THE IMPLEMENTATION OF RECLAIMED STEEL COMPONENTS IN ARCHITECTURAL DESIGN

A case study with 1930's-1970's campus buildings

PERSONAL INFORMATION

Name: Gabi Janse
Student number: -
Place of residence: -
Telephone number: -
E-mail address: -

STUDIO

Name of studio: Architectural Engineering
Design tutor: Annebregje Snijders
Research tutor: Jos de Krieger

ARGUMENTATIONS FOR CHOICE OF STUDIO

In my opinion, the Architectural Engineering studio offers the potential to dive into a wide array of crucial topics. This includes addressing sustainable, technial and societal challenges. What particularly appeals to me is the studio's encouragement of experimentation and creativity, all while ensuring that the end results are both realistic and practical. I value the integrated approach to research and design that this studio advocates. It's a perspective that I am eager to develop further.

INTRODUCTION

The emphasis of the Architectural Engineering studio is on sustainable solutions for contemporary problems in the built environment. This paper will focus on what the process of reusing steel components could mean for material consumption during redevelopment of the TU Delft campus. The aim is to investigate which steel components from the outdated EWI, TN and GS campus buildings are suitable for reuse to prevent demolition waste. How exactly the component should be evaluated for reuse will be closely examined; the potential for reuse will be determined by investigating influential factors. Ultimately, it will become clear which components are suitable for reuse in a new campus building.

KEYWORDS

Steel | Urban mining | Local harvesting | Component reuse | Demolition waste | Circular flow analysis | Value assessment |

DEFINITIONS

Urban mining

"Urban mining is the activity of recovering materials and energy from anthropogenic stocks, where buildings are one of the most important stocks in the city context, since the construction sector is responsible for high rates of natural resource extraction and consumption," (Bender & Bilotta, 2019).

Steel

"A hard, strong grey or bluish-grey alloy of iron with carbon and usually other elements, used as a structural and fabricating material," (Oxford Languages)

Circular flow analysis

"Aimed at the building sector, a circular flow analysis is the systematic evaluation of material and resource flows within construction and urban development. It aims to optimize resource use, reduce waste, and minimize environmental impact throughout a building's lifecycle," (Arora et al, 2020).

Local Harvesting

"Local harvesting in the built environment refers to sourcing construction materials from nearby or regional sources, reducing transportation emissions and supporting the local economy," (Agudelo-Vera et al, 2012).

Component Reuse

"Component reuse is the practice of salvaging and repurposing specific building elements from existing structures in new construction or renovations, aiming to reduce waste and promote sustainability," (Alaka et al, 2020).

