek, het testen van de Tailored GPT of het evalueren van de projectendatabase kunt u contact opnemen via de mail (M.M.B.intVeld@student.tudelft.nl) of telefoon (+31 06 39 87 54 70).

Met vriendelijke groet,

Menno in 't Veld

Appendix VI: Data Management Plan

Plan Overview

A Data Management Plan created using DMPonline

Title: AI enhancing knowledge exchange about university buildings

Creator: Menno in 't Veld

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2021)

ID: 164800

Start date: 12-02-2024

End date: 30-04-2025

Last modified: 06-12-2024

AI enhancing knowledge exchange about university buildings

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

My faculty steward, Janine Strandberg, has reviewed this DMP on 6-12-2024

2. Date of consultation with support staff.

2024-12-06

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Personal information: participants' name, email, company name	.xlsx	Contact information for participants taking part in interviews will be received via e-mail.	Administrative purposes: obtaining informed consent and communicating with the participants.	OneDrive, physically collected informed consents will be scanned and stored in OneDrive	Researcher: Menno in 't Veld Supervisor: Monique Arkesteijn
Audio recordings of interviews with campus real estate managers or other people working with managing university real estate	.mp3	Interviews will be conducted and will be recorded with via Teams and with a voice recorder. Recordings are deleted after transcription.	Gaining insights how campus real estate managers use / want to use / could use knowledge data about real estate	OneDrive and as temporary storage solution the recording device	Researcher: Menno in 't Veld Supervisor: Monique Arkesteijn
Anonymized transcription of interviews	.docx	Anonymous transcriptions created manually based on the audio-recordings.	Privacy-perserving data from participants. From this moment it is no longer necessary to know who said what, but in general how campus real estate managers want to use and use a knowledge database	OneDrive	Researcher: Menno in 't Veld Supervisor: Monique Arkesteijn
Consent forms of participants of the interviews	.pdf	Received from the participants before the start of the interviews.	To obtain written consent of the interviewees.	OneDrive	Researcher: Menno in 't Veld
Thesis report	.pdf	Serves as record of the process as well as documentation.	Long-term documentation	OneDrive	Researcher: Menno in 't Veld Supervisor: Monique Arkesteijn
Dutch university real estate and their performance criteria	.pdf	The data about Dutch university real estate will be collected from open source databases and websites with the help of AI	This data will be used to fill the knowledge database	OneDrive	Researcher: Menno in 't Veld Supervisor: Monique Arkesteijn

4. How much data storage will you require during the project lifetime?

- < 250 GB

II. Documentation and data quality

5. What documentation will accompany data?

- Other - explain below
- Methodology of data collection

The data for this thesis will only be shared in the MSc thesis and not in a data repository. The methodology of data

collection will be explained in the MSc thesis, which will be made available in the TU Delft education repository.

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

- Another storage system - please explain below, including provided security measures
- OneDrive

OneDrive: this is the primary data storage location. Only the researcher (Menno in 't Veld) and the supervisor (Monique Arkesteijn) have access. Everything will be stored in different folders. Informed consent forms and contact information are encrypted separately from research data to minimise risk of re-identification.

Recording device: This will be used as a temporary data storage location. The interviews will be recorded on this device and when the recordings have been uploaded on the OneDrive, they will be deleted from the device.

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

- Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

If you are not sure which option to select, first ask your [Faculty Data Steward](#) for advice. You can also check with the [privacy website](#) . If you would like to contact the privacy team: privacy-tud@tudelft.nl, please bring your DMP.

- Yes

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

If you are not sure which option to select, ask your [Faculty Data Steward](#) for advice.

- No, I will not work with any confidential or classified data/code

9. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your [Faculty Contract Manager](#) when answering this question. If this is not the case, you can use the example below.

The anonymised interview data will be included in the MSc thesis and appendix. The thesis will be made publicly accessible in the TU Delft education repository.

10. Which personal data will you process? Tick all that apply

- Other types of personal data - please explain below
- Data collected in Informed Consent form (names and email addresses)
- Signed consent forms
- Names and addresses
- Email addresses and/or other addresses for digital communication

Personally Identifiable Information (PII): name of the interviewee, work address, email, and university name are processed for administrative reasons.

Audio recordings from the interviews.

11. Please list the categories of data subjects

People who work as campus real estate manager or other people whose work is related to managing university real estate. The location of the research is the Netherlands, so the participants should be working at one universities in the Netherlands.

12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

- No

15. What is the legal ground for personal data processing?

- Informed consent

16. Please describe the informed consent procedure you will follow:

All participants of the interviews will be asked to fill in a form before the start of the interviews in which they are asked to give their informed consent.

17. Where will you store the signed consent forms?

- Same storage solutions as explained in question 6

18. Does the processing of the personal data result in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a [Data Protection Impact Assessment \(DPIA\)](#). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).

If two or more of the options listed below apply, you will have to [complete the DPIA](#). Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA.

If only one of the options listed below applies, your project might need a DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to get advice as to whether DPIA is necessary.

If you have any additional comments, please add them in the box below.

- None of the above applies

22. What will happen with personal research data after the end of the research project?

- Personal research data will be destroyed after the end of the research project
- Anonymised or aggregated data will be shared with others

The anonymised data consists of anonymised interview transcripts. This data will be used in the body of the thesis and the appendix and will not be shared in a data repository.

The audio recordings of the interviews will be destroyed after the anonymised interview transcripts are completed.

All personal data will be destroyed within a month after the end of the project.

V. Data sharing and long-term preservation

27. Apart from personal data mentioned in question 22, will any other data be publicly shared?

- All other non-personal data (and code) produced in the project

The data about Dutch university real estate will be used in the body of the thesis and in the appendix and will not be shared in a data repository.

29. How will you share research data (and code), including the one mentioned in question 22?

- My data will be shared in a different way - please explain below

Anonymised data collected during the project will be included in the body of the thesis and in the appendix. The thesis will be made available in the TU Delft educational repository.

30. How much of your data will be shared in a research data repository?

- 100 GB - 1 TB

31. When will the data (or code) be shared?

- As soon as corresponding results (papers, theses, reports) are published
- At the end of the research project

32. Under what licence will be the data/code released?

- Other - Please explain

Data shared in MSc thesis

VI. Data management responsibilities and resources

33. Is TU Delft the lead institution for this project?

- Yes, the only institution involved

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

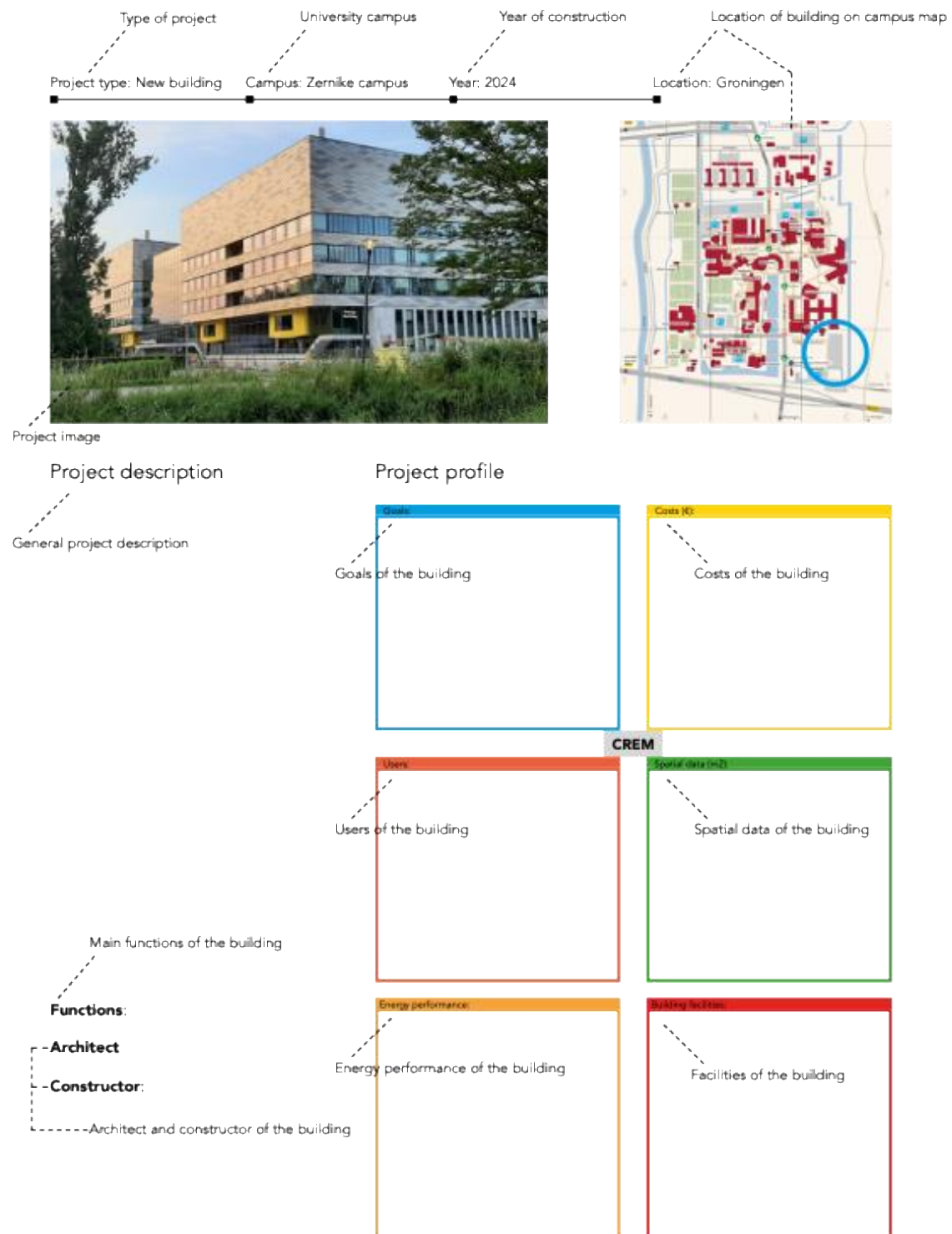
My supervisor dr. ir. M.H. (Monique) Arkesteijn MBA will be responsible for the data after I leave TU Delft.

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

Research data is only shared within the MSc thesis. No additional resources are required

Appendix VII: Project database

Reader's guide



Building Title: Feringa Building

Project type: New building Campus: Zernike campus Year: 2024 Location: Groningen



Project description

The Feringa Building at the University of Groningen, named after Nobel laureate Ben Feringa, is a state-of-the-art facility designed for groundbreaking research and education in fields such as chemistry, nanotechnology, and materials science. Covering 64,000 square meters, its innovative design includes advanced vibration-free laboratories, lecture halls, and collaborative spaces for 1,400 students and 850 staff. Sustainability is central, with the building being fully gas-free, featuring 900 square meters of solar panels, and utilizing efficient climate control systems. The new Feringa Building consists of two construction phases. After several years of construction, the first - and also largest - building section was commissioned in 2024. The second construction phase is scheduled for completion in 2027, the Feringa Building reflects the university's commitment to scientific excellence, sustainability, and interdisciplinary collaboration.

Functions: Education and research

Architect: Ector Hoogstad Architects

Constructor: Ballast Nedam

Project profile

Goals:

- Supporting Cutting-Edge Research: The facility provides state-of-the-art laboratories and specialized spaces to facilitate groundbreaking work in chemical engineering, nanotechnology, materials research, and astronomy.
- Accommodating Growth: With a capacity for approximately 1,400 students and 850 staff members, the building addresses the Faculty of Science and Engineering's expansion needs, offering modern educational and research environments.
- Promoting Sustainability: Incorporating sustainable design elements, such as 900 square meters of solar panels and a gas-free heating system, the building aims to achieve a BREEAM-NL 'Very Good' certification, reflecting its environmental responsibility.
- Enhancing Collaboration: The building's design features interconnected V-shaped wings and communal spaces, fostering interdisciplinary interaction among various research groups and departments.

Costs (€):

CREM

Users:

- Educational Programs: Bachelor's and master's degree programs in Physics, Chemistry, Astronomy, and Industrial Engineering & Management.
- Research Institutes:
 - Stratingh Institute for Chemistry
 - Zernike Institute for Advanced Materials
 - Groningen Biomolecular Sciences and Biotechnology Institute
 - Engineering and Technology Institute Groningen
 - Kapteyn Astronomical Institute
 - Van Swinderen Institute for Particle Physics and Gravity
 - SRON Netherlands Institute for Space Research

Spatial data (m2):

- Spanning 64,000 square meters, the building features a distinctive layout of three interconnected V-shaped wings, each measuring 260 meters in length and 63 meters in width.
- The five-story structure accommodates approximately 1,400 students and 850 staff members.

Energy performance:

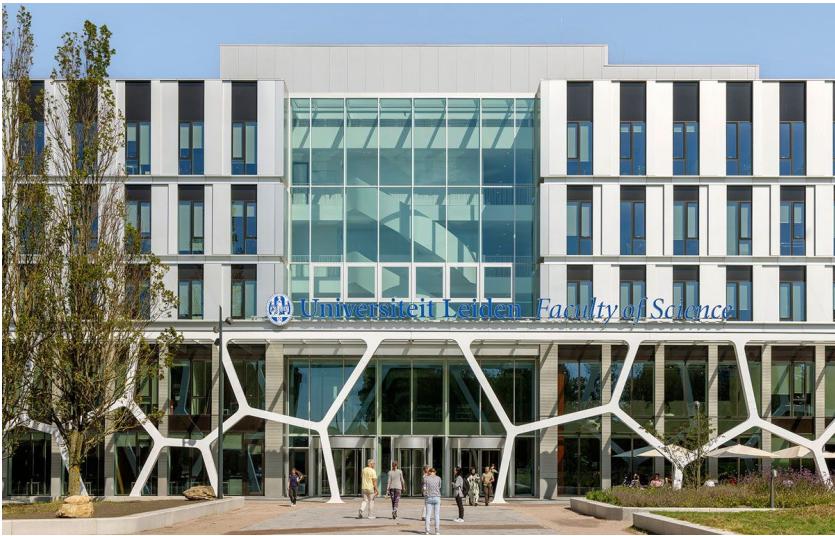
- The Feringa Building at the University of Groningen exemplifies advanced energy performance through several sustainable design features:
- Heating and Cooling: The building operates independently of natural gas, utilizing an Aquifer Thermal Energy Storage (ATES) system combined with efficient heat pumps to manage its heating and cooling needs.
- Insulation and Lighting: High-quality insulation minimizes energy loss, while the design maximizes natural daylight usage, reducing reliance on artificial lighting. When needed, energy-efficient LED lighting is employed throughout the facility.
- Solar Energy: Approximately 900 square meters of solar panels are installed on the rooftop, contributing around 120,000 Wp of electricity to the building's energy requirements.
- Ventilation Efficiency: Laboratories are equipped with advanced fume hoods featuring self-closing sliding windows and demand-controlled ventilation systems, which adjust airflow based on real-time usage, thereby conserving energy.

Building facilities:

- Laboratories: The building houses various specialized laboratories, including physics, chemistry, and low-vibration labs. Equipped with 450 fume cupboards and 35 laser labs.
- Lecture Halls and Classrooms: The facility includes multiple lecture rooms and teaching spaces.
- Cleanrooms: Two ultra-pure research environments are available, essential for disciplines such as nanotechnology and semiconductor research.
- Auditorium: A large auditorium with a seating capacity of over 400, designed to accommodate significant academic events and lectures.
- Canteen: A restaurant seating 250 people.
- Office Spaces: Dedicated office areas are provided for faculty and administrative staff, fostering collaboration and efficient workflow.
- Bicycle Parking: An underground bicycle shed is available for convenient and secure bike storage.

Building Title: Gorlaeus Building (Phase 2)

Project type: New building Campus: LBSP Year: 2024 Location: Leiden



Project description

The Gorlaeus Building (Phase 2) at Leiden University is a state-of-the-art facility for the Faculty of Science, completed in January 2024. Covering 30,000 square meters, it features advanced laboratories, teaching spaces, a library, a brasserie, and areas for study associations, fostering collaboration among students, staff, and researchers. Designed with sustainability in mind, the building includes thermal energy storage, high insulation, and over 1,150 square meters of solar panels, achieving a BREEAM 'Very Good' certification. Its modern, interconnected design promotes interaction and serves as a hub for scientific innovation and education.

Project profile

Goals:

Expanded Facilities: This phase added 30,000 square meters, including a new main entrance on Rosalind Franklinplein, a laboratory wing, teaching rooms, a library, a brasserie, a bar, and spaces for study associations. These additions centralize various institutes and faculty services, fostering interaction and collaboration among students and staff.

Sustainability Initiatives: The building incorporates high insulation levels in facades, roofs, and floors, connects to a thermal energy storage system for sustainable heating and cooling, and features 1,150 square meters of solar panels. These measures aim for a BREEAM 'Very Good' certification, reflecting a strong commitment to environmental responsibility.

Costs (€):

CREM

Users:

central hub for the Faculty of Science, bringing together various institutes and faculty services under one roof:

- Students: Utilize the teaching rooms, library, study areas, and communal spaces for learning and collaboration.
- Academic Staff and Researchers: Conduct research in the advanced laboratories and engage in teaching activities within the modern educational facilities.
- Faculty Services: Operate within the building to support the academic and administrative functions of the Faculty of Science.
- Study Associations: Benefit from dedicated spaces that facilitate student engagement and extracurricular activities.

Spatial data (m2):

30,000 square meters of space, including:

- A new main entrance on Rosalind Franklinplein featuring a distinctive façade.
- Additional laboratory wings.
- Teaching rooms.
- library.
- brasserie and a bar.
- Rooms for study associations.

Functions: Education, laboratories, and research

Architect: INBO and Sweco Architects

Constructor: Heijmans

Energy performance:

Thermal Energy Storage (TES) System: This system provides sustainable heating and cooling by storing thermal energy underground, reducing reliance on conventional energy sources.

High-Performance Insulation: The building's facades, roof, and floor are constructed with high insulation standards (Rc value of 6.0 m²K/W) to minimize heat loss and enhance energy efficiency.

Triple Glazing: The use of triple-glazed windows improves thermal insulation, contributing to reduced energy consumption for heating and cooling.

LED Lighting: Energy-efficient LED lighting is installed throughout the building, decreasing electricity usage.

Solar Panels: Approximately 1,150 square meters of solar panels are installed on the building, generating renewable energy on-site.

These measures have earned Phase 2 of the Gorlaeus Building a BREEAM 'Very Good' certification, reflecting its commitment to environmental sustainability.

Building facilities:

State-of-the-Art Laboratories: Equipped with advanced technology, these labs support cutting-edge research across various scientific disciplines.

Low-Vibration Research Spaces: The building includes specialized low-vibration areas, essential for sensitive experiments requiring minimal environmental interference.

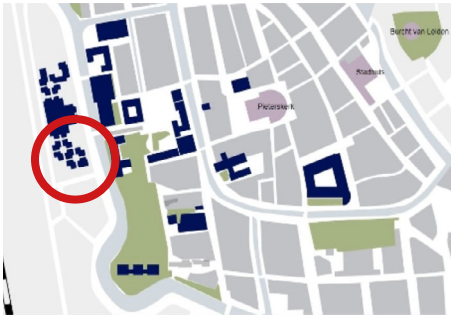
Modern Lecture Theatres and Classrooms: Designed to facilitate effective teaching and learning, these spaces are equipped with contemporary educational technologies.

Collaborative Workspaces: Open-plan areas are provided to encourage interaction and collaboration among students, researchers, and faculty members.

Green Bicycle Storage: The lower storeys of the former Gorlaeus high-rise have been repurposed into a green bicycle storage facility, promoting sustainable transportation.

Building Title: Herta Mohr

Project type: Renovation Campus: Humanities Campus Year: 2024 Location: Leiden



Project description

The Herta Mohr Building at Leiden University, part of the Humanities Campus, is a modern and sustainable academic facility named after renowned Egyptologist Herta Mohr. Covering 11,400 m², it features over 700 study spots, 20 working group rooms, and two large lecture halls, fostering a dynamic and collaborative learning environment. The building emphasizes flexibility, accommodating diverse teaching methods and future academic needs. Its sustainable design includes solar panels and an underground thermal storage system, aligning with Leiden University's commitment to environmental responsibility. As a hub for learning and research, the Herta Mohr Building enhances the university's identity and supports its academic community.

