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	Noa Reerink
Student number	5657024

Studio		
Name / Theme	Circular-adaptable real estate reuse to react to societal changes	
Main mentor	J.W.F. Wamelink	Design & Construction Management (Management in the Built Environment)
Second mentor	A. Meijer	Environmental & Climate Design (Architectural Engineering & Technology)
Argumentation of choice of the studio	I have always been very interested in circularity. Due to climate concerns, there is a lot of pressure on the building sector to adopt sustainable practices. And i recognize the urgency of mitigating climate change and see circular development as a solution to this. This led me to consider combining the topics of circularity and reducing CO2 emissions, which led me to choosing this studio.	

Graduation project	
Title of the graduation project	Reducing carbon emissions by evaluating circular strategies: Quantifying material-related CO2 emissions of circular strategies in the built environment.
Goal	
Location:	The Netherlands
The posed problem,	Global warming is primarily driven by the emissions of carbon dioxide resulting from human activities. The construction industry, driven by urbanization and population growth, plays an important role in this due to its resource-intensive nature. Buildings account for nearly 40% of global energy consumption and one third of associated greenhouse gas emissions. Additionally, the government's goal for the Netherlands is to reduce greenhouse gas emissions by

	55% in 2030 and to achieve climate neutrality in 2050. The focus to reduce CO2 emissions used to be on lowering operational energy emissions, but due to the increase in energy-efficient and net-zero buildings this focus is now shifting. As operational emissions drop, materials' emissions gain importance, shifting environmental studies toward reducing embodied energy. One potential solution to address this challenge of reducing carbon emissions is the adoption of circular economy principles in the construction industry. Circular strategies, such as reduce, reuse, recycle, and recover, have the potential of minimizing waste, reducing resource consumption, and reducing CO2 emissions. However, it is unclear how these strategies compare to each other in terms of their carbon footprint. Research is needed to find out which strategies have what kind of potential to reducing CO2 emissions and how they compare when measured against one another. Additionally, the carbon footprint of buildings is linked to the choice of construction materials. However, this interplay between material selection, carbon emissions and circular strategies is unknown.
research questions and	Main research question: What are the material related CO2 emissions and storage, particularly of the building structure, of the circular 4R-strategies applied in the construction of buildings in the Netherlands? And how does the choice of materials influence this? SQ 1: When in the buildings' lifecycle would the 4R-strategies (Reduce, Reuse, Recycle, Recover) in theory produce CO2 emissions or deliver a CO2 gain? And Why? SQ 2: How do different R-strategies impact the material-related CO2

	emissions and material related CO2 storage of wood, steel, and concrete in the selected building cases? SQ 3: How do the material related CO2 emissions and storage of these R-strategies compare to each other for the building materials wood, steel, and concrete? SQ 4: How can we develop design guidelines and a mathematical optimization decision model that integrates the outcomes of the study to provide guidance for architects, engineers, and contractors in making sustainable choices during early design phases?
design assignment in which these result.	The purpose of this research is to determine what circular strategies have what kind of potential to reduce material-related carbon emissions and how this can be used in practice. This research produces two outputs: design guidelines and a mathematical optimalisation model. The design guidelines are rules that can be consulted by the client, project manager or designer in early phases developing a building. These guidelines translate insights retrieved from this research into practical use. Complementary, the research produces a prototype of a mathematical optimalisation model that can be used to facilitate discussion between all relevant stakeholders in a construction project. For every stakeholder involved in construction projects, navigating the complexities of sustainability and carbon reduction can be challenging. The proposed tool will serve as a means to visualize and discuss these complexities. It is important to note that the model serves as a decision support tool rather than an autonomous decision-making entity. So the model can be used to

	raise awareness, set goals, and make informed decisions about circular strategies and material choices in the early stages of a project.

Process

Method description

A literature study is done to explore the main concepts and find the research gap. This included exploring definitions on circular strategies, calculation methods and material selection. This literature study determined the scope of this research and forms the basis of the empirical research.
In the next phase, three case studies will be conducted. Instead of carrying out the activities corresponding to all three cases simultaneously, a test run is done with one of the cases first. This allows the research design to be tested, any problems to be identified and lessons to be learned to improve the remaining process.
The case studies will mainly serve as a source of data for the subsequent quantitative analysis. Through my internship company, I have access to the data from the cases. Three cases will be selected, and for every case two twin cases of the building's structure will be created. If the original reference project has a concrete structure for example, the twin cases will have timber and steel as their main structural material. Since future life cycles and the functional life span of a building are hard to forecast, scenario's will be developed regarding the building's lifespan and what will occur at the end of its service life.
Material quantities will be collected from the cases to conduct a LCA to calculate the material-related carbon dioxide emissions associated with the different R-strategies and materials for each scenario. This facilitates the comparison between combinations of circular strategies and materials and their carbon footprint. These insights will be used to develop the outcomes of this research: design guidelines and mathematical optimalisation model.

Literature and general practical references

The purpose of the literature review is to provide knowledge around the concept of the circular economy (CE) by using Ellen MacArthur's definition. Moreover, the literature review looks into definitions of circular economy strategies, the method for calculating carbon emissions, importance of material selection and defining lifespan parameters. This forms the basis for the rest of the research.

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)?
   This research relates to the studio "Circular-adaptable real estate reuse to react to societal changes" and the master track Management in the Built Environment. The theme focusses on incorporating circularity and adaptability in the Dutch real estate market. Circularity strategies, such as the principles of reduce, reuse, recycle, and recover, are seen as a way to reduce waste, minimize resource consumption, and mitigate carbon emissions. The Dutch government ambitiously targets to reduce greenhouse gas emissions by 55% by 2030 and achieve carbon neutrality by 2050, which underscores the urgency of reducing carbon emissions. This implicates not only government bodies, but also investors, contractors, consultancy firms and all other types of organizations in the construction sector that aim to reduce carbon emissions and develop sustainable buildings. Circularity has been an important topic throughout the MBE track, and this research adds to that.
2. What is the relevance of your graduation work in the larger social, professional and scientific framework.
   Global warming, primarily driven by carbon dioxide resulting from human activities, presents a serious threat to the planet. And the fact that the construction industry plays a significant role in these carbon emissions is a growing concern. The principle of the circular economy has emerged as a potential solution to mitigate some of these interconnected environmental challenges. But its systematic adoption in the construction industry is rare. Interpretations of circularity strategies vary among stakeholders. Right now the main focus is on recycling. But by researching the differences with other strategies, higher waste hierarchies may be achieved. This research could aid in the discussion between stakeholders, such as the client, suppliers, project managers, contractors and so on. And from a scientific standpoint, quantitative assessments and comparisons of the embodied carbon benefits of circular economy strategies are lacking. This research contributes valuable knowledge to address this gap.