Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Ruben Pot
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Studio		
Name / Theme	Architectural Engineering Graduation Studio	
Main mentor	Stephan Verkuijlen	Architecture (Design tutor)
Second mentor	Dafne Sara Swank	Architecture (Research tutor)
Argumentation of choice of the studio	In the last couple of years, I've developed a significant fascination for high-rise architecture. This started when I embarked on a new chapter and moved to Rotterdam right after completing my bachelor's degree. When moving to Rotterdam, which is of course well known for it's relatively large amount of high-rise buildings, I encountered high-rises on a daily basis, both through city life but never the less at the office where I was working at the time. During my time working there, I never had the opportunity to work on these high-rise projects, at least not for a significant amount of time. Nevertheless, the complexity and grandeur of these projects consistently captured my attention when seeing them every now and then passing by when being in the office. What made the idea of working on high-rise projects more compelling over time. Now during my masters, and more specifically my graduation year, I find myself in a unique position. I have the opportunity to pursue a self-defined case that is centered around the task of designing a high-rise building myself. Upon careful consideration of my options, it became evident that this was best suitable within the Architectural Engineering Graduation Studio. Therefore, I applied for this studio.	

Graduation project	
Title of the graduation project	Empowering Architects for Sustainable High-Rise Development: A Parametric Approach for Sustainable Timber High-Rise Design.
Goal	
Location:	[Project Location]
The posed problem,	[Problem Statement]
research questions and	[Research Question]
design assignment in which these result.	[Design Assignment]
Project location: Unileverplot Weena, Rotterdam, The Netherlands	

General Problem Statement & Research questions

The Netherlands is currently facing a severe housing crisis, with increasing housing prices and a shortage of available housing units. This crisis is exacerbated by rapid urbanization, leading to an explosion in the size of urban populations without a corresponding increase in housing supply. A significant majority of the Dutch population resides in urban areas, constituting about 74% of the total population. Of these urban residents, 44% are located in cities. This high concentration of the population in urban areas puts a strain on the housing resources on these areas, contributing to the housing crisis. The demand for housing is outpacing the supply, leading to skyrocketing housing prices and a shortage of available housing units.

Traditional methods of housing delivery are proving to be insufficient to meet the rising demand, necessitating the need to find a solution for this problem. One such approach is to accelerate urban densification, a strategy that involves maximizing the use of existing urban areas to accommodate more residents. As part of sustainable urban development initiatives, cities in the Netherlands are actively exploring solutions to address the housing crisis. Rotterdam in particular, stands out as a city experimenting with densifying its city center by the means of high-ris e. Which is according to industry experts, among Emiel Arends, necessary to be able to densify cities and solving the housing crisis.

However, despite the potential benefits of high-rise development for sustainable urban development, there are also significant challenges and impacts associated with the conventional materials used for high-rise construction. Concrete is the most widely used construction material in the world, and it is particularly dominant in high-rise construction. While concrete has undeniable structural qualities, it also brings a substantial carbon footprint along that poses a significant burden to the environment

Concrete production is a highly energy-intensive process and contributes significantly to greenhouse gas emissions, notably through carbon dioxide emissions during cement production, one of the key components of concrete. According to Kerkhoven, the construction industry in the Netherlands processes approximately 14 million cubic meters of concrete annually, resulting in a CO_2 emission of approximately 3.5 million tons per year. Notably, 80% of this emission is related to cement production. Kerkhoven notes that the 3.5 million tons accounts for 1.7% of the total annual CO_2 emissions in the Netherlands. The amount of CO_2 emissions per cubic meter of concrete is on average 508 kg.

In recent years, the environmental impact of the excessive use of concrete in high-rise construction has raised concerns. In response driven by sustainability and environmental considerations, the modern construction industry is witnessing a growing interest in timber as a construction material. While this interest has predominantly manifested in low- and mid-rise buildings, there is a notable shift toward incorporating timber in high-rise construction projects now as well. While still a challenging alternative to traditional high-rise construction materials, timber offers the potential to significantly reduce the carbon footprint associated in the building sector.