Project profile

Goals:

Sustainability: The building is the university's first fully gas-free facility, utilizing a Thermal Energy Storage system that reduces carbon emissions by approximately 150,000 kg annually. It has achieved a BREEAM 'Excellent' rating.

Modern Educational Environment: The renovation has transformed the original seven 'houses' into a cohesive, light-filled space under a glass roof, fostering social interaction among students and staff.

Reuse and Circularity: Emphasizing sustainable construction, materials from the original structure were repurposed.

Community Engagement and Accessibility: The building features a large glass façade and a spacious main entrance, enhancing its connection with the city and creating an inviting atmosphere.

Costs (€):

Construction and Investment Costs: While exact figures are not disclosed, the renovation aimed at sustainability and modern facilities suggests a significant investment.

Operational Costs: The building's sustainable features, such as connection to an underground thermal storage system and installation of solar panels, are expected to reduce energy and maintenance costs over time.

CREM

Users:

The building serves as a central hub for various institutes and offices within the Faculty of Humanities. Its primary users include:

Leiden University Institute for Area Studies (LIAS): This institute focuses on interdisciplinary research and education concerning regions such as Asia, the Middle East, and North Africa.

Netherlands Institute for the Near East (NINO): Dedicated to the study of the ancient Near East, NINO supports research and provides resources related to archaeology, languages, and cultures of the region.

Royal Netherlands Institute of Southeast Asian and Caribbean Studies (KITLV): KITLV conducts research on the history, society, and culture of Southeast Asia and the Caribbean.

African Studies Centre Leiden (ASCL): As an interfaculty institute, ASCL undertakes social-science research on Africa, aiming to promote a better understanding of historical, current, and future social developments in Sub-Saharan Africa.

International Institute for Asian Studies (IIAS): IIAS is a global research institute and knowledge exchange platform that promotes interdisciplinary studies on Asia.

Middle Eastern Library: This specialized library offers extensive resources for the study of the Middle East, supporting both students and researchers.

LeidenGlobal: An initiative that connects academic and cultural institutions to promote global and interdisciplinary perspectives.

Faculty Office: The administrative body that supports the Faculty of Humanities' operations and strategic initiatives.

By housing these diverse entities, the Herta Mohr Building fosters interdisciplinary collaboration and serves as a vibrant center for humanities scholarship at Leiden University.

Spatial data (m2):

Building offers over 700 study spots, 20 new rooms for working groups, and two large lecture halls

Gross Floor Area (GFA) and Usable Floor Area (UFA): The renovation expanded the building from 7,850 m² to 11,400 m², indicating a substantial increase in usable space.

Space Allocation: The building includes study spots, working group rooms, lecture halls, and common areas, indicating a balanced allocation between educational and communal spaces.

Functions: Education, library, and research

Architect: De Zwarte Hond

Constructor: Constructif / Kuijpers

Energy performance:

Gas-Free Operation: As the university's first fully gas-free building, it utilizes a Thermal Energy Storage (TES) system, significantly reducing carbon emissions by approximately 150,000 kg annually.

BREEAM 'Excellent' Certification: The building has achieved an 'Excellent' rating in the BREEAM certification system, reflecting its high standards in sustainable building practices.

Enhanced Insulation and Solar Panels: Upgrades include improved insulation and the installation of solar panels, contributing to the building's energy efficiency.

High-Quality, Low-Emission Materials: The selection of materials with low emissions of unhealthy substances ensures superior indoor air quality.

Building facilities:

Educational Spaces: The building offers over 700 teaching and self-study spaces, two lecture halls, work and meeting rooms, and common areas, supporting a dynamic learning environment.

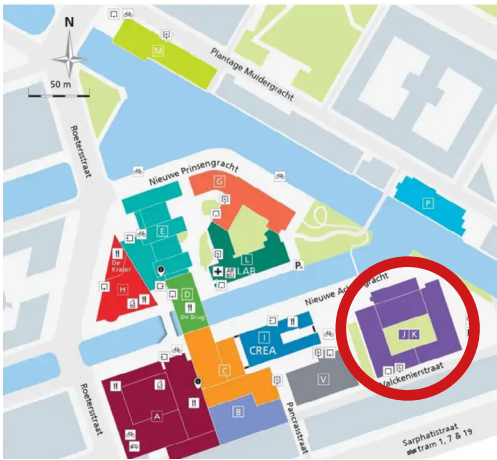
Library Resources: It houses the libraries of the African Studies Centre and Middle Eastern Studies, providing specialized resources for research and study.

Atrium and Social Areas: A spacious central atrium enhances natural light and serves as a central gathering place, promoting interaction among students and staff.

Bicycle Facilities: To encourage sustainable transportation, the building includes expanded and easily accessible bicycle storage, as well as new shower units for cyclists.

Building Title: J/K Building

Project type: Renovation Campus: Roeterseilandcampus Year: 2024 Location: Amsterdam



Project description

The REC J/K Building, located at Valckenierstraat 65-67 on the University of Amsterdam’s Roeterseiland Campus, is a distinctive structure known for its prominent brick chimney. Originally housing the Physics department and its laboratories, the building has been repurposed to serve multiple functions, including educational spaces, study areas, and collaborative hubs. Notably, it hosts the Library Learning Space, offering 140 places across 27 project rooms designed for student collaboration. These rooms, crafted from recycled materials, reflect the university’s commitment to sustainability. Additionally, the building accommodates REC Impact, a center that brings together social entrepreneurs, creative thinkers, and researchers to address global challenges through collaboration. Major maintenance and upgrades have been finished in 2024 to ensure the building remains fit for purpose.

Functions: Education and offices

Architect: Atelier Front

Constructor:

Project profile

Goals:

To provide modern, flexible spaces that support education, research, and collaboration.

To foster interdisciplinary interaction among students, faculty, and external partners.

To implement sustainable practices in building design and usage.

To maintain and upgrade facilities to meet current and future academic needs.

Costs (€):

CREM

Users:

Students utilizing study spaces and project rooms for individual and group work.

Faculty members conducting lectures, seminars, and research activities.

Social entrepreneurs, creative thinkers, and researchers collaborating within REC Impact.

Administrative and support staff facilitating building operations and services.

Spatial data (m2):

Address: Valckenierstraat 65-67, 1018 XE Amsterdam.

Accessibility: A ramp for wheelchair users is located next to the main entrance, ensuring inclusive access.

Energy performance:

Building facilities:

Project Rooms: The building now includes 27 new project rooms designed for student collaboration. These rooms were developed using circular materials, emphasizing sustainability.

Lecture Rooms: Upgrades have been made to create lecture rooms in the basement, ensuring access to natural daylight.

New Entrance: The main entrance has been relocated to Nieuwe Achtergracht to improve accessibility.

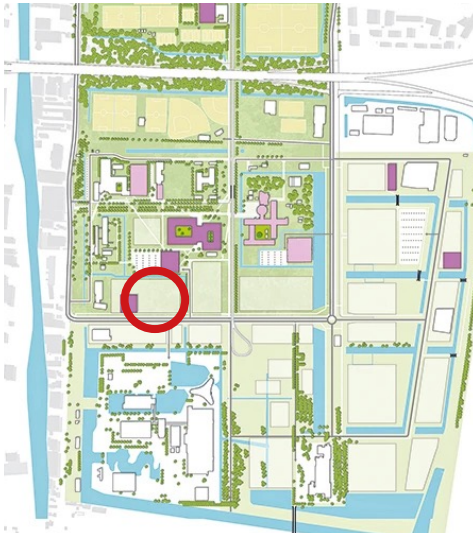
Building Title: Logistics & Environment

Project type: New building

Campus: TU Campus

Year: 2024

Location: Delft



Project description

The Logistics & Environment building at Delft University of Technology (TU Delft), located at Heertjeslaan 5, serves as the central hub for the procurement, storage, and distribution of laboratory supplies, chemicals, and gases for the university's various laboratories. Designed by cepezed architects, the facility encompasses approximately 2,200 square meters and was completed in early 2024.

Emphasizing sustainability and circularity, the building features a modular, demountable structure predominantly constructed from renewable and recycled materials. Its distinctive architecture includes curved green roofs planted with vegetation that enhances local biodiversity, and corten steel sliding gates that contribute to its robust appearance.

The design promotes transparency and openness, with extensive use of glass allowing natural light to permeate the interior, creating a pleasant working environment. Solar panels installed on the roof generate approximately 89,000 kWh of energy, aligning with TU Delft's goal to operate fully sustainably by 2030.

Officially opened on June 20, 2024, the Logistics & Environment building stands as a testament to TU Delft's commitment to innovation, sustainability, and integration with the natural environment.

Functions: Storage and distribution

Architect: Cepezed

Constructor: Arcadis

Project profile

<p>Goals:</p> <p>Centralize Logistics Operations: The facility serves as a central hub for the procurement, storage, and distribution of laboratory supplies, chemicals, and gases used across various university laboratories, streamlining these processes to enhance efficiency and safety.</p> <p>Promote Sustainability and Circularity: The building's design emphasizes sustainability, incorporating renewable and recycled materials, green roofs planted with native vegetation to support local biodiversity, and solar panels generating approximately 89,000 kWh of energy annually. These features align with TU Delft's ambition to operate fully sustainably by 2030.</p> <p>Enhance Safety Standards: Given the handling of hazardous materials, the building incorporates advanced safety measures, including specialized storage areas for flammable liquids, explosives, and lithium-ion batteries, as well as reinforced concrete walls designed to withstand significant pressure, ensuring a secure environment for both personnel and the surrounding community.</p> <p>Improve Employee Well-being: The facility is designed to provide a pleasant working environment, featuring abundant natural light, open spaces, and natural ventilation, contributing to the well-being and productivity of staff members.</p>	<p>Costs (€):</p>
<p>Users:</p> <p>The building serves a variety of user groups, including:</p> <p>Laboratory and Research Personnel: Researchers and technical staff across TU Delft's numerous laboratories depend on the building for the safe and efficient supply of chemicals, gases, and other specialized materials.</p> <p>Logistics and Operations Staff: Employees responsible for inventory management, storage, and distribution utilize the facility's advanced systems and spaces to streamline operations while adhering to strict safety standards.</p> <p>Health and Safety Teams: Specialized teams ensure compliance with safety protocols, particularly regarding hazardous materials, using designated storage areas for items like flammable liquids and lithium-ion batteries.</p> <p>University Sustainability Initiatives: Staff working on TU Delft's sustainability goals leverage the building's green and energy-efficient features, such as solar panels and green roofs, as part of the campus's environmental strategy.</p> <p>Suppliers and Contractors: External vendors and service providers interact with the building's logistics team to deliver and manage materials safely and efficiently.</p> <p>By catering to these diverse groups, the building supports TU Delft's operational, safety, and sustainability objectives while enhancing the university's overall research infrastructure.</p>	<p>CREM</p> <p>Spatial data (m2):</p> <p>Designed by cepezed architects, the facility encompasses approximately 2,200 square meters and functions as a central hub for the procurement, storage, and distribution of laboratory supplies, chemicals, and gases for the university's various laboratories.</p>
<p>Energy performance:</p> <p>Sustainable Energy Generation: The building is equipped with solar panels on its roof, generating approximately 89,000 kWh of electricity annually, contributing to TU Delft's goal of operating fully sustainably by 2030.</p> <p>Green Roofs: The distinctive curved roofs are planted with vegetation that complements the surrounding polder landscape, enhancing insulation and promoting biodiversity.</p> <p>Use of Renewable and Recycled Materials: The construction predominantly consists of renewable and/or recycled materials, reflecting a commitment to environmental responsibility.</p> <p>The building received a BREAAAM excellent certification.</p>	<p>Building facilities:</p> <p>Storage and Distribution: The building manages the procurement, storage, and distribution of laboratory supplies, chemicals, and gases for the university's laboratories.</p> <p>Design Features: The use of corten steel sliding gates and extensive glass creates a robust yet open appearance, allowing optimal daylight entry into the workspaces.</p>

Building Title: Marga Klompé Building

Project type: New building Campus: Tilburg campus Year: 2024 Location: Tilburg



Project description

The Marga Klompé Building at Tilburg University, inaugurated on January 29, 2024, is a pioneering educational facility emphasizing sustainability and circular construction. Designed by Powerhouse Company, it is Europe's first academic building constructed entirely from solid wood, featuring a nearly energy-neutral footprint. The structure encompasses a foyer, an auditorium, 13 lecture halls, and self-study spaces, collectively accommodating approximately 1,000 students. Its design pays homage to the campus's modernist architecture, notably the Cobbenhagen Building, through its natural stone façade and abundant natural light. Named after Marga Klompé, the Netherlands' first female minister and recipient of an honorary doctorate from the university in 1982, the building reflects her legacy of social commitment and innovation.

Functions: Education

Architect: Powerhouse Company

Constructor: BAM Bouw en Techniek

Project profile

Goals:

Sustainability: The building aims to achieve a BREEAM-Outstanding certification, reflecting its high sustainability standards. It operates nearly energy-neutrally, utilizing solar panels for electricity and systems like heat recovery and underground thermal energy storage for heating and cooling.

Circular Construction: Emphasizing circular building principles, the structure features a wooden main load-bearing framework, which is more sustainable than traditional steel or concrete. Materials are designed for disassembly and reuse, aligning with environmental responsibility goals.

Enhancing Educational Facilities: The building provides modern lecture halls, including one seating 450 people, and various study and meeting spaces, accommodating approximately 1,000 students. This expansion supports the university's growing educational needs.

Architectural Harmony: Its design pays homage to the campus's modernist architecture, particularly the Cobbenhagen Building, through features like a natural stone façade and abundant natural light, ensuring aesthetic cohesion.

Honoring Marga Klompé: Named after the Netherlands' first female minister, who received an honorary doctorate from the university in 1982, the building reflects her legacy of social commitment and innovation.

Costs (€):

CREM

Users:

The Marga Klompé Building at Tilburg University serves as a dynamic educational hub, accommodating approximately 1,000 students daily. It features 14 lecture halls, including a main auditorium seating 450 individuals, alongside numerous self-study and meeting spaces. These facilities are utilized by students and faculty across various disciplines for lectures, collaborative projects, and individual study. The building's design emphasizes accessibility, incorporating features such as disabled toilets and hearing support systems to ensure inclusivity for all users.

By providing a versatile and inclusive environment, the Marga Klompé Building fosters academic engagement and community interaction within the university.

Spatial data (m2):

The Marga Klompé Building at Tilburg University is a nearly energy-neutral educational facility, occupying a 33 by 33-meter footprint within the university's forested campus. It comprises a foyer, an auditorium, 13 lecture halls, and self-study areas, collectively accommodating approximately 1,000 students. The building's design pays homage to the campus's modernist architecture, particularly the Cobbenhagen Building, featuring a natural stone façade and abundant natural light. Notably, it is the first academic building in Europe constructed entirely from solid wood, emphasizing sustainability and circular construction principles.

Energy performance:

Nearly Energy-Neutral Design: The building is designed to be nearly energy-neutral, adhering to the Trias Energetica principle, which focuses on minimizing energy consumption, utilizing sustainable energy sources, and efficiently using fossil fuels only when necessary.

BREEAM 'Outstanding' Certification: The Marga Klompé Building has achieved a BREEAM 'Outstanding' rating, reflecting its exceptional sustainability performance.

Innovative Insulation: The building envelope is insulated using materials that include recycled denim jeans, enhancing both thermal performance and acoustic comfort.

Energy-Efficient Systems: The facility incorporates energy-efficient installations, including smart control systems for ventilation and lighting that adjust based on actual demand. Heating and cooling are managed through an efficient ground storage system paired with a heat pump.

Building facilities:

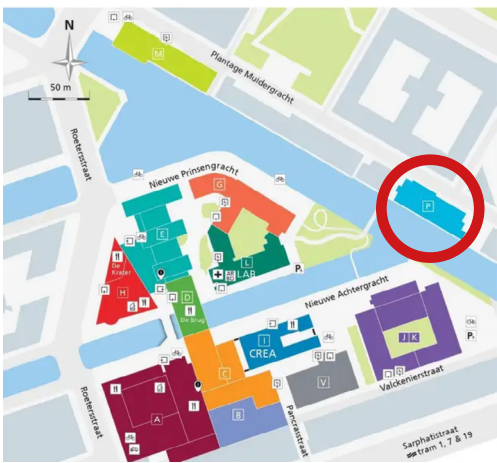
Auditorium and Lecture Halls: The building houses one auditorium and thirteen lecture halls, designed to accommodate approximately 1,000 students.

Self-Study Spaces: Ample self-study areas are provided, offering students a conducive environment for individual learning.

Advanced Audio-Visual Systems: Equipped with cutting-edge AV technology, the building features LED walls, unified communication and collaboration (UCC) video conferencing facilities, and energy-efficient power management systems to enhance the learning experience.

Building Title: P Building

Project type: Renovation Campus: Roeterseilandcampus Year: 2024 Location: Amsterdam



Project description

The REC P Building, located at Plantage Muidergracht 24 on the University of Amsterdam’s Roeterseiland Campus, has recently undergone extensive renovations to meet modern educational standards. Reopened in February 2024, it now serves as the primary facility for the Politics, Psychology, Law, and Economics (PPLE) program, as well as housing the UvA Academy and the Amsterdam Business School. The building features state-of-the-art lecture rooms, study and work areas, and a large lecture hall designed for both on-site and online teaching. Sustainability was a key focus during the renovation, with the implementation of a green roof, energy-efficient LED lighting, and the reuse of materials from the original structure. Additionally, a bicycle parking facility for 128 bicycles has been created underneath the building, accessible via a separate entrance.

Project profile

Goals:

To provide modern, flexible spaces that support interdisciplinary education and research.

To implement sustainable and energy-efficient design principles.

To facilitate both on-site and online teaching through advanced facilities.

Costs (€):

CREM

Users:

Students enrolled in the PPLE program.

Participants in professional development courses offered by the UvA Academy.

Faculty and staff of the Amsterdam Business School.

Spatial data (m2):

Address: Plantage Muidergracht 24, 1018 TV Amsterdam.

Capacity: Accommodates over 1,000 students and employees.

Functions: Education

Energy performance:

Building facilities:

Educational Spaces: The renovated building will house lecture rooms, study and work areas, and a large lecture hall designed to accommodate both large groups and smaller breakout sessions. These spaces are being equipped with facilities to support both on-site and on-line teaching, reflecting modern educational practices.

Bicycle Parking: A new bicycle parking facility with space for 128 bicycles is being constructed underneath the building, accessible via a separate entrance, promoting sustainable transportation options for students and staff.

Building Title: Flux

Project type: New building

Campus: TU campus

Year: 2023

Location: Delft



Project description

The Flux Building at Delft University of Technology (TU Delft) is a modular and demountable educational facility designed to accommodate the university's growing student population. Located centrally on the campus, near the Faculty of Electrical Engineering, Mathematics, and Computer Science, Flux provides four large lecture halls with a combined capacity of over 700 students, along with 20 study spaces. The building is constructed using sustainable materials, including circular floorboards previously utilized during the 2012 London Olympics, and is equipped with solar panels and refurbished furniture. Designed for a lifespan of five to ten years, Flux offers flexibility to adapt to future educational needs and can be dismantled and relocated as required.

Project profile

Goals:

Accommodate Student Growth: Provide immediate additional educational space to meet the demands of increasing student numbers.

Sustainability: Implement eco-friendly construction practices, utilizing reusable and circular materials to minimize environmental impact.

Flexibility: Offer a temporary yet high-quality solution that can be relocated or repurposed based on future university requirements.

Costs (€):

CREM

Users:

Students: Engaged in various academic programs, utilizing the lecture halls and study spaces for learning and collaboration.

Faculty Members: Conducting lectures, seminars, and examinations within the facility's adaptable teaching environments.

Administrative Staff: Supporting the operational aspects of the building and its educational functions.

Spatial data (m2):

Total Area: Approximately 2,115 square meters.

Location: Cornelis Drebbelweg 6, 2628 CM Delft, Netherlands.

The Flux Building exemplifies TU Delft's commitment to sustainable development and adaptive campus planning, ensuring that educational infrastructure evolves in response to changing needs.

Functions: Education

Architect: Broekbakema

Energy performance:

Sustainable Construction: Flux is constructed with a focus on circularity, enabling it to be dismantled and reconstructed elsewhere if needed. The building incorporates circular floorboards repurposed from previous uses, such as the 2012 London Olympics, highlighting its commitment to reusing materials.

Energy Efficiency: Equipped with LED lighting and solar panels, Flux enhances its energy efficiency and reduces its carbon footprint. These features align with TU Delft's sustainability objectives, contributing to the university's broader environmental goals.

