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	Barte van der Zijden
Student number	4856406

Studio		
Name / Theme	Building technology	
Main mentor	Eric van den Ham	Environmental & climate design
Second mentor	Michela Turrin	Computational design and optimization
Argumentation of choice of the studio	My interest in sustainability, computational design, and innovation in the building industry aligns with the objectives of this thesis research. It allows me to explore the integration of digital workflows into sustainable design, to facilitate early-stage decision-making and optimize the reduction of embodied carbon and enhancing circularity. Additionally, collaboration with Arup provides a professional context to validate the developed tool within industry standards.	

Graduation project	
Title of the graduation project	Optimizing sustainable building design: A computational tool for early-stage environmental impact assessment.
Goal	
Location:	Not location-specific
The posed problem,	The building industry is responsible for nearly 40% of global carbon emissions and a significant share of resource depletion, making it a major contributor to climate change. Early-stage design decisions play a critical role in determining a building's long-term environmental impact. However, despite the availability of sustainability metrics, assessment tools, and regulatory frameworks, they are often made without comprehensive sustainability impact insights. Key issues include insufficient real-time integration in the design process, a lack of standardization of metrics and methodologies, and discrepancies between theoretical assessments and real-world outcomes.

	In addition, current assessment tools primarily analyse individual materials rather than considering their integration into material elements and their interconnections, which affect the lifetime and end-of-life scenario of a material. This research aims to address these gaps by developing a parametric computational tool and an element database. Which will allow designers to easily evaluate different designs, materials, and material elements at the early-stage design phase, ensuring that design choices first align with carbon reduction and subsequently with circularity goals.
research questions and	1. How can a computational tool be developed to assess building designs on environmental impact measures? 2. How can sustainability metrics and material databases be integrated into a computational tool for early-stage building assessment? 3. Which metrics and data sources should be incorporated into a computational tool to ensure accurate embodied carbon and circularity assessments in early-stage building design? 4. What limitations exist in current frameworks, tools, and regulations for sustainable design assessment? 5. What validation methods can be used to compare the developed computational tool with established sustainability assessment frameworks?
design assignment in which these result.	Computational design tool with environmental impact assessment.

The objective of this research is to develop a computational design tool that enables architects and engineers to evaluate environmental impacts during early-stage building design. Additionally, the goal is to develop an element database framework to support accurate assessment of the tool and to test and validate it through a case study of a real-life building project in collaboration with Arup.

Process

Method description

2.1. Literature review and theoretical foundation

The research is divided into two primary methodological components: a literature review, to provide background information, and an iterative tool and element database framework development process.

The literature review begins with a general overview of the terms sustainable and circular building design, and identifies key sustainability metrics. This is followed by calculation metrics and methods used for measuring these terms. Then, current frameworks and tools are examined, and their limitations identified. The implementation of material element assessment, and alignment with governmental regulations ’MilieuPrestatie gebouwen’ and ’Paris proof’, is then discussed. Finally, the text elaborates on the current gaps in regulations, assessment tools, and calculations and sets out the aims of the new tool that is being developed.

A broad range of articles was initially gathered and categorized in Excel based on different literature topics, following a thematic classification approach rather than a strictly systematic review process. Literature was sourced primarily from Scopus and Google Scholar, with an emphasis on recent publications due to the fast development in this field of research. Multidisciplinary perspectives were considered wherever relevant, but certain studies were excluded in order to maintain a clear focus on environmental sustainability and building material or element assessment. These exclusions included articles that addressed sustainability from a broad perspective incorporating social and economic dimensions, studies that focused primarily on existing building stock assessment rather than individual buildings, building designs, or materials, articles with a primary emphasis on BIM implementation, and older publications that may not reflect the latest advancements in the field. As the writing process progressed, Mendeley was used to further organize and manage the cited sources.

2.2. Research by design

Following the literature review, this research will use an iterative research through design (RTD) methodology, reflecting the experimental and developmental nature of computational tool development. The adoption of an iterative approach rather than a linear approach is due to the complexity and diversity of metrics and calculation methods for sustainability assessment, together with the development of a parametric tool, which requires continuous refinement based on testing. The iterative process allows for adjustments based on new findings.