Contemporary architecture has already demonstrated the potential of timber in high-rise buildings, with successful structures reaching up to approximately 86 meters in height. Presently, there are relatively few projects on the horizon aiming to exceed this height. One of the notable exceptions include ‘The Dutch Mountains’, proposed to reach to heights of 100m and 130m. Globally, other ambitious projects are slowly emerging in other countries as well, underlining timber's upcoming feasibility in high-rise construction, such as plans for structures as tall as 191 meters in Perth, 300 meters in London, and a towering 350 meters in Tokyo.

Although we see increasing potential for timber in high-rise construction, high-rise designs in contemporary architecture still heavily relies on traditional materials like concrete and steel. Consequently, relatively few architects have experience with the complexities and requirements related to timber-based construction in high-rise design.

To help architects navigating the uncharted territory of timber as the structural material in high-rise design, this project and research aims to provide them with a digital design tool. Based on rules of thumb, this design tool helps architects navigating the complexities and requirements of timber-based high-rise construction. By doing so, architects can unleash their creativity while ensuring that their designs remain structurally realistic. The objective is to empower architects to create remarkable and efficient high-rise designs with a realistic structural basis early on in their design process.

Ultimately, this research seeks to contribute to the shift towards more sustainable timber-based high-rise architecture by reducing the barrier associated with the complexities and requirements that come with timber-based high-rise design. The aim is to make timber a more accessible choice as the main construction material in high-rise design.

Therefore, the main objective of this research is to develop a parametric design tool for timber-based high-rise construction, based on rules of thumb and performance criteria. This tool will enable architects to explore the potential and the constraints of timber as a structural material for high-rise buildings, and thereby to create sustainable and efficient designs that reduce the environmental impact and carbon footprint of high-rise construction. In order to do this the aim to answer the following research question: "*How can a parametric design tool be developed in order to aid architects in the design of sustainable and innovative timber high-rise buildings, guided by fundamental structural principles and performance criteria?*"

In order to answer this research question, I've formulated the following set of sub-questions:

sQ1. "*In contemporary Tall Timber development, what are the key challenges in adopting timber as the main construction material for high-rise buildings (in the Netherlands) and what methods are currently in use in the latest Tall Timber developments?"*

sQ2. "*In what way can the carbon footprint of high-rise structures be reduced effectively by incorporating timber as its main construction material, while also being an economically viable alternative to the conventional high-rise construction materials?"*

sQ3. "*What are the key parameters and (structural) rules of thumb needed for developing the parametric design tool for Tall Timber buildings?"*

Problem Statement Location

Plot The project location chosen for my design study, which will also serve as a case study for my thematical research, is situated in the heart of the Rotterdam Central District (RCD), a part of Rotterdam's 'High-rise zone'. Conveniently positioned in close proximity to Rotterdam Central Station, this location serves all types of public transport within the city, encouraging reduced car dependency alligning with the earlier mentioned principles of the compact city. Presently, the project location consists of 2 parts: The so-called 'Unilverplot', that contains The Unilever Building and TIO Rotterdam building, and Weenacenter, which is a residential tower, as can be seen on 'Figure 3'. According to the Rotterdam High-rise vision, the Unileverplot is suitable for high-rise construction up to 150m. What makes it an excellent candidate for my study.

Addressing Housing Shortages

Within the context of the Rotterdam Central District, the current state of this plot presents substantial unused potential for urban densification. Embracing the principles of a compact city is essential to efficiently intensify urban land use and promote sustainable city development. The urgent issue it addresses is the housing shortage in the Netherlands, particularly in Rotterdam's city center. The addition of a residential tower in this part of the city with extra housing units and diverse programming on this site presents a proactive response to this current housing shortage.

Promoting Mixed-Use Synergy

Currently, the program on the Unilever Plot consists of offices, dwellings, and education, all housed in three separate monofunctional buildings. This segregation limits interaction and hinders the development of a lively urban environment. To address this, my proposal aims to transform the site into a dynamic, mixed-use environment by introducing functions such as hospitality, shopping, and social facilities. These added facilities will not only enhance the quality of life for the residents but also serve as catalysts for further area development. By providing amenities to the current and future inhabitants, this integrated approach will stimulate the growth of the area and act as a kickstart for the introduction of more housing units, creating a self-sustaining ecosystem.