Building facilities:

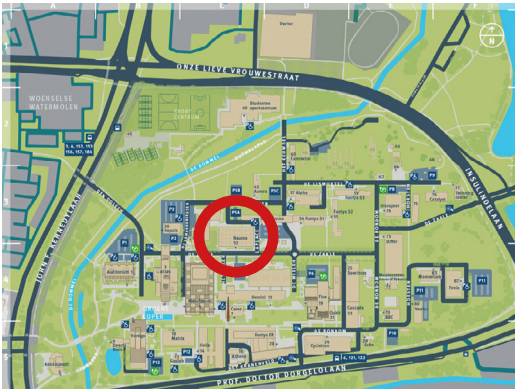
Teaching Rooms: Flux houses four versatile teaching rooms designed to support various instructional methods. Three of these rooms can each accommodate up to 192 students, while the fourth has a capacity of 158 students.

Study Spaces: In addition to the teaching rooms, the building offers 20 study spaces, providing students with dedicated areas for individual or group study sessions.

Furnishings: Flux is furnished with refurbished furniture, some sourced from TU Delft's existing inventory, emphasizing the university's commitment to sustainability and resource efficiency.

Building Title: Neuron

Project type: Transformation Campus: TU/e campus Year: 2023 Location: Eindhoven



Project description

The Neuron building at Eindhoven University of Technology (TU/e), formerly known as the Laplace Building, has been transformed into a dynamic educational center. It now houses the Eindhoven Artificial Intelligence Systems Institute (EAISI), 14 lecture halls, 22 student workspaces, and approximately 400 individual study areas. The renovation, completed in early 2023, preserved the building’s architectural heritage while introducing modern amenities. A notable feature is the “Loom Room,” a nine-meter-high hand-woven textile cube by designer Hella Jongerius, suspended in the atrium to connect the building’s two floors. Officially opened on March 28, 2023, by Prince Constantijn van Oranje, Neuron serves as a vibrant hub for learning, collaboration, and innovation, reflecting TU/e’s commitment to advancing artificial intelligence and providing state-of-the-art educational facilities.

Functions: Education and research

Architect: Team V Architecture

Constructor: Laplace Transformation construction consortium

Project profile

Goals:

Centralize AI Research and Education: Neuron serves as the headquarters for the Eindhoven Artificial Intelligence Systems Institute (EAISI), providing dedicated spaces for AI research and facilitating collaboration among experts in the field.

Enhance Educational Facilities: The building includes 14 lecture halls, 22 group workspaces, and approximately 400 individual study areas, designed to support diverse learning activities and promote student engagement.

Preserve Architectural Heritage: Originally constructed in 1972 as a computer center, Neuron’s renovation aimed to retain its architectural, cultural, and historical significance while updating its functionality to meet contemporary academic needs.

Incorporate Artistic Elements: The inclusion of “Loom Room,” a nine-meter-high hand-woven textile cube by designer Hella Jongerius, enriches the building’s aesthetic appeal and fosters a creative atmosphere.

Costs (€):

CREM

Users:

serves a diverse group of users:

Students: Neuron offers 14 lecture halls, 22 group workspaces, and approximately 400 individual study areas, providing an environment conducive to learning and collaboration.

Faculty and Educators: Instructors utilize Neuron’s modern teaching facilities, including lecture halls equipped for hybrid education, to deliver courses and engage with students effectively.

Researchers: The building houses the Eindhoven Artificial Intelligence Systems Institute (EAISI), serving as a central location for AI research and fostering interdisciplinary collaboration among scholars.

Visitors and Collaborators: Neuron hosts various events, such as symposiums and workshops, attracting external guests and facilitating partnerships with industry and academic peers.

By accommodating these groups, Neuron functions as a vibrant hub for education, research, and community engagement within the TU/e campus.

Spatial data (m2):

The Neuron building at Eindhoven University of Technology (TU/e) encompasses approximately 12,330 square meters of space. It features two large lecture halls, multifunctional classrooms, smaller group spaces, and around 650 study spots. The building’s design includes a partially raised roof with a special wooden construction, creating a high and light atrium space on the second floor. This bright area is connected to the first floor by an opening, enhancing the sense of openness and facilitating interaction among users. Additionally, the building houses the Eindhoven Artificial Intelligence Systems Institute (EAISI), providing dedicated spaces for AI research and collaboration. These spatial features collectively support Neuron’s role as a central hub for education and research within the TU/e campus.

Energy performance:

Facade Enhancement: The original facade was stripped and fitted with new glazing, improving thermal performance and energy efficiency.

Patio Enclosures: The existing open patios, which previously fell short in energy efficiency, were covered using the original steel roof construction. This modification enhances the building’s insulation and reduces energy consumption.

Building facilities:

Lecture Halls: 14 lecture halls equipped with modern amenities to facilitate effective teaching and learning.

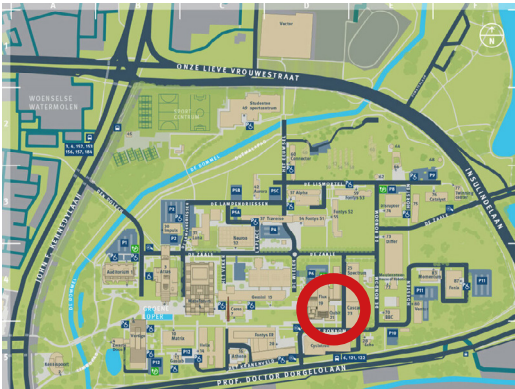
Workspaces: 22 smaller workspaces, including OGO (Design-Oriented Education) spaces and train compartment-style areas, designed to support collaborative projects and group work.

Study Areas: Approximately 400 individual study spaces, divided into silent and noise-permitting zones, catering to diverse student preferences.

Atrium with Art Installation: A spacious atrium featuring “Loom Room,” a nine-meter-high hand-woven cube by designer Hella Jongerius, serving as a focal point and enhancing the aesthetic appeal of the building.

Building Title: Qubit

Project type: New building Campus: TU/e campus Year: 2023 Location: Eindhoven



Project description

The Qubit Building at Eindhoven University of Technology (TU/e) serves as the central hub for quantum technology research and collaboration on campus. Completed in 2023, it primarily accommodates the Coherence and Quantum Technology (CQT) research group, providing state-of-the-art laboratories, workspaces, and educational facilities. Notably, Qubit features TU/e's first underground laboratories, encompassing approximately 640 square meters, designed to minimize vibrations and environmental disturbances—essential for sensitive experiments with ultracold atoms and advanced laser equipment. Above ground, the building comprises three floors connected to the adjacent Flux and Cascade buildings via a footbridge, facilitating seamless interaction among departments. The design emphasizes flexibility, allowing for future adaptations to various functions or users. Qubit also includes a reception area styled in the spirit of Quantum Delta NL, serving as an interactive space to engage students, industry partners, and the public with quantum technology advancements.

Functions: Education and research

Architect: Diederendirrix

Constructor:

Project profile

Goals:

- Centralize Quantum Research: Qubit serves as the primary facility for the Coherence and Quantum Technology (CQT) research group, providing state-of-the-art laboratories and workspaces to advance quantum technology research.
- Establish a Quantum Technology Hub: Beyond housing CQT, Qubit functions as a central hub for quantum technology activities in Eindhoven, fostering collaboration among researchers, industry partners, and students.
- Facilitate Advanced Experiments: The building includes TU/e's first underground laboratories, designed to minimize vibrations and environmental disturbances, essential for sensitive quantum experiments.
- Promote Flexibility and Future Adaptability: Qubit's design allows for easy reconfiguration to accommodate different functions or users in the future, ensuring long-term utility.
- Enhance Public Engagement: The building features a reception area styled in the spirit of Quantum Delta NL, serving as an interactive space to engage students, industry partners, and the public with quantum technology advancements.

Costs (€):

CREM

Users:

- The building serves as a central hub for quantum technology research and collaboration, accommodating a diverse group of users:
- Coherence and Quantum Technology (CQT) Research Group: Qubit is the primary facility for the CQT group, providing state-of-the-art laboratories and workspaces essential for their research in quantum physics.
- Eindhoven Hendrik Casimir Institute (EHCI): The offices of the EHCI, which focuses on quantum materials and technology, are located within Qubit, fostering interdisciplinary collaboration.
- Electrical Engineering Department: Colleagues from Electrical Engineering involved with Quantum Delta NL have designated office spaces in Qubit, promoting integration across departments.
- Students and Visitors: Qubit's reception area, designed in the spirit of Quantum Delta NL, serves as an interactive space to engage students, industry partners, and the public with advancements in quantum technology.
- By accommodating these diverse groups, Qubit functions as a vibrant center for education, research, and community engagement within the quantum technology sector at TU/e.

Spatial data (m2):

The Qubit Building at Eindhoven University of Technology (TU/e) encompasses approximately 2,100 square meters, distributed over three above-ground levels and a basement. The basement houses TU/e's first underground laboratories, designed to minimize vibrations and environmental disturbances, essential for sensitive quantum experiments. The building is strategically situated between the Flux and Cascade buildings, with a footbridge traversing its first floor, connecting these adjacent structures to facilitate seamless interaction among departments. The design emphasizes flexibility, allowing for future adaptations to various functions or users, ensuring long-term utility.

Energy performance:

While specific energy performance metrics for the Qubit Building are not detailed in the available sources, the design emphasizes flexibility and sustainability. The building's construction and facade are engineered to allow for future adaptations, ensuring long-term usability and efficiency.

Building facilities:

- Laboratories:** The building houses state-of-the-art laboratories, including a radiation bunker and a room with a vibration-free floor, essential for precise laser equipment and quantum research.
- Workspaces:** Multiple office rooms and meeting spaces are available to facilitate collaboration among researchers and students.
- Teaching Spaces:** Dedicated teaching rooms are designed to support the educational activities of the CQT group, fostering an environment conducive to learning and innovation.
- Reception Area:** Located on the first floor, the reception area serves as the heart of the building, providing a welcoming space for visitors and members of the university community.

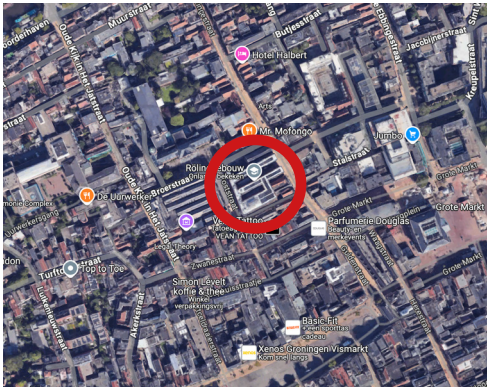
Building Title: Röling Building

Project type: Renovation

Campus: Binnenstad

Year: 2023

Location: Groningen



Project description

The Röling Building, located at Oude Boteringestraat 18 in Groningen, serves as the central hub for the Faculty of Law at the University of Groningen. This facility accommodates over 4,000 students and more than 450 staff members, providing a cohesive environment for legal education and research. Originally designed by Italian architect Giorgio Grassi and completed in 1992, the building initially housed the Public Library (Openbare Bibliotheek). Following the library's relocation to Forum Groningen in 2019, the structure underwent significant renovations to meet the specific needs of the Faculty of Law. These refurbishments included the addition of an extra floor to address space constraints and the creation of modern teaching rooms, workspaces with ample natural light, and a moot court for law students.

In 2022, the building was named in honor of Professor Bernard Röling (1906–1985), a distinguished scholar who served as Professor of Criminal Law, Criminal Procedure, and Criminology at the University from 1949 until his death. Professor Röling was notable for founding the Institute of Polemology in 1962, focusing on the causes of war and conditions for peace, and for his role as a judge in the Tokyo War Crimes Tribunal after World War II. The Röling Building's strategic location and thoughtfully designed spaces foster a dynamic and collaborative atmosphere, enhancing the academic experience for both students and faculty within the Faculty of Law.

Functions: Education and offices

Original Architect: originally designed by Giorgio Grassi in 1992

Renovation Architect: Cruz y Ortiz and INBO

Project profile

Goals:

Centralize Faculty Operations: By relocating from the Harmonie Building to the Röling Building, the Faculty of Law aimed to consolidate its previously dispersed departments into a single, cohesive location, fostering enhanced collaboration among over 4,000 students and 450 staff members.

Preserve Architectural Heritage: The building, originally designed by Italian architect Giorgio Grassi in 1992, underwent renovations that respected its historical significance while updating its functionality to meet contemporary academic needs.

Enhance Educational Facilities: The refurbishment included the addition of an extra floor and the creation of modern teaching rooms, workspaces with ample natural light, and a moot court for law students, providing a conducive environment for legal education and research.

Promote Sustainability: Aligned with the university's commitment to sustainability, the building incorporates features such as solar panels, heat pumps, and energy-efficient ventilation systems to minimize its environmental footprint.

These goals collectively aim to provide a functional, sustainable, and inspiring environment for the Faculty of Law's academic community.

Costs (€):

CREM

Users:

The building serves as a central hub for a diverse group of users:

Students: Over 4,000 law students utilize the building for attending lectures, participating in seminars, and accessing study and social spaces. The building's moot court provides a practical setting for legal simulations and training.

Faculty and Staff: More than 450 academic and administrative personnel work in the building, leveraging its modern offices and meeting spaces to conduct research, teaching, and faculty operations.

Visitors and Collaborators: External stakeholders, including guest lecturers, legal professionals, and collaborators, use the building for academic events, conferences, and workshops.

Public: Certain spaces, such as the moot court during public events, and areas open for community engagement, allow public access, fostering broader interaction.

By accommodating these user groups, the Röling Building creates a vibrant and collaborative environment for education, research, and engagement within the Faculty of Law.

Spatial data (m2):

The building serves as the central facility for the Faculty of Law. The building underwent significant renovations to accommodate the faculty's needs. An additional floor was added to provide sufficient space for over 4,000 students and more than 450 staff members.

Key Spatial Features:

Active Learning Classrooms: The ground floor houses four Active Learning Classrooms—Singer-Dekkerzaal, Scheltemazaal, Bakker-Nortzaal, and Brunsemazaal—each accommodating up to 42 students. These rooms are equipped with large fixed LCD screens, mobile LCD screens with Airtime connections, and multiple whiteboards to facilitate interactive learning.

Accessibility: The building features two wheelchair-accessible entrances with automatic swing doors. Two lifts at the end of the central hall provide access to all floors. Wheelchair-accessible toilets are available on the ground and second floors. Additional facilities include a nursing mothers' room and a first-aid room that doubles as a quiet space.

Energy performance:

Solar Panels: The building is equipped with solar panels to harness renewable energy, reducing reliance on non-renewable power sources.

Solar Control Glass: Installation of solar control glass helps in minimizing heat gain, thereby reducing the need for artificial cooling.

Heat Pumps and Thermal Energy Storage (WKO): The heating system utilizes heat pumps in conjunction with a thermal energy storage system, shared with the University Library, to efficiently manage heating and cooling needs.

Balanced Ventilation with Heat Recovery: All rooms feature balanced ventilation systems connected to energy-efficient air handling units equipped with heat recovery capabilities.

CO2-Based Ventilation Control: Lecture halls are equipped with CO2-based volume control systems that adjust ventilation capacity based on occupancy, ensuring optimal air quality and energy efficiency.

Temperature Regulation: The heating system is set to a maximum temperature of 19 degrees Celsius, with cooling provided when temperatures exceed 26 degrees Celsius.

Building facilities:

Workspaces: The large library floors have been transformed into workspaces that receive ample natural light, creating a conducive environment for staff and students.

Moot Court: A dedicated moot court has been established for law students to practice and hone their legal skills in a simulated courtroom setting.

Teaching Rooms: Various teaching rooms have been incorporated to facilitate diverse educational activities.

Meeting Spaces: Numerous areas have been designated for meetings, encouraging collaboration and interaction among faculty and students.

Building Title: The Langezijds Building

Project type: Transformation Campus: Universiteit Twente Year: 2023 Location: Enschede



Project description

The Langezijds Building, located on the University of Twente’s campus in Enschede, was inaugurated in April 2023 as the new home for the Faculty of Geo-Information Science and Earth Observation (ITC). Originally constructed in 1972, this 220-meter-long structure underwent a significant transformation to become one of the most sustainable buildings on campus, achieving an energy label of A+++.

The renovation introduced three atriums, referred to as “green lungs,” which provide natural light, fresh air, and indoor gardens, creating a biotope for flora and fauna. The building now houses modern teaching spaces, laboratories, a large study center, offices, and a food-work café, all designed to foster collaboration and innovation among its approximately 700 students and staff.

Project profile

Goals:

Sustainability: Transform the existing structure into an energy-efficient, future-proof facility, achieving an A+++ energy label.

Enhanced Learning Environment: Provide state-of-the-art educational spaces that support modern teaching methodologies and research activities.

Community Building: Create a social heart within the building to encourage interaction among students, faculty, and staff.

Costs (€):

CREM

Users:

Students: Engaged in geo-information science and earth observation programs.

Faculty and Researchers: Conducting advanced research and delivering educational programs.

Administrative Staff: Supporting the operations of the ITC faculty.

Spatial data (m2):

Total Area: Approximately 13,783 square meters.

Length: 220 meters, making it one of the longest buildings in the country.

Key Features: Three atriums with indoor gardens, modern classrooms, laboratories, a study center, and a food-work café.

The Langezijds Building exemplifies the University of Twente’s commitment to sustainability and innovation in higher education facilities.

Functions: Education and offices

Architect: Civic Architects, VDNDP, and Studio Groen+Schild

Constructor: consortium Dura Vermeer Bouw Hengelo, Trebbe, and Croonwolder&dros

Energy performance:

Energy Label Upgrade: The building has been upgraded from an energy label G to A+++ , reflecting its enhanced energy efficiency.

Solar Panels: Approximately 1,000 solar panels have been installed on the roof, contributing to the building’s renewable energy generation.

Sustainable Design Features: The renovation preserved the original concrete and steel structures while incorporating large atriums that provide natural light, fresh air, and serve as biotopes for flora and fauna, reducing the need for artificial lighting and ventilation.

Building facilities:

Educational Spaces: The building houses modern teaching spaces, including lecture halls and classrooms equipped with advanced technology to support interactive learning.

Laboratories: State-of-the-art laboratories are available for research and practical applications in geo-information science and earth observation.

Study Center: A large study center provides students with a conducive environment for individual and group study sessions.

Offices: The facility includes offices for faculty and administrative staff, designed to foster collaboration and efficiency.

Food-Work Café: A central food-work café in the building’s social heart offers a space for dining and informal meetings, enhancing the sense of community.

Building Title: BG3 Building

Project type: Renovation Campus: Universiteitskwartier Year: 2022 Location: Amsterdam



Project description

The BG3 Building, located at Binnengasthuisstraat 9 in Amsterdam, serves as the central hub for the Faculty of Humanities (FGw) at the University of Amsterdam. In March 2022, the faculty's board and administrative offices relocated to this building, which comprises two architecturally distinct sections: the original Administration Building from 1916, designed by J.M. van der Meij, and an oval-shaped annex added in 1995 by architect Theo Bosch. The 2021 renovation focused on harmoniously connecting these sections while preserving their unique architectural elements. Innovative techniques were employed, such as opening up the pavilion's ceiling and applying acoustic spray mortar to enhance sound quality. Sustainability measures included upgrading the air control system to reduce natural gas consumption. The ground floor houses VOX-POP, a platform that organizes public events to promote the visibility of the humanities.

Functions: Offices and event & exhibition spaces

Original Architect: J.M. van der Meij

Project profile

Goals:

To centralize the Faculty of Humanities' administration and support services.

To provide spaces for public engagement and events that highlight humanities research and education.

To preserve and integrate historical architectural elements while implementing sustainable building practices.

Costs (€):

CREM

Users:

Faculty of Humanities' board members and administrative staff.

Students and staff participating in events organized by VOX-POP.

Visitors attending meetings, discussions, and public events related to the humanities.

Spatial data (m2):

Address: Binnengasthuisstraat 9, 1012 ZA Amsterdam.

Architectural Composition: Combines the historic 1916 Administration Building and the 1995 oval-shaped pavilion.

Energy performance:

Sustainability Features: Upgraded air control systems to enhance energy efficiency and reduce gas usage.

Building facilities:

University Library: BG3 houses a significant portion of the University Library's collections, providing students and researchers with access to a wide range of academic resources.

Study Spaces: The building offers dedicated study areas designed to support both individual and group study sessions, equipped with necessary amenities to facilitate learning.