2.3. Tool development

The embodied carbon assessment tool will consist of the following components: the embodied carbon calculation methodology, the element database and the circularity assessment framework.

2.3.1. Embodied carbon calculation methodology

The methodology for calculating embodied carbon starts with the principles of Life Cycle Assessment (LCA) and industry calculation methods as a basis for assessing environmental impact. Along the process, improvements can be made to integrate circularity principles. The approach will use material-specific embodied carbon factors obtained from the National Environmental Database (NMD) and other Environmental Product Declarations (EPDs).

2.3.2. Element database framework

The element database framework will be developed using a structured methodology that categorizes materials into distinct building components with for example material properties, connection methods, disassembly potential and lifespan. This will involve data collection from verified environmental sources such as the National Environmental Database (NMD) and Environmental Product Declarations (EPDs). The use of an element database will allow for the selection of a pre-defined library of elements as input to the embodied carbon calculation and the benchmarking of results.

2.3.3. Circularity assessment framework

The circularity assessment framework will establish a structured method for embedding circularity principles within the embodied carbon assessment, rather than treating it as a separate metric. To achieve this it is necessary to establish standardized criteria for assessing material circularity, drawing from industry guidelines and literature findings.

2.3.4. Computational methods

The tool will be developed in Rhino Grasshopper, with potential Python scripting. To start, the calculation methodology and element database will be set up in Excel. The functionalities of the final tool include; embodied carbon calculation, circularity assessment, database integration and material element creation and assessment. The expected outputs will be a normal distribution of expected embodied carbon values and a geometry of the conceptual building design.

2.3.5. Development phases

The development process will be as follows; starting with defining the calculation methods for both embodied carbon and circularity. Integrating these with a parametric model will lead to the concept version of the tool with different materials as variables. Then the material database will be integrated, followed by some manually created building elements. Next a working dynamic element database will be developed and then implemented with the tool. The tool will be refined iteratively, with improvements based on testing and validation and benchmarking.

2.4. Validation, benchmarking and case study

2.4.1. Validation Approach

The validation of intermediate versions of the tool and database will be done through manual calculations and testing, to ensure eventual alignment with industry benchmarks and valid calculations. Eventually, a quantitative approach of validation will be done through a real-world case study, comparing its performance with a combination of proven industry tools and calculation methods. If possible, the final product will be validated through qualitative evaluation (e.g., user feedback). The consistency of the element database will be verified against other existing industry databases.

2.4.2. Benchmarking Strategy

The tool will be compared with current industry tools to ensure it provides value where existing tools fall short. Parallel assesses of case studies will be conducted, using both conventional tools and the new tool. The evaluation will focus on assessing improvements in calculation accuracy and the possibility for real-time and early stage design feedback.

2.5. The case study
A case study will be used to test the tool, ensuring practical applicability. The selection criteria will include relevance to early-stage design, availability of data for embodied carbon assessment and circularity principles. This exact study will be chosen during the coming phases and will apply the tool to an existing or planned building project, compare the results to industry benchmarks, and analyse advantages and limitations.

Literature and general practical references

Note: below the conceptual reference list. More literature has been gathered, these are the sources which are cited in the text right now.

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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 project is strongly related to Building Technology, focusing on computational design optimization, innovation in the built environment, and digital workflows. These areas align with the objectives of our master track. Furthermore, the project connects to the broader MSc AUBS program through its emphasis on integrating sustainability assessments into current design processes and improving the built environment and reducing its negative impact on the environment.

2. What is the relevance of your graduation work in the larger social, professional and scientific framework.

This research addresses a pressing building industry challenge by equipping architects and engineers with a decision-support tool for sustainable design. The tool enhances early-stage decision-making, ensuring that projects align with circular economy principles, carbon reduction targets, and regulatory frameworks. By bridging the gap between academic research and industry practice, this project supports the transition to a low-carbon and circular built environment.