Alignment with the 'Boulevard Model' Weena

The current program on the Unilever Plot does not align with the municipality's "Boulevard Model", an ambition document on Weena Street. This model emphasizes vibrant ground-level activities, leisure amenities, and an engaging streetscape. Unfortunately this never came into fruition. Therefore my design challenges to harmonize the new high-rise construction with this established urban planning guideline, fostering an active and dynamic street-level environment.

In summary, the Unilever Plot presents an ideal canvas to address multiple urban challenges: densification, housing shortage, and alignment with the city's urban planning vision. By proposing a high-rise tower constructed through a sustainable method derived from my thematic research, I aim to not only enhance the physical landscape but also contribute to the vitality and liveliness of the Rotterdam Central District.

Process

Method description

Among others the methods and thechniques used for the research include; Literature Study, Case Study Analysis, Interviewing Industry Experts, Data Analysis, Tool Development (and Tool Evaluation and Optimalisation).

1. Literature Study

In order to address the above mentioned sub-questions and thereby the research question, a series of literature studies were selected as primary sources to develop a good understanding of the following aspects; contemporary tall timber development challenges and techniques(1), costs and profitability of timber as a structural material (2), lowering CO2 Emissions (3) and identifying structural rules of thumb for Tall Timber structural design (4).

2. Case Study Analysis

The case-study analysis will focus on some real-world projects that are at the forefront of Tall Timber development. For this part of the research I have selected 3 projects, the selection of these projects is based on location, therefore I selected the two tallest completed Tall Timber buildings in Europe (2nd and 3rd tallest in the world) and the tallest timber-based buildings in The Netherlands (4th tallest in the world). The focus of these case studies to bring out key aspects or techniques rather than comparing the same for each project, contributing to get an overall understanding of Tall Timber projects.

3. Interviews

The interviews with industry experts will encompass individuals specializing in timber construction, high-rise design and engineering, parametric design, BIM Workflow Optimization, and business development. Selections will be made based on the participants' extensive experience and expertise in their respective fields. To ensure a comprehensive understanding of the diverse perspectives uncovered in the research, the panel of experts includes a structural engineer with expertise in timber construction and high-rise design, two engineering consultants with a focus on timber-based high-rise construction, and two architects, one specializing in Parametric design and the other bringing broad experience in high-rise design.

4. Data Analysis
The collected data from the literature review, case studies and expert interviews will be analyzed, documented and synthesized into a comprehensive set of additional data that is added to this research as appendices. Additional data that didn't derive from answering to the research questions needed for developing the parametric design tool, is gathered once more in '5.4. Data Analysis'.

5. Tool Development
I will use Grasshopper, a visual programming language in Rhinoceros 3D, in order to create a parametric design tool for architects aiming to design tall timber buildings. The goal of the tool is to provide feedback on structural feasibility and sustainability, allowing users to optimize their designs. Additionally, the Grasshopper script is compatible with software such as 'Rhino Inside Revit' and 'Grasshopper – Archicad Live Connection', enabling it to support and facilitate a wide range of architects.

6. Tool Evaluation and Optimalisation (Not included in the research, this will follow during design in MSc4)
The design study on the Unilever plot in Rotterdam's Central District, where I aim to incorporate a 150m mixed-use residential tower with a focus on timber construction, will serve as a case study to validate the effectiveness of the parametric design system I aim to develop (Which is the research goal). During this phase I will most likely need to optimize the tool, since it will be the first time it will be tested. The selection of this location aligns with my research objectives and provides an ideal setting for the study.

Literature and general practical preference

Compact City Concept

The compact city concept, is a strategic urban planning approach, which aims to create sustainable urban environments through dense, diverse, and efficient design. This involves optimizing space use, promoting public transport connectivity to reduce reliance on personal vehicles, and ensuring proximity to essential services, thus minimizing car dependency which is beneficial for the environment. Connected with sustainable urban planning, it addresses challenges posed by population growth and fosters resource efficiency. Notably, the concentration of activities in high-rises, a key element of the compact city concept, contributes significantly to reducing carbon emissions by shortening commute distances . This research embraces these principles, serving as a crucial framework that aligns with the goals of sustainable urban planning and contributes to the reduction of carbon emissions.