Administrative Offices: Various administrative departments are located within BG3, supporting the university's operational functions.

Building Title: Duboisdomein 30

Project type: Transformation Campus: Year: 2022 Location: Maastricht



Project description

Duboisdomein 30, colloquially known as the “Black Box,” is a significant facility within Maastricht University. Originally constructed in 1988 as the headquarters and printing press for the newspaper De Limburger, the building was designed by Swinkels/Paschier, now known as Architecten aan de Maas. In 2010, Maastricht University began leasing the building to address space shortages and later purchased it to accommodate the expanding Faculty of Science and Engineering. A major transformation was undertaken to convert the former press hall into a modern research and development laboratory, completed in 2021. The renovated facility now houses several research groups, laboratories, and the European ET Pathfinder test location for the Einstein Telescope, which is instrumental in advancing gravitational wave research. Additionally, the building serves educational purposes and includes offices for the university’s Facility Services and parts of the Faculty of Health, Medicine, and Life Sciences. Despite its modernization, Duboisdomein 30 retains architectural elements that reflect its historical roots.

Functions: Offices, research and education

Original Architect: Swinkels/Paschier, now known as Architecten aan de Maas

Project profile

Goals:

Address Space Constraints: Initially leased in 2010 to alleviate space shortages following the cancellation of a planned campus building, the facility was later purchased to accommodate the expanding Faculty of Science and Engineering.

Support Advanced Research: The building now houses the European ET Pathfinder, a test facility for the Einstein Telescope, facilitating cutting-edge research in gravitational wave detection.

Enhance Educational Infrastructure: By converting the former press hall into modern laboratories and educational spaces, the university provides state-of-the-art facilities for students and staff.

Preserve Architectural Heritage: The renovation retained distinctive elements of the original 1988 design, maintaining its historical significance while adapting it for contemporary use.

These goals reflect Maastricht University's commitment to expanding its research capabilities, enriching educational experiences, and preserving cultural heritage.

Costs (€):

CREM

Users:

The building accommodates a diverse group of users:

Faculty of Science and Engineering (FSE): Several research groups and facilities within FSE are housed here, including the European ET Pathfinder test location for the Einstein Telescope, which focuses on gravitational wave research.

Facility Services Department: This department operates from Duboisdomein 30, providing a broad range of services such as building maintenance, food and beverage, sustainability initiatives, and safety and security measures to support the university community.

Faculty of Health, Medicine, and Life Sciences (FHML): Portions of FHML utilize the building for various academic and administrative functions.

By serving these diverse groups, Duboisdomein 30 plays a crucial role in supporting Maastricht University's educational, research, and operational activities.

Spatial data (m2):

Energy performance:

Building facilities:

Research Facilities: The building hosts the European ET Pathfinder test location, a significant initiative aimed at advancing gravitational wave research through the Einstein Telescope project.

Laboratories: Dedicated laboratory spaces support various scientific endeavors within the Faculty of Science and Engineering.

Educational Spaces: The building includes educational facilities designed to support teaching and learning activities.

Administrative Offices: It houses offices for the Facility Services department and parts of the Faculty of Health, Medicine, and Life Sciences.

Building Title: Echo Building

Project type: new building Campus: TU campus Year: 2022 Location: Delft



Project description

The Echo Building at TU Delft, completed in May 2022, is an innovative, energy-generating interfaculty education facility designed by UNStudio. It is considered the most sustainable building on the TU Delft campus, contributing significantly to the university's goal of becoming fully sustainable by 2030. The building houses a variety of multifunctional teaching spaces and study areas, designed to accommodate diverse teaching methods, from lectures to project-based learning and self-study for around 1,700 students.

Architecturally, Echo promotes openness and transparency, integrating natural light and creating strong visual connections with the surrounding campus. Its innovative design earned the Prix Versailles award for its ecological efficiency and architectural unity.

Functions: Education

Architect: UNStudio

Constructor: BAM Bouw en Techniek

Project profile

Goals:

Accommodate Growing Student Numbers: Echo provides additional educational spaces to meet the increasing demand, featuring seven teaching rooms with flexible layouts, including a 700-seat lecture hall that can be divided into three separate rooms.

Enhance Educational Flexibility: The building supports various teaching methods and study styles, offering over 300 study places for group work and self-study, thereby fostering a dynamic learning environment.

Achieve Sustainability Goals: Echo is an energy-producing building, contributing to TU Delft's ambition to operate a CO2-neutral and circular campus by 2030. It incorporates solar panels, effective insulation, and a thermal storage system to generate more energy than it consumes, including user-related energy for laptops, lighting, and catering.

Promote Interfaculty Collaboration: As an interfaculty educational building, Echo facilitates collaboration among different departments, providing spaces for education, debates, self-study, and offices, thereby enhancing interdisciplinary interaction.

Create an Open and Inviting Environment: The building's transparent design allows visibility of educational activities from the outside, fostering a sense of community and engagement among students, staff, and visitors.

Costs (€):

CREM

Users:

The building serves a diverse group of users:

Students: Echo provides over 300 study spaces for group work and self-study, along with seven teaching rooms designed to accommodate various teaching methods and study styles.

Faculty Members: Instructors utilize Echo's flexible teaching rooms, including a 700-seat lecture hall that can be divided into three separate rooms, to deliver lectures, facilitate group discussions, and conduct project-based teaching.

Administrative Staff: The building includes office spaces for staff involved in the coordination and support of educational activities, contributing to the efficient operation of academic programs.

Visitors and External Partners: Echo's design encourages engagement with the broader community, hosting debates, seminars, and collaborative events that attract visitors and industry partners.

By accommodating these groups, Echo fosters a vibrant and collaborative environment that enhances the educational experience and supports TU Delft's commitment to sustainability and innovation.

Square meters:

GFA 8,844 m2
UFA is not specified in sources, but UFA/GFA ratio is typically around 70% in educational buildings
Number of floors: 4

% of Educational Space: The majority of the space is allocated for educational purposes

% of Specific Space: Echo provides some specialized spaces for debates, project-based learning, and case-study rooms

The building encompasses approximately 8,844 square meters, providing educational spaces for around 1,700 students.

Energy performance:

Energy Generation: Echo is the first energy-positive university building in the Netherlands, equipped with approximately 1,200 solar panels on its roof. These panels generate more energy than the building consumes, covering all operational needs, including lighting, equipment, and user devices.

Ventilation System: The building employs an innovative displacement ventilation system that supplies fresh air from the floor, ensuring efficient air circulation and maintaining a healthy indoor environment.

Daylight Optimization: Echo's design maximizes natural light through extensive glass façades, reducing reliance on artificial lighting and enhancing occupant well-being. Deep aluminum awnings and climbing plants on the exterior help control solar heat gain, contributing to the building's energy efficiency.

Building facilities:

Flexible Teaching Spaces: Echo houses seven adaptable teaching rooms that can be reconfigured to support various educational formats, accommodating between 150 to 700 people. This flexibility allows for a range of teaching methods and collaborative learning experiences.

Study Areas: The building offers diverse study environments, including quiet zones for individual work and open areas for group collaboration, catering to different student preferences.

Sustainable Materials: In line with its sustainability goals, Echo incorporates materials such as bamboo and recycled PET bottles in its construction. Notably, 90% of the furniture used in the building has been repurposed, emphasizing resource efficiency.

Building Title: LAB42 Building

Project type: New building Campus: Science Park Year: 2022 Location: Amsterdam



Project description

LAB42, inaugurated in September 2022 at Amsterdam Science Park, is the University of Amsterdam's (UvA) state-of-the-art hub for digital innovation and artificial intelligence (AI). Designed by Benthem Crouwel Architects, the building spans approximately 14,184 square meters and exemplifies sustainable architecture with its energy-neutral design. LAB42 brings together students, researchers, and industry professionals, fostering collaboration across informatics and AI disciplines. The building's modular structure ensures flexibility, allowing spaces to be reconfigured to meet evolving needs. Its transparent and accessible design promotes interaction, featuring open-plan areas, meeting rooms, and dedicated zones for startups and established companies. Sustainability is central to LAB42's ethos, with 1,800 square meters of solar panels integrated into the roof and façades, a geothermal heat pump system, and the use of recycled materials throughout its construction. This innovative environment positions LAB42 as a leading center for AI and digital innovation in Europe.

Functions: Education and research

Architect: Benthem Crouwel Architects

Constructor: Visser & Smit Bouw BV and Kropman Installatietechniek BV

Project profile

Goals:

To serve as an international hub for talent development in digital innovation and AI.

To facilitate partnerships between students, researchers, and businesses, fostering knowledge exchange and co-creation.

To provide a flexible and sustainable environment that can adapt to future educational and research needs.

Costs (€):

CREM

Users:

Students from the UvA's Informatics Institute and the Institute for Logic, Language, and Computation.

Researchers focusing on AI and digital innovation.

Entrepreneurs, startups, and established companies collaborating with the university.

Spatial data (m2):

Total Area: Approximately 14,184 square meters.

Energy performance:

Energy Neutrality: LAB42 is an energy-neutral building, producing as much energy as it consumes. This is achieved through the installation of approximately 1,800 square meters of solar panels on the roof and integrated into the facade.

Sustainable Systems: The building utilizes a rainwater collection system for toilet flushing and features smart cooling mechanisms for server rooms. Additionally, LAB42 is connected to the university's central thermal storage system, enhancing its energy efficiency.

Geothermal heat pump system for heating and cooling.

Use of recycled materials, including felt from recycled PET bottles for acoustic panels and reclaimed steel and aluminum in construction.

Building facilities:

Educational and Research Spaces: LAB42 houses the Informatics Institute (IVI), the Institute for Logic, Language and Computation (ILLC), and the Innovation Center for Artificial Intelligence (ICAL). It provides modern lecture halls, classrooms, and specialized research facilities to support education and innovation in information sciences and AI.

Collaborative Workspaces: The building offers flexible workspaces designed to promote interaction among students, researchers, and entrepreneurs. These spaces can be easily reconfigured to accommodate various functions, reflecting the dynamic nature of the disciplines housed within.

Amenities: An inviting atrium serves as a central gathering place, featuring dining facilities and areas for informal meetings. The design emphasizes natural light and incorporates greenery to create a healthy and pleasant indoor environment.

Building Title: Langeveld Building

Project type: New building Campus: Woudestein Year: 2022 Location: Rotterdam



Project description

The Langeveld Building at Erasmus University Rotterdam, inaugurated in November 2022, is a state-of-the-art, multifunctional educational facility designed to accommodate approximately 3,000 students daily. Spanning six stories and 8,748 square meters, it features lecture halls, teaching rooms, a lounge area, and ample study spaces. The building exemplifies sustainability with a BREEAM Outstanding certification, utilizing an innovative ventilation system powered by wind and solar energy, and incorporating extensive greenery and wooden elements to enhance well-being. Named after Professor Hendrika Maria Langeveld, the first female professor at the university, it reflects a commitment to sustainable development and honors a significant academic legacy.

Functions: Education

Architect: Paul de Ruiter Architects

Constructor: BAM Bouw en Techniek

Project profile

Goals:

Sustainability: Achieving a BREEAM-NL 'Outstanding' certification with a score of 91.5%. It operates energy-neutrally, generating surplus energy through rooftop solar panels, heat pumps, and an underground thermal energy storage system.

Innovative Ventilation: Utilizing the 'Earth, Wind & Fire' system, the building employs natural forces—wind and solar energy—to drive its ventilation. This system consumes 85% less energy than traditional methods, ensuring a healthy indoor climate.

Circularity: With a Circularity Performance Score of 9, the building incorporates recycled materials, including repurposed elements from other university structures, emphasizing resource efficiency.

Well-being and Flexibility: The design integrates biophilic elements, such as extensive greenery and wooden features, to enhance occupants' well-being. Its flexible layout accommodates evolving educational needs, supporting various teaching methods and future adaptations.

Costs (€):

CREM

Users:

multifunctional educational facility designed to serve approximately 3,000 students daily. It accommodates a diverse range of users, including:

- Students: From various faculties, utilizing lecture halls, teaching rooms, study spaces, and lounge areas for academic and social activities.
- Faculty and Staff: Engaging in teaching, administrative duties, and collaborative projects within the building's flexible spaces.
- Visitors and Guests: Participating in events, seminars, and other activities hosted within the building's versatile environments.

Spatial data (m2):

The Langeveld Building at Erasmus University Rotterdam is a six-story, multifunctional educational facility encompassing approximately 8,748 square meters. It accommodates around 3,000 students daily, offering lecture halls, teaching rooms, a lounge area, and ample study spaces. The building's transparent facades allow natural light to permeate the interior, creating a connection with the surrounding campus environment.

Energy performance:

Energy Neutrality: The building achieves energy neutrality through an innovative natural ventilation system known as the Earth, Wind & Fire (EWF) concept. This system harnesses wind and solar energy to drive ventilation, resulting in an energy-positive performance.

BREEAM Certification: The Langeveld Building has been awarded a BREEAM-NL Outstanding certification with a score of 91.5%, placing it among the top five most sustainable educational buildings in Europe.

Building facilities:

Flexible Educational Spaces: The building offers large, open floor areas without columns, allowing for adaptable configurations to support various teaching methods and future educational needs.

Biophilic Design Elements: Incorporating natural elements, such as untreated tree trunks in the central atrium, the design fosters a connection with nature, enhancing the well-being of students and staff.

Building Title: Aletta Jacobshal

Project type: Expansion

Campus: Zernike campus

Year: 2020

Location: Groningen



Project description

The Aletta Jacobshal, located at Blauwborgje 4 on the Zernike Campus of the University of Groningen, serves as a central facility for lectures and examinations. Recognizing the need for increased capacity, the university expanded the building between 2018 and 2020, adding new lecture halls, examination rooms, an additional foyer, study areas, and increased bicycle parking. The expansion nearly doubled the building's gross floor area by approximately 5,400 square meters. Sustainability was a key focus, with the incorporation of geothermal energy systems and solar panels to enhance energy efficiency. In early 2024, the university converted the last analogue examination room into a digital exam space, increasing the total capacity to nearly 1,800 digital testing stations. These developments underscore the university's commitment to providing modern, sustainable, and efficient facilities for its academic community.

Functions: Education and examination halls

Architect: Onix NL

Constructor: BAM Bouw en Techniek

Project profile

Goals:

- Increase Capacity:** To accommodate the growing student population and the rising demand for examination and lecture spaces, the university expanded the building to include additional lecture halls and examination rooms.
- Enhance Student Facilities:** The extension introduced new study environments and an extra foyer, providing students with improved areas for study and relaxation.
- Promote Sustainable Practices:** In line with the university's commitment to sustainability, the project incorporated a geothermal energy storage system for efficient heating and cooling, and installed over 500 solar panels to reduce the building's carbon footprint.
- Improve Accessibility:** The expansion included additional bicycle sheds to encourage eco-friendly transportation among students and staff.

Costs (€):

CREM

Users:

- The building is primarily utilized by:
 - Students:** They attend lectures and take examinations in the hall's various rooms, including two lecture halls seating 200 and 450 individuals, and examination spaces accommodating up to 590 candidates.
 - Faculty and Staff:** Instructors and administrative personnel use the facilities for teaching, proctoring exams, and organizing academic events.
 - Visitors and External Organizations:** The hall may also host conferences, seminars, and other events, attracting participants from outside the university community.
- The building's design includes additional foyers, study environments, and bicycle storage to support these diverse users.

Spatial data (m2):

Total Floor Area: The expansion added approximately 5,400 square meters of gross floor space, bringing the total area to around 10,800 square meters.

Energy performance:

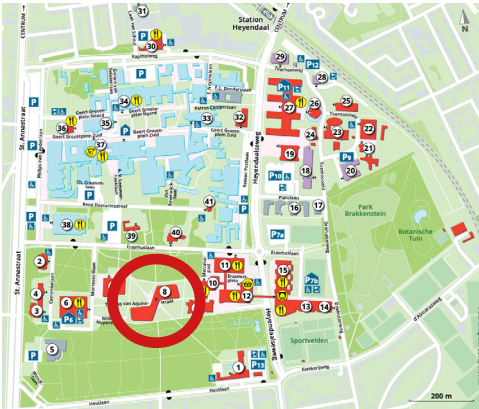
- Sustainability Enhancements:** The expansion project incorporated several sustainable features to improve the building's energy performance:
 - Geothermal Energy System:** A geothermal system was installed to provide efficient heating and cooling, reducing reliance on conventional energy sources.
 - Solar Panels:** Over 500 solar panels were mounted on the roof, contributing to the building's renewable energy generation.
 - Climate Control System:** An advanced climate control system was implemented to optimize indoor environmental quality and energy efficiency.

Building facilities:

- Lecture Halls:** The expansion added two new lecture halls with seating capacities of 200 and 450, respectively, equipped with modern audiovisual technology to support diverse teaching methods.
- Examination Hall:** A new examination hall was constructed, accommodating 590 digital exam stations to facilitate large-scale assessments.
- Foyer and Study Areas:** An additional foyer provides a spacious waiting and relaxation area for students, while new study facilities offer conducive environments for individual and group study sessions.
- Bicycle Storage:** Recognizing the importance of sustainable transportation, the expansion included increased bicycle storage capacity to encourage cycling among students and staff.

Building Title: Maria Montessori Building

Project type: New building Campus: Radboud Universiteit Year: 2020 Location: Nijmegen



Project description

The Maria Montessori Building, inaugurated in 2020, is the home of the Faculty of Social Sciences at Radboud University in Nijmegen. Designed by INBO Architects, it is the first energy-neutral university building in the Netherlands, generating as much energy annually as it consumes. The building spans 25,500 square meters over five floors and accommodates approximately 1,275 employees and 5,200 students. Its design emphasizes small-scale, people-friendly spaces, featuring daylight-filled workrooms, comfortable living rooms, cozy seating areas, and wide staircases to encourage dialogue and cross-pollination among users. The building's meticulous integration into the landscape, with soft shapes and façade structures, enhances its human scale and connection to the surrounding environment.

Project profile

Goals:

Sustainability: Achieve energy neutrality, making it the most sustainable building on campus.

Facilitate Education and Research: Provide state-of-the-art facilities for teaching and research in social sciences.

Promote Interaction: Create spaces that encourage collaboration among students, faculty, and researchers.

Costs (€):

CREM

Users:

Students: Engaged in various social science disciplines.

Faculty and Researchers: Conducting teaching and research activities.

Administrative Staff: Supporting the operations of the Faculty of Social Sciences.

Spatial data (m2):

Total Area: Approximately 25,000 square meters.

Number of Floors: Five.

Location: Thomas van Aquinostraat 4, 6525 GD Nijmegen.

The building's design focuses on creating a small-scale, people-friendly environment, with soft shapes and façade structures that make the scale approachable. Daylight-filled workrooms, comfortable living rooms, cozy seating areas, wide staircases, and a variety of study areas encourage dialogue and cross-pollination.

Functions: Education and research

Architect: INBO

Constructor: Berghege and Heerkens van Bavel

Energy performance:

Energy Neutrality: The Maria Montessori Building is celebrated as the first energy-neutral university building in the Netherlands. It generates as much energy as it consumes annually, primarily through the installation of 1,669 solar panels on its roof. This achievement underscores the university's commitment to sustainable development.

BREEAM-NL Excellent Certification: The building has been awarded the BREEAM-NL Excellent certificate, reflecting its high standards in sustainable construction and environmental performance.

Building facilities:

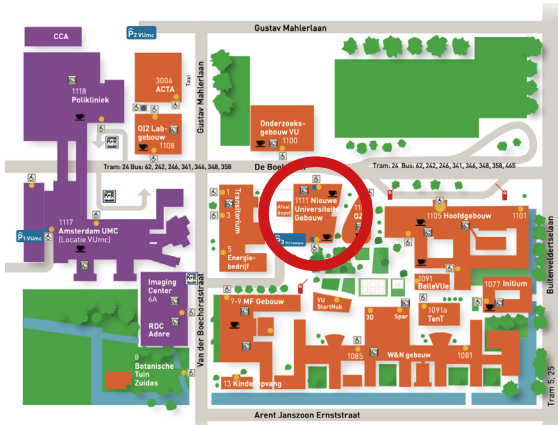
Educational Spaces: The building offers a variety of lecture halls, seminar rooms, and practical laboratories, all designed to support diverse teaching methods and research activities. The spaces are equipped with modern technology to facilitate effective learning and collaboration.

Study Areas: Students have access to numerous study zones, including quiet areas for individual work and collaborative spaces for group projects. The design emphasizes natural light and open spaces to create a conducive learning environment.

Grand Café de Iris: Serving as a central meeting point, the Grand Café de Iris provides a welcoming atmosphere for students and staff to relax, dine, and engage in informal discussions.

Building Title: New University Building

Project type: New building Campus: VU Campus Year: 2020 Location: Amsterdam



Project description

The New University Building at Vrije Universiteit Amsterdam, completed in 2020, serves as a multifunctional hub integrating education, research, and cultural activities. Strategically located on De Boelelaan, it features flexible spaces that accommodate lectures, theater performances, and film screenings, often utilizing the same rooms for diverse purposes. The building houses the departments of Computer Science, Mathematics, and the Institute for Environmental Studies, as well as the VU Education Lab. Cultural amenities include the Griffioen Cultural Centre and Rialto cinema, which began their programming in 2021. Sustainability is a key focus, with the design aiming for BREEAM-NL Excellent certification, incorporating energy-efficient systems and adaptable spaces to meet evolving needs. The New University Building stands as a vibrant center where academia and culture converge, fostering a dynamic campus environment.

Functions: Education

Architect: Team V Architectuur

Constructor: Visser & Smit Bouw and Boele & van Eesteren

Project profile

Goals:

Multifunctionality: The building integrates education, research, and cultural activities by utilizing flexible spaces that serve as lecture halls during the day and transform into theaters or cinemas in the evening.

Sustainability: Designed to meet BREEAM-NL 'Excellent' certification standards, the building incorporates sustainable materials, energy-efficient systems, and a rooftop landscape that promotes biodiversity.

Community Engagement: By housing facilities like the Griffioen Cultural Centre and Rialto cinema, the building fosters interaction between the university and the broader community, creating a vibrant campus atmosphere.

Flexibility and Future-Proofing: The innovative design allows for adaptable spaces that can evolve with changing educational and cultural needs, ensuring long-term relevance and usability.

Costs (€):

CREM

Users:

Students and Faculty: Primarily from the Faculty of Science, including the departments of Computer Science, Mathematics, and the Institute for Environmental Studies, who utilize the building's educational and research facilities.

Cultural Enthusiasts: Attendees of programs offered by the Griffioen Cultural Centre and Rialto cinema, which utilize the building's adaptable spaces for theater performances and film screenings.

Lifelong Learners: Participants in courses and training provided by the VU Academic Centre for Behaviour and Movement, encompassing the LEARN! Academy, VU Teachers' Academy, and HOVO Amsterdam.

Researchers and Innovators: Users of state-of-the-art laboratories, such as the Social AI Lab and Bio-Inspired Robot Lab, conducting advanced research in fields like artificial intelligence and robotics.

Spatial data (m2):

BVO:

- 12 floors: 31.000 m2
- Education: 12.250 m2
- Office: 8.650 m2
- Halls: 4.100 m2
- Facilities: 6.100 m2

The ground floor is publicly accessible and also acts as a passageway to Campus Square. On the upper floors 2,500 m2 (NVO) is accessible for communal use and culture.

It accommodates approximately 4,600 students and 1,000 staff members.

The building includes an underground parking garage spanning three floors and 24,000 square meters.

Energy performance:

Sustainability Certification: The building has achieved a BREEAM-NL Excellent rating, reflecting its high standards in sustainability and energy efficiency.

Green Roof: A peat roof, reminiscent of the area's historical peat bogs, has been installed. Beneath this green roof lies an additional layer designed to collect rainwater, which helps mitigate flooding during heavy rainfall and contributes to cooling the building during warmer periods.

Energy-Efficient Systems: The building employs energy-efficient lighting, heating, and cooling systems, including the use of natural energy sources such as heat and cold storage.

Building facilities:

Educational and Research Spaces: The building is equipped with modern lecture halls, collaborative classrooms, and state-of-the-art laboratories, including specialized labs like the Social AI Lab and the Bio-inspired Robot Lab.

Cultural Amenities: It houses the Griffioen Cultural Centre and Rialto cinema, allowing for a diverse range of cultural events, including theater performances and film screenings, often utilizing the same spaces used for educational purposes during the day.

Dining and Social Areas: The ground floor features a grand café and other facilities such as shops, creating a vibrant social environment for students, staff, and visitors.

Parking: An underground parking garage spans three levels, providing space for 600 cars and 1,600 bicycles, with amenities like charging stations for electric vehicles and designated areas for electric bicycles.

Building Title: Tapijnkazerne (phase 1)

Project type: Redevelopment Campus: Campus Maastricht Year: 2020 Location: Maastricht



Project description

The Tapijn Building at Maastricht University, completed in March 2020, marks the first phase of transforming the historic Tapijnkazerne into a vibrant educational hub. Originally constructed between 1916 and 1919 as military barracks, the site has been redeveloped into a public city park featuring modern educational facilities and dining options. The renovation emphasizes sustainability, achieving energy neutrality by eliminating natural gas usage and incorporating features like LED lighting, CO2-controlled ventilation, and superior insulation. Notably, the Tapijn Building is the first European university structure to attain WELL Building Standard Silver certification, underscoring its commitment to occupant health and well-being. The design thoughtfully integrates the site's historical significance with contemporary educational needs, creating an open and inviting space for students, staff, and the broader community.

Functions: Education and research

Architect: LIAG Architects and Building Consultants

Constructor: Mertens Bouwbedrijf BV

Project profile

Goals:

Educational Enhancement: The transformation provides modern facilities for the School of Business and Economics, UMIO, and the University Library, including lecture halls, Problem-Based Learning spaces, and new learning environments, thereby enriching the university's educational infrastructure.

Community Integration: By converting the former military site into a public park with educational buildings, the project fosters interaction among students, businesses, and local residents, strengthening the bond between the university and the city.

Sustainability and Well-being: The renovation emphasizes sustainability, aiming for a four-star BREEAM certification and achieving WELL Building Standard registration, focusing on health, well-being, and energy neutrality.

Preservation of Heritage: The design maintains the historical integrity of the Tapijnkazerne by preserving key architectural features and integrating new structures that respect the site's cultural significance.

Costs (€):

CREM

Users:

The Tapijn Building at Maastricht University serves a diverse group of users, fostering a vibrant academic community:

Students: The building offers 160 inspiring study places with colorful furniture and ample natural light, making it a favored study environment.

Faculty and Staff: Members of the School of Business and Economics, UMIO, and the University Library utilize the building's facilities for education and research activities.

Community Members: The redevelopment includes public spaces and eateries, encouraging interaction among students, businesses, and local residents, thereby strengthening the bond between the university and the city.

Spatial data (m2):

The Tapijn Building at Maastricht University, part of the first phase of redeveloping the historic Tapijnkazerne, comprises three interconnected pavilions surrounding the former parade ground. These structures are linked by an underground plinth, maximizing above-ground space for public parkland. The building offers two lecture halls, Problem-Based Learning rooms, and innovative learning spaces, providing 160 study places with abundant natural light and vibrant furnishings. This design fosters a dynamic and inviting academic environment, seamlessly integrating the university's educational facilities with the surrounding urban landscape.

Energy performance:

Energy Neutrality: Phase 1 of the Tapijnkazerne redevelopment achieved energy neutrality, meaning the buildings generate as much energy as they consume. This was accomplished through the implementation of energy-efficient systems and the integration of renewable energy sources.

BREEAM-NL Excellent Certification: The design for the renovation was awarded the BREEAM-NL New Construction and Renovation certificate with a score of 80.14%, earning an "Excellent" rating. This certification reflects the project's high standards in sustainability across various categories, including energy, health, and materials.

Building facilities:

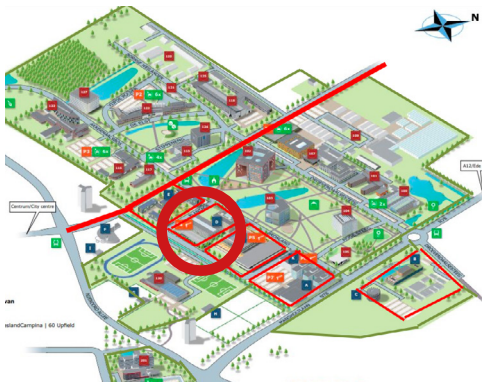
Educational Spaces: The renovated buildings house lecture halls, tutorial rooms, and study areas designed to support Problem-Based Learning (PBL). These spaces are equipped with modern technology to facilitate interactive and collaborative learning.

University Library: A branch of the university library is located within the complex, providing students and staff with access to a vast collection of resources and study facilities.

Common Areas: The design includes common rooms and meeting spaces furnished to encourage informal interactions and group discussions, enhancing the sense of community among users.

Building Title: Plus Ultra II

Project type: New building Campus: Wageningen campus Year: 2020 Location: Wageningen



Project description

Plus Ultra II, inaugurated in 2020, is an innovation and incubation center located on Wageningen University's campus. Spanning approximately 10,500 square meters, it offers laboratories, cleanrooms, pilot plants, multifunctional research spaces, meeting rooms, presentation areas, and offices. Designed to foster collaboration among startups, established companies, and researchers, the facility focuses on sectors such as agriculture, food, sustainability, and health. Its open atrium design encourages interaction and knowledge exchange, promoting innovation. Plus Ultra II is physically connected to the original Plus Ultra building, enhancing synergy between the two facilities. Developed by Kadans Science Partner, the building underscores Wageningen University's commitment to advancing research and entrepreneurship in life sciences and related fields.

Functions: Education, laboratories, and offices

Architect: Proof of the Sum

Constructor: Goossen Te Pas Bouw

Project profile

Goals:

Foster Innovation and Collaboration: The center provides an environment where startups, established companies, and researchers can collaborate on innovative projects, particularly in agriculture, food, and related sectors.

Support Business Growth: By offering flexible spaces—including laboratories, cleanrooms, pilot plants, and offices—Plus Ultra II accommodates companies at various development stages, facilitating their growth within the WUR ecosystem.

Enhance Knowledge Exchange: The building's open atrium and shared facilities encourage interaction among tenants, promoting knowledge sharing and synergies that drive innovation.

Advance Research in Key Areas: Plus Ultra II supports research in food, agriculture, sustainability, and health, aligning with WUR's mission to address global challenges in these fields.

Through these objectives, Plus Ultra II contributes to WUR's commitment to fostering a dynamic and innovative campus environment.

Costs (€):

CREM

Users:

Startups and Scale-ups: Early-stage companies in sectors such as agriculture, food, sustainability, and health utilize the building's incubator facilities to develop and expand their ventures.

Established Companies: Organizations like the Yili Innovation Center Europe and Foodcase International have offices and research spaces within Plus Ultra II, fostering collaboration with academic and industry partners.

Student-Led Initiatives: Student challenges and entrepreneurial projects benefit from the building's resources, promoting innovation and practical experience among the student body.

Research Centers: Institutions such as the OnePlanet Research Center occupy dedicated spaces, advancing research in areas like agri-food and health.

WUR Departments: The university's Value Creation division is housed in Plus Ultra II, enhancing the integration of academic research with industry applications.

Spatial data (m2):

The building is a multifunctional facility encompassing approximately 10,500 square meters. It offers a variety of spaces designed to foster innovation and collaboration among startups, established companies, and researchers in fields such as agriculture, food, sustainability, and health.

Energy performance:

BREEAM-NL Excellent Certification: Plus Ultra II has been awarded the BREEAM-NL Excellent certificate for its sustainable design.

Sustainable Features:

- **Solar Panels:** The building is equipped with a full solar panel roof, contributing to its energy efficiency.
- **Intelligent Air Handling System:** An advanced air handling system optimizes indoor climate control while minimizing energy consumption.
- **Use of Natural Materials:** The construction incorporates natural materials, enhancing both sustainability and occupant well-being.
- **Fossil Fuel-Free Utilities:** Primary utilities operate without the use of fossil fuels, aligning with contemporary environmental standards.

Building facilities:

Laboratories and Research Areas: The building houses laboratories, cleanrooms, pilot plants, and multifunctional research spaces, supporting a wide range of scientific activities.

Office Spaces: Flexible office areas are available to accommodate both startups and established companies, fostering a collaborative work environment.

Meeting and Presentation Rooms: Multiple meeting rooms and presentation spaces facilitate conferences, workshops, and collaborative sessions.

Incubator Function: An incubator space is dedicated to supporting early-phase startups and student entrepreneurs, providing resources and mentorship to nurture innovation.

Central Atrium: A central atrium serves as the heart of the building, encouraging interaction among occupants and enhancing the sense of community.

Additionally, Plus Ultra II includes a parking garage with over 300 spaces and dedicated bicycle parking, with provisions for electric vehicles.

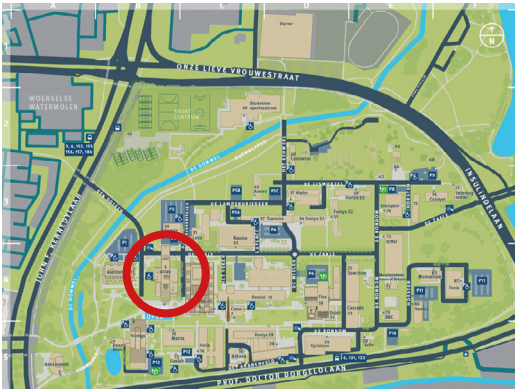
Building Title: Atlas Building

Project type: Renovation

Campus: TU/e campus

Year: 2019

Location: Eindhoven



Project description

The Atlas Building at TU Eindhoven, originally constructed in the 1960s, underwent a comprehensive renovation completed in 2019. This transformation has earned it recognition as one of the world's most sustainable educational buildings, achieving a BREEAM 'Outstanding' certification with a score of 96.01%. The renovation preserved the building's architectural heritage while integrating advanced sustainable technologies, such as a high-performance climate façade and intelligent lighting systems. These innovations have reduced the building's CO2 emissions by approximately 80%, even as its user capacity has more than doubled. Atlas now serves as a central hub on the TU/e campus, housing the departments of Industrial Design and Industrial Engineering & Innovation Sciences, as well as various educational facilities, study areas, and dining options. Its design emphasizes transparency and openness, fostering collaboration among students, faculty, and staff.

Functions: Education, offices, and research

Architect: Team V Architecture

Constructor: RSVP, comprising Team V Architecture, Van Rossum (structural engineers), Valstar Simonis (building services engineers), and Peutz (building physics and sustainability consultants)

Project profile

Goals:

Sustainability: Achieving a BREEAM 'Outstanding' certification with a score of 96.01%, Atlas stands as one of the world's most sustainable educational buildings. The renovation reduced CO2 emissions by approximately 80%, incorporating features like a highly insulating glass façade, elimination of fossil fuel usage, and connection to a geothermal energy system.

Innovation: Serving as a 'Living Lab,' Atlas integrates state-of-the-art materials and smart technologies, such as an intelligent lighting infrastructure and a climate-responsive façade, to foster research and development in sustainable building practices.

Community Engagement: By housing the departments of Industrial Design and Industrial Engineering & Innovation Sciences, along with various educational facilities, study areas, and dining options, Atlas functions as a central hub that promotes interaction among students, faculty, and visitors, enhancing the campus's vibrancy.

Costs (€):

CREM

Users:

The Atlas Building at Eindhoven University of Technology (TU/e) serves a diverse community, including:

Students: Utilize lecture halls, study areas, and collaborative spaces for academic activities.

Faculty and Staff: From the Departments of Industrial Design and Industrial Engineering & Innovation Sciences, as well as university corporate services and the Executive Board, who occupy offices and meeting rooms.

Researchers: Engage with the building's 'Living Lab' environment to study and develop sustainable technologies.

Visitors: Attend events, exhibitions, and utilize amenities such as restaurants and the University Club.

By accommodating these groups, Atlas fosters a dynamic and collaborative atmosphere, aligning with TU/e's mission to integrate education, research, and community engagement.

Spatial data (m2):

The Atlas Building at Eindhoven University of Technology (TU/e) is a 16-story structure encompassing approximately 44,000 square meters of floor space. The high-rise section primarily accommodates the Departments of Industrial Design and Industrial Engineering & Innovation Sciences, as well as university corporate services and the Executive Board. The lower section features educational halls, study and flexible workplaces, staff restaurants, and the University Club. Strategically positioned between the Auditorium and MetaForum, Atlas serves as a central hub on the TU/e campus, facilitating interaction among students, faculty, and staff. The building's design emphasizes transparency and openness, fostering a collaborative academic environment.

Energy performance:

BREEAM Certification: Atlas has achieved a BREEAM-NL 'Outstanding' rating with a score of 96.01%, making it one of the most sustainable educational buildings globally.

CO2 Emissions Reduction: The renovation led to an approximate 80% reduction in CO2 emissions, even as the building's user capacity more than doubled.

Innovative Façade: The building features a highly insulating glass façade with floor-to-ceiling windows that can open automatically. This design facilitates natural ventilation and night flushing, where windows open at night to cool the building and purify the air.

Energy Systems: Atlas operates without fossil fuels, having disconnected from the gas grid. It utilizes smart LED lighting and solar panels to meet a significant portion of its electricity needs.

Building facilities:

Educational Spaces: The building houses lecture halls, classrooms, and study areas designed to support modern teaching methods and collaborative learning.

Central Atrium: A striking 12-story red staircase serves as a central feature, connecting various floors and fostering interaction among students and staff.

Departmental Offices: Atlas accommodates the departments of Industrial Design and Industrial Engineering & Innovation Sciences, providing office spaces tailored to their needs.

Building Title: CUBE

Project type: New building Campus: Tilburg campus Year: 2018 Location: Tilburg



Project description

The CUBE Building at Tilburg University, designed by KAAAN Architecten and opened in 2018, serves as an Education and Self-Study Center. Spanning 11,000 square meters, it accommodates approximately 2,200 students and lecturers daily. The building's design features a spacious indoor study plaza, a transparent auditorium, and two patios, promoting openness and seamless integration with the surrounding green landscape. Its homogenous layout ensures no closed-off facades, fostering a sense of equality and connection to nature. CUBE also houses the "Recharge yourself!" catering facility, offering a variety of refreshments to energize its users.

Functions: Education

Architect: KAAAN Architecten

Constructor: VORM Bouw

Project profile

Goals:

Enhancing Learning Environments: The CUBE Building provides state-of-the-art facilities for education and self-study, including a central study plaza, lecture halls, group study areas, and self-study workstations. It accommodates up to 2,500 students and faculty members daily, meeting the demands of a growing academic community.

Sustainability: Designed with sustainability in mind, the building emphasizes energy efficiency, natural lighting, and an environmentally friendly approach to construction, creating a tranquil and resource-conscious space for learning and collaboration.

Architectural Integration: The building's square, low-rise design harmonizes with the green campus and complements Tilburg University's modernist architectural style. Its open, transparent layout encourages connection and collaboration.

Modern Design Principles: Featuring open spaces, high ceilings, and patios, the CUBE Building fosters an inviting atmosphere that supports academic interaction and personal focus.

Costs (€):

CREM

Users:

Students: The building accommodates up to 2,500 students daily, providing facilities such as lecture halls, group study areas, and self-study workstations. It supports students from various faculties engaging in individual or collaborative learning.

Faculty and Lecturers: Academic staff utilize the building for lectures, seminars, and meetings, taking advantage of its modern, well-equipped teaching spaces.

Visitors: The CUBE Building also hosts events and workshops, welcoming external participants and contributing to the university's role as a hub for academic and social interaction.

Spatial data (m2):

The CUBE Building at Tilburg University is a two-story, square-shaped structure encompassing 11,000 square meters. It accommodates approximately 2,200 students and lecturers daily, providing lecture halls, group study areas, and self-study workstations. The building's design features a central indoor study plaza, flanked by a transparent auditorium and two green patios, fostering an open and collaborative atmosphere. Its compact, low-rise architecture harmonizes with the surrounding green landscape and complements the campus's modernist architectural style, particularly the adjacent Cobbenhagen Building. CUBE is anchored to the landscape by paved pathways leading to its corner entrances, seamlessly integrating with the campus environment.

Energy performance:

Energy Efficiency: CUBE is an exceptionally energy-efficient building, performing approximately 25% better than the standard energy efficiency requirements in the Netherlands. This is achieved through several sustainable features:

- Climate Control: The building utilizes ground heat and cold storage systems in conjunction with heat pumps to regulate indoor temperatures efficiently.
- Solar Panels: Solar panels installed on the roof contribute to the building's energy supply, harnessing renewable energy to reduce reliance on non-renewable sources.
- Lighting: Maximum use of daylight is complemented by presence-sensitive LED lighting, which adjusts based on occupancy to conserve energy.
- Water Management: Rainwater is collected and managed through an infiltration system, promoting sustainable water use.