Embodied Carbon Calculation

In contrast to traditional metrics like MPG, which focus on operational efficiency, this research prioritizes the Embodied Carbon Calculation. This method offers a comprehensive view of a building's environmental impact, spanning extraction, manufacturing, transportation, and end-of-life considerations. By emphasizing the entire lifecycle, the goal is to provide a more complete insight of how sustainable timber-based high-rise projects really are, aligning with the broader research objective.

The Paris Proof Commitment

The Paris Proof Commitment, advocated by the Dutch Green Building Council, aims to realize the global Paris climate accords by shifting the focus from energy labels to actual energy consumption measurements. This aligns seamlessly with the research objective of evaluating the sustainability of timber-based high-rise projects. Emphasizing the significance of actual energy use as a more accurate metric, the commitment contributes to broader climate goals, fostering rapid sustainability in urban environments.

The European Green Deal

In parallel to The Paris Proof Commitment, the European Green Deal, a ambitious initiative by the European Commission, seeks to transform the EU into a resource-efficient and competitive economy with no net greenhouse gas emissions by 2050. Going beyond the Paris Agreement, the European Green Deal sets more stringent targets, reflecting a comprehensive approach to combat climate change. The research is inherently linked to these transformative agendas, as it explores how timber, with its exceptional carbon storage capacities, can contribute to reducing the carbon footprint of high-rise structures. This aligns with the ambitious goals outlined in both the Paris Proof Commitment and the European Green Deal, collectively shaping the research trajectory towards a more sustainable built environment.

Tall Timber

"Tall timber" in the building industry refers to the use of wood as the primary structural material in the construction of taller buildings. This method, known as "mass timber" construction, involves the use of large, solid wood panels, columns, or beams to construct buildings. This term is pushing the boundaries of what is traditionally considered possible with timber construction. Elements used in tall timber are called Engineered Wood Products (EWPs), which include materials like Cross-Laminated Timber (CLT), Laminated Veneer Lumber (LVL), and Glued Laminated Timber (GLT), which are composite wood products with enhanced structural properties. In this research, there will be examined how these EWPs contribute to sustainable building practices by assessing their environmental impact, structural performance, and compliance with regulations. This will involve a life cycle assessment, evaluating their strengths compared to traditional materials, and exploring innovative design applications enabled by these materials.

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A,U,BT,LA,MBE), and your master programme (MSc AUBS)?
2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

The topic of my research revolves around contemporary tall timber construction, exploring challenges, techniques, and sustainability aspects. This aligns closely with the Master Track in Architecture, as it involves in-depth investigations into architectural design principles, materials, and construction methods, specifically focusing on the innovative use of timber in high-rise buildings.

The overall master program encompasses a broad perspective on architecture, urban planning, and building sciences. My research on tall timber construction contributes to the building sciences aspect by delving into the structural and material considerations of high-rise architecture. It connects with urbanism by potentially influencing the landscape of sustainable urban development through the exploration of timber as a construction material.

Tall timber construction has significant implications for sustainable urban development. The use of timber as a primary material can contribute to reduced carbon footprints, addressing environmental concerns and aligning with global sustainability goals. Therefore, my graduation work is relevant in promoting environmentally friendly practices in the construction industry, which has broader societal implications in the face of climate change.

Professionally, my research addresses challenges faced by architects, engineers, and developers in adopting tall timber construction. The development of a parametric design tool holds practical significance for professionals involved in designing high-rise structures, offering a decision-support system that balances sustainability, costs, and profitability. This tool can potentially shape future practices in the field of architecture.

In the scientific context, my work contributes to the body of knowledge in architecture, building sciences, and sustainability. The identification of challenges, techniques, and design considerations provides valuable insights for future research in tall timber construction. The parametric design tool, as a proposed innovation, adds to the scientific discourse by introducing a practical application of research findings in the field.