Building facilities:

Study Plaza: At the heart of CUBE lies a spacious indoor study plaza, providing a central area for students to engage in individual or group study sessions.

Auditorium: A transparent auditorium adjacent to the study plaza offers a venue for lectures, presentations, and events, fostering a dynamic learning environment.

Lecture Rooms: The building houses both large and small lecture halls equipped with modern technology to support diverse teaching methods.

Tutorial Rooms and Meeting Spaces: Various rooms are available for tutorials and meetings, facilitating interactive learning and collaboration among students and faculty.

Cafeteria and Lounge Areas: CUBE includes a catering area and lounges where students and staff can relax, socialize, and recharge between study sessions.

Building Title: Wijnhaven Building

Project type: New building Campus: Campus Den Haag Year: 2017 Location: Den Haag



Project description

The Wijnhaven Building, situated in The Hague's city center, serves as the central hub for Leiden University's Campus The Hague. Accommodating approximately 3,500 students, it offers modern classrooms, study areas, and collaborative spaces. The building hosts activities from six of the university's seven faculties, with a notable presence from the Faculty of Governance and Global Affairs. Additionally, Delft University of Technology occupies the fifth floor, and a high-tech studio is available for Massive Open Online Courses (MOOCs). Its strategic location near The Hague Central Station and proximity to government institutions provide students and staff with unique opportunities for engagement in governance and global affairs. The Wijnhaven Building exemplifies Leiden University's commitment to integrating academic excellence within the administrative heart of the Netherlands.

Functions: Education and library

The redevelopment project was undertaken by Proper Stok Groep B.V., a subsidiary of Heijmans, in collaboration with investor Achmea and tenant Leiden University

Project profile

Goals:

Academic Integration: Wijnhaven accommodates approximately 3,500 students from six of the university's seven faculties, providing modern classrooms, study areas, and collaborative spaces to enhance interdisciplinary learning.

Strategic Location: Situated among government ministries and near The Hague Central Station, the building offers students and researchers direct access to national and international institutions, enriching academic programs in governance, global affairs, and related fields.

Community Engagement: By hosting events and fostering interactions between the university and the city, Wijnhaven strengthens ties with local organizations and the broader community, promoting societal impact and collaboration.

Modern Facilities: The building features amenities such as a library, information desk, study association spaces, and dining options, creating a conducive environment for academic and social activities.

Costs (€):

CREM

Users:

Students: Approximately 3,500 students from six of the university's seven faculties attend classes and utilize the building's 630 study spaces, including 280 silent study areas and 140 computer-equipped stations.

Faculty and Staff: Around 250 university staff members have offices in Wijnhaven, supporting teaching and research activities across various disciplines.

Delft University of Technology (TU Delft) Students and Staff: The fifth floor houses TU Delft's MSc programme in Engineering and Policy Analysis, facilitating collaboration between institutions.

Researchers and Visitors: The building's strategic location near government ministries and The Hague Central Station provides opportunities for engagement with policymakers, enhancing research and public events.

Spatial data (m2):

The Wijnhaven Building at Leiden University's Campus The Hague encompasses approximately 14,000 square meters of educational and research facilities. It provides 630 study spaces, including 280 silent study areas and 140 computer-equipped stations. The building features five lecture halls of varying sizes and 21 adaptable classrooms with flexible walls to accommodate diverse teaching methods. Additional amenities include a library, an information desk, areas designated for study associations, and offices for around 250 university staff members. Strategically located near The Hague Central Station, Wijnhaven serves as a central hub for academic activities, fostering collaboration among students, faculty, and external partners.

Energy performance:

The university aims to significantly reduce CO2 emissions and energy consumption, striving for fossil-free construction and renovation practices. This commitment involves efficient space utilization, transitioning to self-generated green energy, and implementing circular renovation and building management strategies.

Building facilities:

Lecture Halls and Classrooms: The Wijnhaven Building houses five lecture halls of varying sizes and 21 smaller classrooms with movable walls, allowing for flexible learning environments.

Study Spaces: Students have access to over 630 study places, including 280 quiet workspaces and 140 computer-equipped stations, facilitating both individual and collaborative study sessions.

Library: A dedicated library within the building provides access to a vast collection of academic resources, supporting the research and learning needs of students and staff.

Student Association Areas: Centralized spaces are designated for study associations, promoting student engagement and community building.

Staff Offices: The building includes working areas for approximately 250 staff members, fostering close collaboration between faculty and students.

Catering Facilities: On-site dining options are available, offering convenience for students and staff during their time on campus.

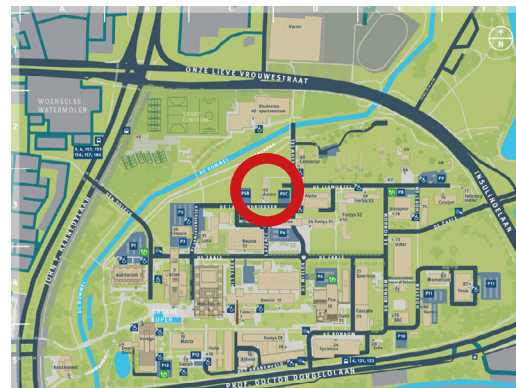
Building Title: Aurora

Project type: New building

Campus: TU/e campus

Year: 2016

Location: Eindhoven



Project description

The Aurora Building, completed in 2016, is a 14-story residential tower on the Eindhoven University of Technology (TU/e) campus, providing 303 housing units primarily for international students and PhD candidates. Developed by housing corporation Woonbedrijf, Aurora was constructed using prefabricated concrete elements, enabling rapid assembly and completion within 82 days. Its slender design aligns with the existing high-rise structures along the Dommel River, contributing to the campus's cohesive architectural aesthetic. Strategically located near academic buildings and recreational facilities, Aurora enhances campus life by fostering a vibrant, 24/7 community. The building's design emphasizes communal spaces to encourage interaction among residents, thereby enriching the student experience at TU/e.

Project profile

Goals:

Enhancing Campus Vitality: By providing on-campus housing for international students and PhD candidates, Aurora contributes to a dynamic, 24/7 campus environment, aligning with TU/e's vision of a lively and versatile campus.

Accelerated Construction: Utilizing prefabricated concrete elements, the building was erected swiftly, with the structure reaching its full height in just 82 days, demonstrating an efficient construction process.

Architectural Cohesion: Aurora's slender design complements the existing high-rise buildings along the Dommel River, maintaining the campus's cohesive architectural aesthetic.

Through these goals, the Aurora Building enhances the residential experience for students and contributes to the university's strategic vision for a vibrant and integrated campus community.

Costs (€):

CREM

Users:

The Aurora Building at Eindhoven University of Technology (TU/e) primarily accommodates international students and PhD candidates, offering 303 furnished units for both short and long-term stays. This residence supports TU/e's goal of creating a vibrant, 24/7 campus environment. Additionally, two Dutch students reside in Aurora to serve as primary contacts for fellow residents, assisting with various needs and fostering a sense of community. By housing a diverse group of students, Aurora enhances the university's international character and provides a supportive living space for its academic community.

Spatial data (m2):

The Aurora Building at Eindhoven University of Technology (TU/e) is a 14-story residential tower completed in 2016, providing 303 housing units primarily for international students and PhD candidates. Strategically located on the TU/e campus, it offers residents scenic views of the campus, the Dommel River, and nearby sports fields. The building's slender design complements the existing high-rise structures along the Dommel River, maintaining architectural harmony within the campus landscape. Constructed using prefabricated concrete elements, the building's assembly was completed in just 82 days, showcasing an efficient construction process. Aurora's location and design contribute to a vibrant campus environment, enhancing the residential experience for its diverse academic community.

Functions: Student accommodation

Architect: collaboration between Office Winhov (Amsterdam) and Office Haratori (Zürich), in cooperation with BDG Architecten (Almere)

Constructor: Hurks Bouw

Energy performance:

Building facilities:

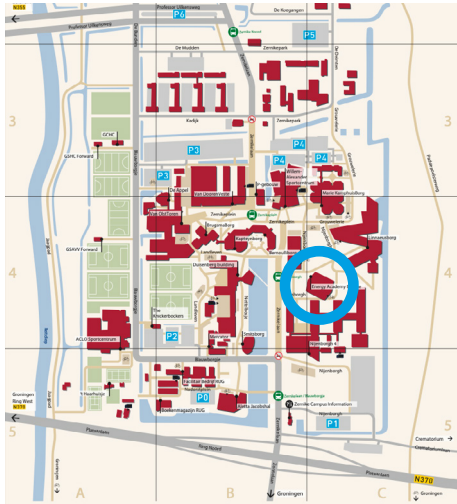
Residential Units: Aurora offers 303 fully furnished units, primarily intended for international students. These units are designed to provide comfortable living spaces that cater to the needs of students during their academic tenure at TU/e.

Common Areas: Each floor includes communal spaces that encourage social interaction and community building among residents. These areas are designed to foster a sense of belonging and provide opportunities for collaborative activities.

Bicycle Storage: Recognizing the importance of cycling in the Netherlands, the building is equipped with ample bicycle storage facilities, promoting sustainable transportation among its residents.

Building Title: Energy Academy Europe

Project type: New building Campus: Zernike campus Year: 2016 Location: Groningen



Project description

The Energy Academy Europe (EAE) building at the University of Groningen, completed in 2016, stands as the Netherlands' most sustainable educational facility. Located on the Zernike Campus, this 14,819-square-meter structure brings together academia, industry, and research to drive energy innovation. The building employs natural elements—earth, water, air, and sunlight—to optimize energy efficiency. Features include a solar chimney for natural ventilation, a labyrinth beneath the building for thermal energy storage, and a roof fully covered with solar panels. These design elements contribute to its BREEAM 'Outstanding' certification, with an impressive score of 89.62%. The EAE serves as a collaborative hub for the University of Groningen, Hanze University of Applied Sciences, and industry partners, exemplifying a commitment to a sustainable energy future.

Functions: Education and research

Architect: Broekbakema and De Unie Architecten

Constructor: consortium of Friso Aannemingsmaatschappij BV and Koopmans Bouwgroep, with engineering support from Arup and Ingenieursbureau Wassenaar

Project profile

Goals:

Sustainability: The EAE building is designed to be energy-positive, producing more energy than it consumes. It utilizes natural elements—earth, water, air, and sunlight—to optimize energy efficiency, featuring a solar chimney for natural ventilation, a thermal labyrinth for air pre-conditioning, and a roof fully covered with solar panels. These innovations have earned it a BREEAM 'Outstanding' certification, with a score of 89.62%.

Collaboration: The building serves as a hub where academia, industry, and research converge to drive energy innovation. It facilitates partnerships among the University of Groningen, Hanze University of Applied Sciences, and various industry stakeholders, fostering interdisciplinary cooperation.

Education and Research: EAE focuses on key energy themes such as renewable energy sources, smart grids, energy efficiency, and CO2 reduction. The building provides state-of-the-art facilities to support education and research in these areas, aiming to accelerate the transition to a sustainable energy future.

Costs (€):

CREM

Users:

The Energy Academy Europe (EAE) building at the University of Groningen serves a diverse group of users, fostering collaboration in energy education, research, and innovation:

University of Groningen: Students and faculty engage in interdisciplinary programs focusing on sustainable energy solutions.

Hanze University of Applied Sciences: Collaborates in educational and research initiatives within the EAE framework.

Industry Partners: Organizations such as GasTerra and Energy Valley participate in joint projects, leveraging the building's facilities to advance energy innovation.

Researchers and Innovators: Utilize the building's state-of-the-art laboratories and collaborative spaces to develop and test new energy technologies.

Spatial data (m2):

The building encompasses approximately 15,000 square meters of space. It serves as a collaborative hub for industry, education, and research in the energy sector.

Energy performance:

BREEAM 'Outstanding' Certification: The building has achieved a BREEAM-NL 'Outstanding' rating, reflecting its exceptional sustainability standards.

Energy-Positive Design: Innovative use of natural elements—earth, water, air, and sunlight—enables the building to generate more energy than it consumes. Features include a solar chimney for natural ventilation, a 200-meter underground labyrinth for air pre-conditioning, and a 3D roof structure maximizing solar energy capture.

Solar Roof: A large, slanted roof of approximately 4,000 square meters, fitted with around 2,000 solar panels, optimally oriented south to maximize solar energy capture.

Natural Ventilation: A solar chimney facilitates natural airflow, reducing reliance on mechanical ventilation systems.

Thermal Labyrinth: Located in the basement, this feature captures and stores thermal energy, aiding in the building's heating and cooling processes.

Building facilities:

Educational and Research Spaces: The building houses laboratories, lecture halls, and offices, facilitating interdisciplinary collaboration among students, researchers, and industry professionals.

Atrium and Winter Garden: A central atrium serves as the building's heart, promoting interaction and knowledge exchange. The adjacent winter garden offers a public space for relaxation and informal meetings.

Building Title: Gorlaeus Building (Phase 1)

Project type: New building Campus: LBSP Year: 2016 Location: Leiden



Project description

The Gorlaeus Building (Phase 1) at Leiden University, completed in 2016, is part of a multi-phase development to modernize the Faculty of Science’s infrastructure. Located on the university’s Science Campus, this state-of-the-art facility spans approximately 45,000 square meters and integrates advanced research and educational spaces. Phase 1 includes cutting-edge laboratories, lecture halls, and collaborative study areas designed to support interdisciplinary research in physics, chemistry, and biology. Sustainability is a key feature, with the building achieving a BREEAM ‘Very Good’ certification through energy-efficient systems, including thermal energy storage and solar panels. As a cornerstone of the Faculty of Science, the Gorlaeus Building fosters innovation and collaboration, creating an inspiring environment for students, researchers, and faculty.

Project profile

Goals:

Centralization of Facilities: To consolidate the Faculty of Science’s institutes, previously dispersed across various locations, into a single, cohesive environment. This unification fosters interdisciplinary collaboration and enhances the efficiency of both research and education.

State-of-the-Art Infrastructure: To provide advanced research and educational facilities that support cutting-edge scientific inquiry and innovative teaching methodologies. The design includes modern laboratories, lecture halls, and communal spaces that encourage interaction among students and faculty.

Sustainability: To construct an environmentally responsible building that meets high sustainability standards. Phase 1 achieved a BREEAM ‘Very Good’ certification, incorporating energy-efficient systems and sustainable materials to minimize its ecological footprint.

Costs (€):

CREM

Users:

The building serves as a central hub for the Faculty of Science, accommodating a diverse group of users:

Faculty Institutes: The building houses several institutes, including the Leiden Institute of Physics, Leiden Observatory, Leiden Institute of Advanced Computer Science, Mathematical Institute, Leiden Institute of Chemistry, and the Leiden Academic Centre for Drug Research.

Students: Undergraduate and postgraduate students utilize the building’s modern lecture halls, laboratories, and study areas for their academic activities.

Faculty and Staff: Academic and administrative personnel have offices and meeting spaces within the building, facilitating teaching, research, and operational functions.

Researchers: The state-of-the-art laboratories and research facilities support scientists engaged in various scientific disciplines, promoting interdisciplinary collaboration.

Spatial data (m2):

The Gorlaeus Building (Phase 1) at Leiden University, completed in 2016, encompasses a gross floor area of 46,000 square meters. This phase includes state-of-the-art research laboratories, lecture halls, and collaborative spaces designed to foster interdisciplinary interaction among the Faculty of Science’s various institutes. A prominent feature is the central atrium, serving as an informal meeting area for lecturers, students, and visitors, enhancing the building’s open and collaborative atmosphere. The design emphasizes transparency and connectivity, with glass walls and open spaces facilitating visibility and communication across different departments. Sustainability was a key consideration, with Phase 1 achieving a BREEAM ‘Very Good’ certification, reflecting its adherence to high environmental standards.

Functions: Education, laboratories, and research

Architect: Ector Hoogstad Architecten

Constructor: Heijmans Bouw

Energy performance:

The building achieved a BREEAM-NL ‘Very Good’ certification with a score of 62.5%, reflecting its commitment to sustainability.

Implemented a thermal energy storage system, utilizing geothermal energy for heating and cooling, significantly reducing CO2 emissions and achieving energy savings of approximately 55-60%.

Equipped with high-efficiency energy recovery ventilation systems to minimize energy consumption.

Building facilities:

A central atrium serving as an informal meeting space for lecturers, students, and visitors, promoting interdisciplinary collaboration.

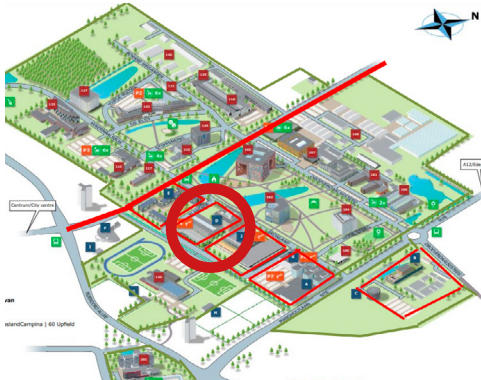
Advanced research laboratories and teaching facilities designed to support cutting-edge scientific work.

Flexible lecture halls and classrooms equipped with modern technology to facilitate various teaching methods.

Dedicated study areas and common spaces to encourage student interaction and learning.

Building Title: Plus Ultra I

Project type: New building Campus: Wageningen campus Year: 2015 Location: Wageningen



Project description

The Plus Ultra I building at Wageningen University & Research (WUR) is a state-of-the-art innovation hub located on the university's Wageningen Campus. Completed in 2015, it was designed to foster collaboration between researchers, entrepreneurs, and startups in the agrifood and life sciences sectors. The building features flexible office spaces, laboratories, and meeting areas, promoting interdisciplinary cooperation.

Plus Ultra I is characterized by its sustainable design, incorporating energy-efficient systems, green materials, and abundant natural light. It holds a BREEAM Excellent certification, reflecting its high environmental performance. The architecture integrates open and transparent spaces to encourage interaction.

Home to numerous startups and research-driven companies, Plus Ultra I plays a crucial role in Wageningen's innovation ecosystem. It is part of Kadans Science Partner's network, supporting knowledge exchange and business development. The success of Plus Ultra I led to the construction of its successor, Plus Ultra II, in 2020.

Functions: Education, research, and offices

Architect: Wiegerinck Architectuur Stedenbouw

The construction of Plus Ultra I was undertaken by Kadans Science Partner, in collaboration with Wageningen University & Research. The project was completed in late 2015, and since then, the building has served as a breeding ground and business complex for knowledge-intensive companies and institutions in the agricultural and food industry.

Project profile

Goals:

Plus Ultra I aims to serve as an incubator and collaborative hub for start-ups and established companies in the agricultural and food industries.

The design focuses on promoting synergy, collaboration, and open innovation among its occupants.

The building's spatial layout encourages interaction, knowledge sharing, and the development of new ideas.

Costs (€):

CREM

Users:

The primary users of Plus Ultra I include knowledge-intensive technological start-ups, established companies, and institutions operating in the agro-food sector. The building also supports start-ups by providing business desks and support services.

Spatial data (m2):

Total Floor Area: 7,735 square meters BVO

Number of Floors: Five

Energy performance:

The building has achieved a BREEAM-NL Excellent certification, reflecting its high environmental performance standards. Sustainable features include the use of solar-powered heat pumps for heating and cooling, and slatted screens that minimize heat gain during summer months. These design elements contribute to the building's energy efficiency and align with the university's sustainability objectives.

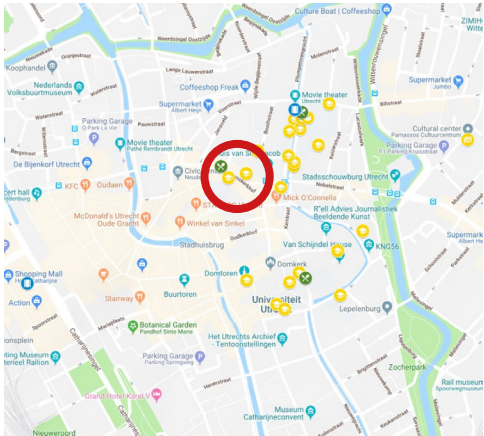
Building facilities:

Facilities Include:

- Laboratories
- Cleanrooms
- Air-conditioned rooms
- Multifunctional research spaces
- Techno-halls
- Conference rooms
- Presentation spaces
- Offices
- Central atrium serving as a communal area

Building Title: Janskerkhof 2-3a

Project type: Renovation Campus: Binnenstadscampus Year: 2015 Location: Utrecht



Project description

Janskerkhof 2-3a, located in the historic heart of Utrecht, is a significant building within Utrecht University. It primarily houses the Faculty of Law, Economics, and Governance, providing lecture halls, seminar rooms, and study spaces for students and staff. The building's monumental architecture reflects its rich history, featuring classicist elements and a distinctive natural stone portal dating back to 1643. Inside, modern facilities support contemporary education and research activities. The building is open from Monday to Thursday, 8:00-22:00, and Friday, 8:00-19:00. Please note that, due to its monumental status, accessibility may be limited. Situated on Janskerkhof Square, the building is surrounded by historical landmarks, shops, and restaurants, with a vibrant flower market held every Saturday, enriching the academic environment with cultural and social amenities.

Functions: Education and research

The Janskerkhof 2-3a Building is a historic structure with origins dating back to 1247, initially serving as the Minrebroederklooster (Monastery of the Friars Minor). After the Reformation, parts of the building were repurposed, and in 1816, it became part of Utrecht University.

Project profile

Goals:

Modernize Educational Facilities: Transforming the historic structure into a contemporary education and study center for the Faculty of Law, Economics, and Governance, aligning with current academic standards.

Preserve Historical Integrity: Maintaining the building's monumental character, including its classicist natural stone portal from 1643, to honor its rich heritage.

Enhance Accessibility: Improving access to accommodate a diverse university community, while acknowledging the challenges presented by its monumental status.

These objectives ensure that Janskerkhof 2-3a serves as a functional, inclusive, and historically respectful academic space.

Costs (€):

CREM

Users:

The building primarily serves:

Faculty of Law, Economics, and Governance: This includes the faculty board, support staff, and the Utrecht University School of Law.

Students: Law students attend lectures and utilize study spaces within the building.

Visitors and Collaborators: Individuals attending academic events, meetings, or collaborative projects hosted in the building.

This diverse user base contributes to a dynamic academic environment at Janskerkhof 2-3a.

Spatial data (m2):

Study Spaces: The building offers various study rooms with capacities ranging from 6 to 20 seats, designed for both individual and group study.

Accessibility: As a monumental building, accessibility may be limited.

Additional Facilities: The building includes amenities such as a front desk and designated areas for quiet study.

Situated in the heart of Utrecht, Janskerkhof 2-3a is surrounded by historical landmarks, shops, and restaurants, with a vibrant flower market held every Saturday, enriching the academic environment with cultural and social amenities.

Energy performance:

Given its status as a listed (monumental) building, implementing modern energy efficiency measures can be challenging due to preservation requirements. However, Utrecht University is committed to sustainability and may have undertaken efforts to improve the building's energy efficiency within the constraints of its historical significance.

Building facilities:

Study Spaces: The building offers various study rooms for both individual and group work. Notable rooms include:

- Room GA0.20: Located on the ground floor, this room provides 11 self-study places.

- Rooms 1.07 and 1.08: Situated on the first floor, each room offers 6 self-study places.

- Rooms 1.17A/B/C: Also on the first floor, these connected rooms collectively provide 27 self-study places.

- Rooms GA2.05 - GA2.08: Located on the second floor, these rooms are designated for group study, each accommodating up to 20 individuals.

Accessibility: While the main entrance is accessible only via stairs, alternative wheelchair-accessible entrances are available. Elevators are present to provide access to all floors, and accessible restrooms are located near the main entrance.

Building Title: Polak Building

Project type: New building Campus: Woudestijn Year: 2015 Location: Rotterdam



Project description

The Polak Building, inaugurated in 2015, is a multifunctional educational facility at Erasmus University Rotterdam’s Woudestein campus. Designed by Paul de Ruiter Architects, it encompasses approximately 8,400 square meters and aligns with the university’s commitment to active, small-scale learning environments.

The building features over 600 modern study spaces, including lecture halls on the first floor and quiet study areas on the upper levels. A central atrium, illuminated by natural light, connects all floors and fosters interaction among students. The ground floor houses various retail services, such as a hairdresser, launderette, campus store, and eateries, enhancing campus life.

Sustainability is integral to the Polak Building’s design. It utilizes natural ventilation, optimal insulation, and features a transparent façade with adjustable blinds to regulate sunlight and temperature. These elements contribute to the building’s energy efficiency, supporting the university’s goal of being among the most sustainable campuses in the Netherlands.

Overall, the Polak Building exemplifies a modern, sustainable educational space that enhances the academic and social experiences of the university community.

Functions: Education

Architect: Paul de Ruiter Architects

Constructor: SMT Bouw & Vastgoed and Croon Elektrotechniek, with Wolter & Dros supplying the installations

Project profile

Goals:

Facilitating Active, Small-Scale Education: The building’s design supports the university’s educational strategy by providing over 600 modern study spaces, including lecture halls and areas for independent or group study, fostering an engaging learning environment.

Enhancing Campus Life: Situated along the campus’s main axis, the Polak Building features retail spaces such as a hairdresser, launderette, campus shop, and eateries on the ground floor, contributing to a vibrant campus atmosphere.

Promoting Sustainability: The building incorporates sustainable materials and technologies, including natural ventilation, optimal insulation, and a transparent façade with adjustable blinds to regulate sunlight and temperature, aiming to position the university among the most sustainable campuses in the Netherlands.

Costs (€):

CREM

Users:

Students: The building offers over 600 modern study spaces, including lecture halls on the first floor and quiet study areas on the upper levels, catering to both individual and group study needs.

Faculty and Staff: Educators and administrative personnel utilize the lecture rooms and various facilities within the building to conduct classes and support academic activities.

Retail Services: The ground floor accommodates retail spaces such as a hairdresser, launderette, campus shop, and eateries, serving the university community and visitors.

Visitors and External Partners: The building’s accessible design and amenities make it a welcoming space for guests and collaborators engaging with the university.

By catering to these varied users, the Polak Building fosters a vibrant and interactive environment that enhances the educational experience and campus life at Erasmus University Rotterdam.

Spatial data (m2):

The Polak Building at Erasmus University Rotterdam is a five-story educational facility encompassing approximately 8,400 square meters. It offers over 600 modern study spaces, including lecture halls on the first floor and quiet study areas on the upper levels. A central atrium, illuminated by natural light, connects all floors and fosters interaction among students. The ground floor houses various retail services, such as a hairdresser, launderette, campus store, and eateries, enhancing campus life. Sustainability is integral to the building’s design, featuring natural ventilation, optimal insulation, and a transparent façade with adjustable blinds to regulate sunlight and temperature. These elements contribute to the building’s energy efficiency, supporting the university’s goal of being among the most sustainable campuses in the Netherlands.

Energy performance:

Sustainable Design: The Polak Building is celebrated for its energy-efficient design, aligning with the university’s commitment to sustainability.

Natural Ventilation and Daylighting: The building’s architecture emphasizes accessibility, transparency, and ample daylight, creating a pleasant indoor climate.

Building facilities:

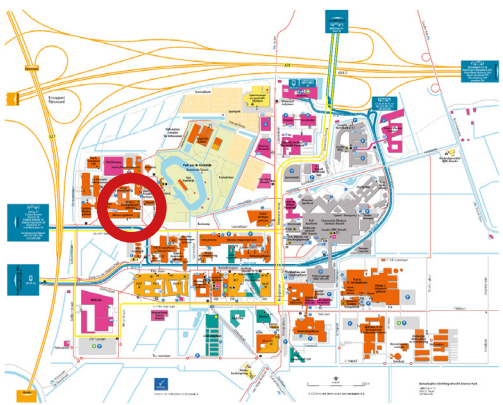
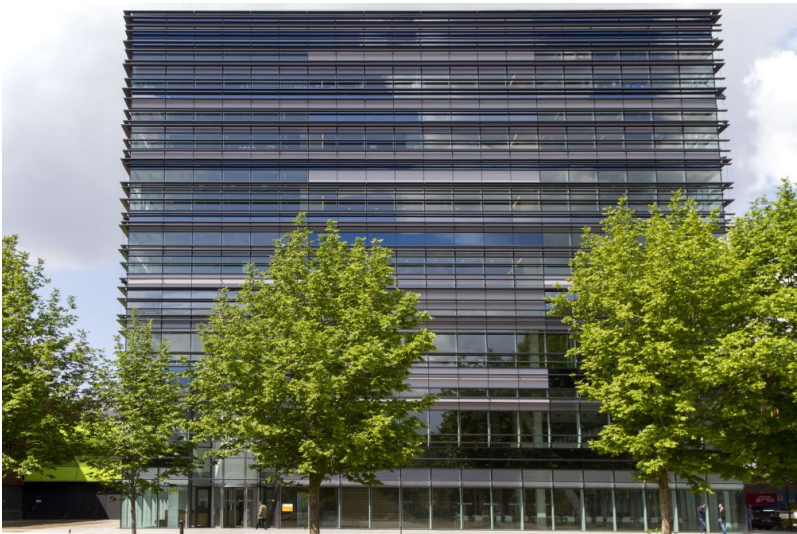
Lecture Rooms: Located on the first floor, these spaces are designed to accommodate large groups, facilitating smooth transitions between classes.

Study Areas: Upper floors offer quiet zones for individual and group study, providing a conducive environment for focused academic work.

Retail and Services: The ground floor houses various amenities, including a hairdresser, launderette, campus store, and temporary lecture hall, enhancing the convenience for students and staff.

Building Title: Victor J. Koningsberger Building

Project type: New building Campus: Utrecht Science Park Year: 2015 Location: Utrecht



Project description

The Victor J. Koningsberger Building, located at Budapestlaan 4a-b in Utrecht Science Park, serves as an educational hub for Utrecht University’s Faculties of Science, Geosciences, and Medicine. Designed by Ector Hoogstad Architecten, the building emphasizes transparency and flexibility, featuring laboratories, lecture halls, and study spaces that foster interdisciplinary collaboration. A distinctive feature is the full-height atrium with a grand staircase, enhancing openness and natural light. The building is part of the northwest education cluster, connecting seamlessly with the Minnaert and Buys Ballot buildings via a first-floor loop, facilitating easy movement between facilities. Sustainability is integral to its design, with transparent façades balancing natural light and energy efficiency. Named after botanist and former university rector Victor Jacob Koningsberger, the building reflects his legacy in advancing scientific education and research.

Functions: Education

Architect: Ector Hoogstad Architecten

Constructor: Züblin

Project profile

Goals:

- Enhancing Interdisciplinary Education: The building serves as an educational hub for the Faculties of Geosciences, Science, and Medicine, providing lecture halls, laboratories, and study spaces to facilitate interdisciplinary learning and collaboration.
- Promoting Sustainability: Designed with transparency and natural light in mind, the building incorporates sustainable materials and energy-efficient systems, reflecting the university’s commitment to environmental responsibility.
- Fostering Connectivity: The building is part of the northwest education cluster, seamlessly connecting with the Minnaert and Buys Ballot buildings via a first-floor loop, enhancing accessibility and interaction among students and staff.
- Honoring Academic Legacy: Named after botanist and former university rector Victor Jacob Koningsberger, the building commemorates his contributions to science and the university community.

Costs (€):

CREM

Users:

- The building serves a diverse academic community, including:
 - Students: From the Faculties of Science, Geosciences, and Medicine, utilizing lecture halls, computer rooms, practical laboratories, and various study spaces for both individual and group work.
 - Faculty and Staff: Engaged in teaching, research, and administrative duties within the building’s facilities.
 - Visitors and Collaborators: Participating in academic events, meetings, and collaborative projects hosted in the building’s versatile spaces.
- This inclusive environment fosters interdisciplinary collaboration and enhances the educational experience at Utrecht University.

Spatial data (m2):

- The Victor J. Koningsberger Building at Utrecht University is a multifunctional educational facility designed to support the Faculties of Science, Geosciences, and Medicine. It features a variety of spaces to accommodate diverse academic activities:
- Designed with sustainability in mind, the building features transparent façades that allow ample natural light, reducing the need for artificial lighting and enhancing energy efficiency. Its layout promotes easy connectivity with adjacent structures, such as the Minnaert and Buys Ballot buildings, fostering an integrated educational environment.
- Overall, the Victor J. Koningsberger Building provides a versatile and sustainable space that supports a wide range of academic activities, aligning with Utrecht University’s commitment to excellence in education and research.

Energy performance:

- Sustainable Design: The building emphasizes natural light, openness, and transparency, contributing to its low net energy consumption. Features such as a full-height central atrium and strategic use of vertical blinds on the façade optimize daylight intake while minimizing energy use.

Building facilities:

- Lecture Theaters: Equipped with telecoil systems in halls Atlas, Pangea, and Cosmos to assist individuals with hearing impairments.
- Study Spaces: Offers various study areas, including quiet zones and group workspaces, to accommodate different learning preferences.
- Laboratories: Houses state-of-the-art labs on the upper floors, designed for practical work and research across multiple disciplines.
- Catering Facilities: Includes the SPAR Koningsberger kiosk, providing convenient access to food and beverages for students and staff.

Building Title: Erasmus University College Building

Project type: Transformation Campus: City campus Year: 2014 Location: Rotterdam



Project description

Erasmus University College (EUC), established in 2013, is housed in the historic former Central Library of Rotterdam at Nieuwemarkt 1A. Constructed between 1917 and 1923, this building is a notable example of the Amsterdam School architectural style, characterized by decorative brickwork and a distinctive tower. Remarkably, it survived the 1940 bombardment of Rotterdam, serving as a testament to the city's resilience. In 2014, after a meticulous restoration led by architect Erick van Egeraat, the building was repurposed to accommodate EUC, the undergraduate honors college of Erasmus University Rotterdam. The renovation preserved its historical elements while integrating modern educational facilities, including lecture halls, seminar rooms, and study areas. Situated in the heart of Rotterdam, EUC offers students a vibrant urban campus that blends historical significance with contemporary academic resources.

Functions: Education and offices

Architect: Erick van Egeraat

The project adhered to the principles of the Venice Charter for the Conservation and Restoration of Monuments and Sites, ensuring that the building's historical integrity was maintained throughout the restoration process

Project profile

<p>Goals:</p> <p>The renovation of Erasmus University College's historic building aimed to:</p> <p>Preserve Historical Significance: Restoring original architectural elements, such as decorative brickwork, coffered ceilings, wood paneling, and stained glass, to honor the building's heritage as one of the few structures that survived the 1940 bombardment of Rotterdam.</p> <p>Integrate Modern Educational Facilities: Transforming the interior to include state-of-the-art lecture halls, seminar rooms, and study areas, thereby creating a conducive environment for contemporary learning while maintaining the building's historical character.</p> <p>Enhance Sustainability: Incorporating sustainable installations and materials to meet current environmental standards, ensuring the building operates efficiently and responsibly in its new role.</p>	<p>Costs (€):</p>
<p>Users:</p> <p>The building at Erasmus University primarily serves:</p> <p>Students: Engaged in the Liberal Arts & Sciences program, utilizing lecture halls, seminar rooms, and study areas for academic activities.</p> <p>Faculty and Staff: Involved in teaching, research, and administrative roles, operating within offices and meeting spaces.</p> <p>Visitors and Collaborators: Participating in academic events, meetings, and collaborative projects hosted within the building's facilities.</p> <p>This diverse user base fosters a dynamic and interactive academic environment within the EUC building</p>	<p>Spatial data (m2):</p> <p>The Erasmus University College (EUC) building, located at Nieuwemarkt 1A in Rotterdam, encompasses approximately 5,500 square meters. Originally constructed between 1917 and 1923 as the Central Library of Rotterdam, the structure showcases the Amsterdam School architectural style, noted for its decorative brickwork and expressive detailing. In 2014, a meticulous restoration led by architect Erick van Egeraat transformed the historic edifice into a modern educational facility. The renovation preserved original features such as coffered ceilings, wood paneling, natural stone elements, and stained glass, while integrating contemporary amenities. The building now includes 19 purpose-built, high-tech tutorial rooms, open study areas, and a well-equipped library, all designed to support EUC's Liberal Arts & Sciences program. Situated in the heart of Rotterdam, the EUC building offers students a dynamic urban campus that harmoniously blends historical significance with modern educational resources.</p>
<p>Energy performance:</p>	<p>Building facilities:</p> <p>Lecture Rooms: Equipped with modern audio-visual technology to support interactive learning experiences.</p> <p>Study Areas: Designated quiet zones and collaborative spaces cater to both individual and group study needs.</p> <p>Library: A resource-rich library provides students with access to a vast collection of academic materials.</p> <p>Common Areas: Comfortable lounges and communal spaces foster interaction and community building among students and staff.</p>

CREM

Building Title: Grotius Building

Project type: New building Campus: Radboud Universiteit Year: 2014 Location: Nijmegen



Project description

The Grotius Building, inaugurated in 2014, serves as the home of Radboud University's Faculty of Law. Designed by Benthem Crouwel Architects, the building spans five floors, including a recessed penthouse and a subterranean level, creating a compact yet spacious environment. Its horizontal articulation and extensive use of glass harmonize with the campus's green, park-like setting, fostering an open and inviting atmosphere. A central atrium, illuminated by natural light, features a cascading series of wide stairs that connect all floors, encouraging interaction among students and staff. The interior incorporates natural materials, predominantly wood, to create a warm and comfortable ambiance. Sustainable design elements, such as reflective canopies that diffuse daylight and minimize direct sunlight, contribute to the building's energy efficiency. The Grotius Building also houses essential facilities, including lecture halls, the law library, and a restaurant, all centered around the vibrant atrium.

Functions: Education and research

Architect: Benthem Crouwel Architects

Constructor: Bouwbedrijf Berghege

Project profile

Goals:

- Providing a Dedicated Space for the Faculty of Law: The building serves as the central hub for the Faculty of Law, offering lecture halls, study areas, and offices to support legal education and research.
- Enhancing Campus Integration: Situated as an autonomous, open structure within the green campus, the building fosters interaction with its surroundings, creating an optimal learning environment.
- Promoting Sustainability and Comfort: The design incorporates natural materials, such as wood, to create a warm atmosphere, while features like cantilevered canopies reflect daylight into the building, enhancing energy efficiency.
- By achieving these goals, the Grotius Building contributes to a cohesive, sustainable, and dynamic academic environment at Radboud University.

Costs (€):

CREM

Users:

- The Grotius Building at Radboud University primarily serves the Faculty of Law, accommodating:
- Students: Utilizing lecture halls, study areas, and the law library for academic activities.
- Faculty and Staff: Engaged in teaching, research, and administrative functions within dedicated offices and meeting rooms.
- Visitors: Attending events, seminars, or utilizing facilities like the restaurant and coffee corner.
- This diverse user base fosters a dynamic academic environment within the Grotius Building.

Spatial data (m2):

- The Grotius Building at Radboud University is a five-story structure, including a recessed penthouse and a subterranean level, designed to accommodate the Faculty of Law. Its compact yet spacious layout features cantilevered floors with recessed glass façades, promoting interaction with the surrounding park-like campus. A central atrium, illuminated by natural light, connects all floors and serves as the building's core. The interior utilizes durable, recyclable materials, with extensive use of wood in floors, walls, cabinets, ceilings, and façade posts, creating a warm and inviting atmosphere. The atrium floor is made of stone, providing a robust surface for high-traffic areas. The building houses lecture halls, study areas, offices, a law library, and dining facilities, all centered around the vibrant atrium. Accessibility features include wheelchair-friendly design and accessible toilets on the ground floor and floors -1, 1, 2, and 3.

Energy performance:

- BREEAM Excellent Certification: The Grotius Building has achieved a BREEAM Excellent rating, reflecting its high standards in sustainability and environmental performance.
- Energy Efficiency: The building consumes 45% less energy than comparable structures, underscoring its commitment to energy efficiency.
- Sustainable Features:
 - Solar Panels: Approximately 300 customized Powerglaz solar panels are installed in the building's atria, contributing to its renewable energy generation.
 - LED Lighting: As part of the university's "LED's GO" project, the Grotius Building has been retrofitted with energy-efficient LED lighting, resulting in significant energy savings.

Building facilities:

- Lecture Halls: The building features a large lecture hall accommodating up to 500 students, designed to facilitate modern teaching methodologies.
- Library: Spanning three floors, the library is a central feature of the building, offering extensive resources and study spaces for students.
- Study Areas: A variety of study spaces, including both individual and group areas, are distributed throughout the building to cater to diverse student needs.
- Restaurant and Terrace: The on-site restaurant, located on the ground and first floors, includes a spacious terrace that connects to the library, providing a pleasant environment for dining and relaxation.
- Lactation room

Building Title: Orion Building

Project type: New building Campus: Wageningen campus Year: 2013 Location: Wageningen



Project description

The Orion Building, inaugurated in September 2013, is a central educational facility at Wageningen University & Research. Designed by Ector Hoogstad Architecten, this pentagonal structure features façades of metal-coated glass, contributing to its distinctive appearance. Orion accommodates approximately 2,600 students and includes various lecture halls, classrooms, and laboratories for disciplines such as biology, physics, and inorganic chemistry. A notable feature is the large auditorium, capable of seating over 700 individuals, which can be subdivided into smaller sections to facilitate diverse educational activities. The building also houses "The Spot," a student café located on the ground floor, serving as a social hub for students and staff. Emphasizing sustainability, Orion achieved a GreenCalc score exceeding 480, making it one of the most energy-efficient buildings on the Wageningen Campus. This efficiency is primarily due to the effective use of sustainable energy resources. Overall, Orion exemplifies a harmonious blend of modern design, functionality, and environmental responsibility, enhancing the academic experience at Wageningen University & Research.

Functions: Education

Architect: Ector Hoogstad Architecten

Constructor: Visser & Smit Bouw

Project profile

Goals:

Accommodate Growing Student Numbers: Designed to serve approximately 2,600 students, Orion addresses the increasing demand for educational space, providing 17 lecture halls, 7 colloquium rooms, 12 PC rooms, 36 group workrooms, and 16 multifunctional practical training areas.

Enhance Educational Flexibility: The building features adaptable spaces, including a large auditorium that can be subdivided into up to six separate halls, allowing for versatile teaching configurations to meet diverse educational needs.

Promote Sustainability: Achieving a GreenCalc score exceeding 480, Orion stands as one of the most energy-efficient buildings on campus, primarily through the efficient use of sustainable energy resources.

Foster Social Interaction: Facilities such as "The Spot," a student café, and various communal areas are designed to encourage social engagement among students and staff, enriching the campus experience.

Costs (€):

CREM

Users:

The building serves a diverse academic community, including:

Students: Engaged in various disciplines, utilizing the building's lecture halls, practical training rooms, and study areas for educational activities.

Faculty and Staff: Conducting teaching, research, and administrative duties within the building's offices and specialized facilities.

Visitors and Collaborators: Participating in academic events, conferences, and collaborative projects hosted in Orion's versatile spaces.

Additionally, the building's amenities, such as the student café "The Spot," are accessible to the broader university community, fostering social interaction and engagement.

Spatial data (m2):

The Orion Building at Wageningen University & Research is a prominent educational facility designed to accommodate approximately 2,600 students. The building encompasses a total floor area of about 21,000 square meters, distributed over nine levels, including eight above ground and one subterranean floor, reaching a height of 45 meters.

The building's pentagonal design, with façades of metal-coated glass, not only enhances its aesthetic appeal but also contributes to its sustainability, achieving a GreenCalc score exceeding 480, making it one of the most energy-efficient buildings on the Wageningen Campus.

Energy performance:

GreenCalc Score: Orion boasts a GreenCalc score exceeding 480, making it one of the most energy-efficient buildings on the Wageningen Campus. This high score is primarily achieved through the efficient use of sustainable energy.

Sustainable Features:

- **Concrete Core Activation:** The building utilizes concrete core activation for temperature regulation, enhancing energy efficiency.
- **Geothermal Heat Pump:** A geothermal heat pump system is integrated to provide sustainable heating and cooling solutions.
- **Energy-Efficient Lighting:** ETAP Lighting supplied energy-efficient and dimmable luminaires, contributing to the building's overall sustainability.

Building facilities:

Lecture Halls: Orion features a large auditorium with a capacity of over 700 seats, which can be flexibly divided into smaller spaces as needed.

Laboratories: The building houses various laboratories equipped for biology, physics, and inorganic chemistry practicals, supporting a wide range of educational activities.

Study Spaces: Multiple group workspaces and individual study areas are available throughout the building, catering to diverse student needs.

Catering Facilities: On the ground floor, students can enjoy meals and beverages at "The Spot," a café that remains open until 10 PM on weekdays, providing a social hub for the campus community.

Building Title: The Education Center Erasmus MC

Project type: New building Campus: Erasmus MC Year: 2013 Location: Rotterdam



Project description

The Education Center at Erasmus University Medical Center (Erasmus MC) serves as the central hub for medical education, accommodating over 6,000 students across various programs, including Medicine, Clinical Technology, and Nanobiology. Designed by KAAJN Architecten, the center features an expansive “education plaza” with more than 400 study spaces, fostering collaboration and self-study. Surrounding this central area are 40 colloquium and lecture halls, facilitating a diverse range of educational activities. The design emphasizes openness and connectivity, creating a cohesive environment that bridges different medical disciplines. In 2013, the Education Center was awarded the Rotterdam Architecture Prize, recognizing its significant contribution to the city’s architectural landscape. The center is undergoing renovations from July 2024 through the second quarter of 2025, during which certain facilities may have limited accessibility.

Functions: Education and medical library

Architect: KAAJN Architecten

Project profile

Goals:

- Centralize Educational Activities: Serving as the “educational beating heart” of Erasmus MC, the center consolidates lecture halls, classrooms, and study areas to facilitate seamless interaction among students and faculty across various medical disciplines.
 - Enhance Learning Environments: The design features an expansive “education plaza” with over 400 study spaces, including designated silent areas and comfortable lounge corners, fostering both collaborative and individual learning experiences.
 - Improve Accessibility and Resources: By providing modern facilities equipped with advanced ICT resources, the center aims to support diverse educational needs, ensuring students have access to necessary tools for their academic development.
- These goals collectively contribute to a cohesive and dynamic educational environment, aligning with Erasmus MC’s commitment to excellence in medical education.

Costs (€):

CREM

Users:

- The building primarily serves:
- Students: Over 6,000 individuals enrolled in programs such as Medicine, Clinical Technology, Nanobiology, Research Masters, and PhD studies utilize the center’s lecture halls, colloquium rooms, and study areas.
 - Faculty and Staff: Engaged in teaching, research, and administrative duties, they access the center’s facilities for lectures, seminars, and collaborative activities.
 - Visitors and Collaborators: Participants in academic events, workshops, and collaborative projects hosted within the center’s versatile spaces.
- The center fosters a dynamic academic environment, promoting interaction among various disciplines within Erasmus MC.

Spatial data (m2):

- The Education Center at Erasmus University Medical Center (Erasmus MC) is a pivotal facility designed to support the academic endeavors of over 6,000 students across various medical disciplines. Its central feature, the education plaza, offers more than 400 study spaces, including designated silent areas and comfortable lounge corners, fostering both collaborative and individual learning environments. Surrounding this plaza are 40 colloquium and lecture halls, such as Lecture Halls 1 and 2 and the Professor Andries Querido Hall, all equipped with advanced audiovisual technology to facilitate diverse educational activities. The design emphasizes openness and connectivity, with a large, column-free glazed roof structure that floods the interior with natural light, creating an inviting atmosphere for study and interaction. Additionally, the center provides essential amenities, including computer and printing facilities, to support the comprehensive academic needs of its users. Please note that the Education Center is undergoing renovations from July 2024 through the second quarter of 2025, during which certain facilities may have limited accessibility.

Energy performance:

- While specific metrics on the building’s energy performance are not publicly detailed, the design emphasizes sustainability and energy efficiency through:
- Natural Lighting: A large, column-free glazed roof structure spans the main educational square, maximizing daylight penetration and reducing reliance on artificial lighting.
 - Efficient Use of Space: The repurposing of existing structures and the thoughtful layout contribute to reduced energy consumption by optimizing heating, cooling, and lighting needs.

Building facilities:

- Education Square: At the heart of the center lies a spacious area featuring a 35-meter-long, four-story-high bookcase wall and various study islands, creating a dynamic learning environment.
- Library: Adjacent to the education square, the library offers extensive resources and study spaces for students.
- Seminar and Lecture Rooms: The center includes modern seminar rooms and refurbished lecture halls equipped with contemporary educational technologies.
- Thesis Defense Room: A dedicated space is available for thesis defenses and other academic presentations.

Building Title: Amsterdam University College Building

Project type: New building Campus: Science park Year: 2012 Location: Amsterdam



Project description

Amsterdam University College (AUC), established in 2009, is a collaborative Liberal Arts and Sciences institution jointly operated by the University of Amsterdam (UvA) and Vrije Universiteit Amsterdam (VU). Situated at Science Park 113 in Amsterdam, AUC offers an interdisciplinary curriculum modeled after the American liberal arts system, culminating in a joint Bachelor's (Honours) degree from both UvA and VU. The AUC building, designed by Mecanoo architects and completed in 2012, encompasses approximately 5,800 square meters and accommodates around 900 students. Its distinctive design features a rust-colored façade and a green roof, symbolizing sustainability and innovation. The interior includes modern classrooms, a library, a restaurant, and communal spaces that foster a vibrant academic community. Located within Amsterdam Science Park, AUC benefits from proximity to a hub of scientific research and innovation, providing students with ample opportunities for academic and professional development. The campus environment encourages collaboration and cross-disciplinary engagement, aligning with AUC's mission to cultivate globally oriented graduates equipped to address complex societal challenges.

Functions: Education and library

Architect: Mecanoo Architecten

Constructor: M.J. De Nijs & Zonen BV

Project profile

Goals:

Create an Inspiring Academic Environment: The building features large voids at its core, fostering visual connections across different floors. A winding staircase through these voids symbolizes community, while double-height spaces like the restaurant and study hall offer expansive views of Science Park, enhancing the educational atmosphere.

Reflect Sustainability: Achieving a Greencalc+ rating of 200, the building incorporates a compact form to optimize the wall-to-floor ratio. It utilizes thermal energy storage and concrete core activation, with a sedum green roof providing insulation and water storage, underscoring AUC's commitment to environmental responsibility.

These goals collectively aim to provide a dynamic, sustainable, and inclusive space that supports the academic and social needs of AUC's diverse community.

Costs (€):

CREM

Users:

The building primarily serves:

Students: Enrolled in AUC's Liberal Arts and Sciences program, they attend classes, engage in group projects, and utilize study areas within the building.

Faculty and Staff: Responsible for teaching, research, and administrative duties, they operate from offices and classrooms housed in the facility.

Visitors and Collaborators: Participate in academic events, workshops, and meetings held in the building's various spaces.

This diverse user base fosters a vibrant academic community within the AUC building.

Spatial data (m2):

The Amsterdam University College (AUC) building, located at Science Park 113 in Amsterdam East, encompasses approximately 6,000 square meters across four floors. Designed by Mecanoo architecten, the structure features a square footprint with a distinctive Cor-Ten steel façade, lending it a warm yet formal appearance. The building's design includes large voids at its core, creating visual connections between floors and fostering a sense of community among students and faculty. A prominent winding staircase traverses these voids, symbolizing connectivity. Diagonal roofs running north-south form a spacious attic with a striking, folded timber-clad ceiling. The interior houses classrooms, project rooms, study areas, administrative offices, a common room, and a café, all under one roof to facilitate interaction and collaboration. Sustainability features include a sedum green roof for insulation and water management, as well as ground source heat-cold storage and concrete core activation systems to enhance energy efficiency. The building's compact form and strategic design elements contribute to its status as a sustainable and inspiring academic environment.

Energy performance:

The AUC building is designed with a strong emphasis on sustainability, achieving a Greencalc+ rating of 200. Key features contributing to its energy performance include:

Thermal Energy Storage and Concrete Core Activation: These systems efficiently manage the building's heating and cooling needs, reducing energy consumption.

Green Roof: The expansive sedum-covered roof provides natural insulation, aids in water retention, and supports biodiversity.

Solar Panels: In 2016, 116 solar panels were installed on the roof, contributing to the building's renewable energy generation.

Building facilities:

Classrooms and Lecture Rooms: Equipped with modern educational technologies to support interactive learning.

Study Areas: Various study spaces, including the Darwin Area and the Upper Common Room, provide environments for both individual and group study.

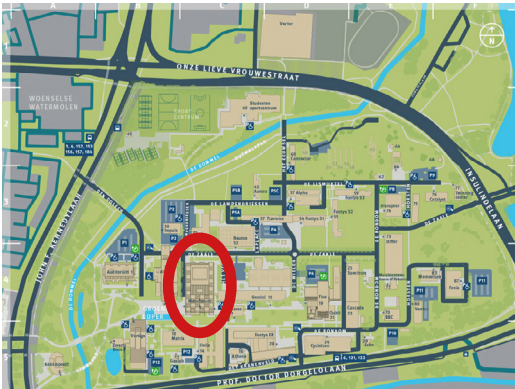
Library: A dedicated library space offers resources and quiet areas for research and reading.

Common Room: A spacious area designed for student interaction and relaxation.

Restaurant: A dining facility providing meals and refreshments for students and staff.

Building Title: MetaForum

Project type: Transformation Campus: TU/e campus Year: 2012 Location: Eindhoven



Project description

The MetaForum building, located centrally on the Eindhoven University of Technology (TU/e) campus, serves as a vibrant hub for students, faculty, and visitors. This innovative structure is a transformation of the historic W-hal, originally constructed in 1958 as a flexible space for machinery and experiments. In 2012, Ector Hoogstad Architecten revitalized the W-hal, integrating modern facilities while preserving its architectural heritage. MetaForum houses the university's central library, numerous study areas, lecture halls, and various amenities, including dining options and service desks. A notable feature is the new building atop the original hall, accommodating the Faculty of Mathematics and Computer Science. This addition appears to 'float' above the hall, supported by slender steel columns, creating an open and inviting atmosphere below. The design emphasizes openness and connectivity, with footbridges linking MetaForum to surrounding buildings and panoramic staircases enhancing accessibility. The building's transformation has been recognized with awards such as the Gulden Feniks for best transformation and designation as a national monument, underscoring its significance in blending historical preservation with modern functionality.

Functions: Education, library, and offices

Architect: Ector Hoogstad Architecten

Constructor: Hurks Bouw Zuid

Project profile

Goals:

Centralize Student Facilities: MetaForum serves as a central hub, accommodating various study facilities for students from all departments. The building transitions from dynamic zones to areas designated for concentrated, individual work, fostering an environment conducive to diverse study needs.

Preserve Architectural Heritage: The project involved transforming the historic W-hal, one of the university's oldest buildings, into a modern main building. This approach reflects a commitment to honoring and revitalizing the university's architectural legacy.

Enhance Campus Connectivity: Strategically located at the campus's center, MetaForum functions as a focal point, integrating seamlessly with surrounding structures through footbridges and open connections. This design fosters interaction and accessibility across the university.

Promote Sustainability and Flexibility: The building emphasizes energy-efficient construction and the use of sustainable materials. Flexibility and multifunctionality were central to its design, ensuring the facility can adapt to evolving educational needs.

Costs (€):

CREM

Users:

The building serves a diverse group of users:

Students: From all departments, they utilize MetaForum's extensive study facilities, including dynamic zones for group work and quiet areas for individual study.

Faculty and Staff: Engaged in teaching and administrative roles, they access the building's lecture rooms, offices, and service desks.

Visitors and the General Public: The central library within MetaForum is accessible to the public for consultation of the printed collection, fostering a broader community engagement.

This inclusive environment positions MetaForum as the university's "living room," promoting interaction and collaboration among all users.

Spatial data (m2):

The MetaForum building at Eindhoven University of Technology (TU/e) encompasses approximately 26,912 square meters, serving as a central hub for academic and social activities.

The design emphasizes openness and connectivity, with footbridges linking MetaForum to surrounding buildings and panoramic staircases enhancing accessibility. This thoughtful spatial arrangement fosters interaction and collaboration among the university community.

Energy performance:

Natural Lighting: The building's design maximizes the use of natural light through its distinctive "checkerboard-patterned" roof and transparent facades, reducing the need for artificial lighting.

Adaptive Reuse: By repurposing the existing W-hal structure, the project minimized the environmental impact associated with new construction, aligning with sustainable building practices.

Building facilities:

University Library: Situated on the ground floor and basement levels, the library offers extensive resources and study spaces for students and staff.

Faculty of Mathematics and Computer Science: A new structure, appearing to 'float' above the original hall, houses this faculty, providing modern offices and meeting rooms.

Lecture Halls and Study Areas: The building includes various lecture rooms and ample study spaces, designed to accommodate both group collaborations and individual work.

Catering Facilities and Service Desks: Located within the building to support daily campus life, these amenities enhance the convenience for users.

Event Plaza: A covered events area in the southern section of the building, serving as a venue for university performances, parties, and concerts.

Building Title: Faculty Club

Project type: New building Campus: Tilburg campus Year: 2011 Location: Tilburg



Project description

The Faculty Club at Tilburg University, designed by Shift Architecture Urbanism and completed in 2011, serves as a multipurpose pavilion for academic staff and their guests. Situated on the campus's edge, adjacent to the historic Oude Warande forest, the building's minimalist design features a natural stone exterior, harmonizing with the surrounding landscape. The interior includes a restaurant and functional spaces for meetings, receptions, and events, accommodating groups ranging from small gatherings to larger assemblies of up to 80 people. Expansive windows provide ample natural light and offer views of the forest, creating an inspiring environment for both formal and informal occasions. Managed by Bonheur Horeca Groep, the Faculty Club offers seasonal menus and daily specials, catering to diverse culinary preferences. Its strategic location and architectural elegance make it a distinctive venue for fostering academic collaboration and hosting various events within the university community.

Functions: Restaurant and meeting rooms

Architect: Shift Architecture Urbanism

Constructor: Van der Weegen
Bouwgroep

Project profile

Goals:

Foster Academic Collaboration: The Faculty Club serves as a dedicated space for academic staff and their guests to convene, facilitating interactions that enhance scholarly engagement and interdisciplinary collaboration.

Provide Versatile Meeting Spaces: Equipped with two meeting rooms accommodating groups of 4 to 30 individuals, and a restaurant adaptable for conferences or presentations for up to 80 attendees, the Faculty Club offers flexible venues for various academic and professional gatherings.

Enhance Campus Aesthetics: Designed by Shift Architecture Urbanism, the building's minimalist architecture, featuring a natural stone exterior, complements the campus's existing structures and the adjacent Oude Warande forest, enriching the university's architectural landscape.

By achieving these goals, the Faculty Club contributes to a vibrant academic community and supports the university's mission of fostering knowledge exchange and collaboration.

Costs (€):

CREM

Users:

The building serves a diverse group of users:

- Academic Staff and University Members: Professors, researchers, and other university personnel utilize the Faculty Club for meetings, collaborative sessions, and social gatherings, fostering academic engagement and interdisciplinary collaboration.
- Business Partners and External Guests: The venue accommodates stakeholders, academic guests, and business partners for conferences, receptions, and formal events, providing a professional setting that enhances the university's external relations.
- Event Attendees: Individuals attending various functions, such as festive gatherings, receptions, and informal meetings, find the Faculty Club an ideal location due to its versatile spaces and excellent catering services.

This inclusive approach positions the Faculty Club as a central hub for both the university community and its external partners, promoting interaction and collaboration across different sectors.

Spatial data (m2):

The Faculty Club at Tilburg University, designed by Shift Architecture Urbanism and completed in 2011, is a multipurpose pavilion located on the campus's edge, adjacent to the historic Oude Warande forest. The building's minimalist design features a natural stone exterior, harmonizing with the surrounding landscape.

The Faculty Club's design emphasizes transparency and openness, with large glass facades that blur the boundaries between interior spaces and the adjacent forest, creating an inspiring environment for both formal and informal occasions.

Energy performance:

Natural Lighting: Large, recessed windows and a glazed rear façade maximize natural light, reducing the need for artificial lighting.

Material Efficiency: The building's compact form and integration of structure and services within walls and floors contribute to energy efficiency.

Building facilities:

Restaurant: Accommodates up to 80 guests, offering a space for dining with views of the surrounding forest.

Lounge: A comfortable area featuring a fireplace, designed for informal gatherings and relaxation.

Meeting Rooms: Two conference rooms equipped to host groups ranging from 4 to 30 people, suitable for meetings and presentations.

Terrace: A covered outdoor space connected to the lounge and restaurant, allowing for open-air events and dining.