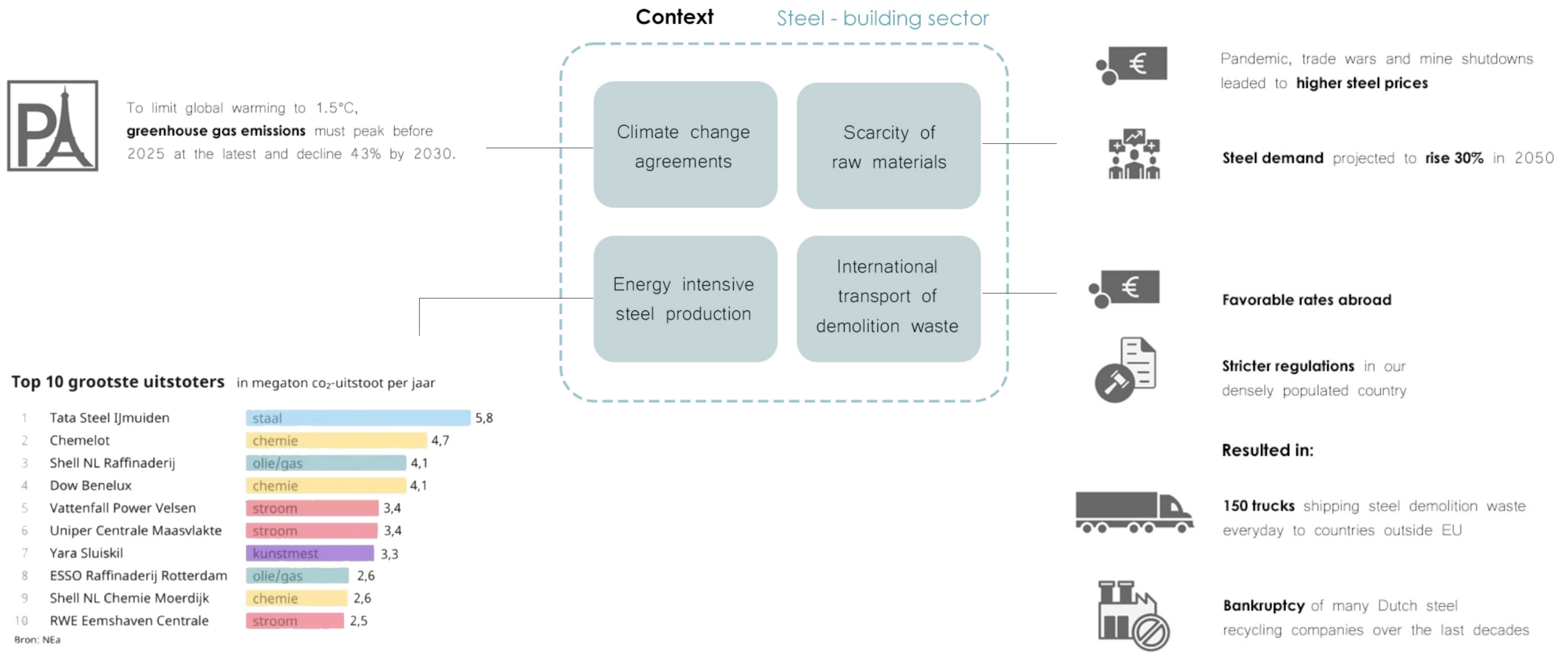
Value assessment

"Value assessment, in the context of the built environment, refers to the systematic evaluation of the worth, benefit, or importance of a particular element, component, material, or aspect within a construction project or urban development. It involves considering various factors such as cost, performance, sustainability, aesthetics, and functional attributes to determine the overall value that a specific element brings to a project,"

Context Steel - building sector

Climate reports, such as the 2015 Paris Agreement (United Nations, 2015) and the more recent “AR6 Climate Change 2023” report from the Intergovernmental Panel on Climate Change (IPCC, 2023), underscore the urgent need for change. These reports emphasize the necessity to limit global warming to 1.5°C, with greenhouse gas emissions peaking no later than 2025 and declining by 43% by 2030. The construction sector, a significant consumer of raw materials, accounts for 40% of national CO2 emissions. Among the contributors to this environmental impact, steel production stands out as one of the most energy-intensive and CO2-emitting industries globally. For example, Tata Steel IJmuiden, a major steel producer, is the largest polluter in the Netherlands (see figure 1). Beyond its effects on climate, steel production also poses health risks; in the area of IJmuiden, the risk of lung cancer is 5% higher than in other parts of the Netherlands (Frisse Wind NU!, 2023).

In addition to emissions, there is a growing scarcity of raw materials. The rising demand for new steel production exerts pressure on the natural resources iron ore and coal. Projections indicate a 30% increase in steel demand by 2050. Factors like the 2020 pandemic, trade wars, and mine closures, have increased steel prices (Equify Financial, 2023). Moreover, the steel demolition waste trade operates on a global scale. Each day, 150 trucks cross the Dutch borders to transport demolition waste abroad, due to favorable rates and stringent regulations in our densely populated country. This dynamic led to the closure of numerous Dutch steel recycling companies (Schampers, 2020). Furthermore, reusing building components results in significantly lower environmental impacts compared to using recycled materials. For instance, new steel structures consisting of around 60% recycled content, has still an environmental impact that is 25 times higher than reusing the equivalent reclaimed steel content (Geyer et al., 2012).



Top 10 grootste uitstoters Nederland (Frisse Wind NU!, 2023)

Fig. 1

Delft University of Technology understands the importance of the sustainability transition, as outlined in its Sustainable Vision 2022. The university wants to be carbon neutral by 2030. Sustainability is also a prominent aspect in the urban development plans for TU Delft's South campus (Posad Maxwan & TU Delft Campus Real Estate, 2019). However, sustainable construction can be costly. Implementing initiatives like sustainable energy generation, nature-inclusive zones, green roofs, and water buffers requires substantial investment, potentially diverting resources from other developmental priorities. The local harvesting and reuse of steel components in new buildings offer a potential solution, providing economic benefits, contributing to the sustainable character of the campus and serving to raise awareness about the possibilities of reuse among campus users.

Beyond the sustainability transition, TU Delft faces other challenges. The university offers limited space for initiatives, associations, and workshops, with a program focused on academic activities during regular hours. Smaller associations struggle to find accommodations in the city due to negative perceptions. While not legally responsible for student-related issues, TU Delft acknowledges a sense of responsibility (Delta, 2022). However, a lack of facilities for social interaction on campus persists, potentially alienating students from student life. Many students living independently express difficulty in forming connections. National surveys indicate high rates of anxiety, depression, and loneliness (Van der Veldt, 2022). Thus, TU Delft must establish more spaces to encourage social interaction.

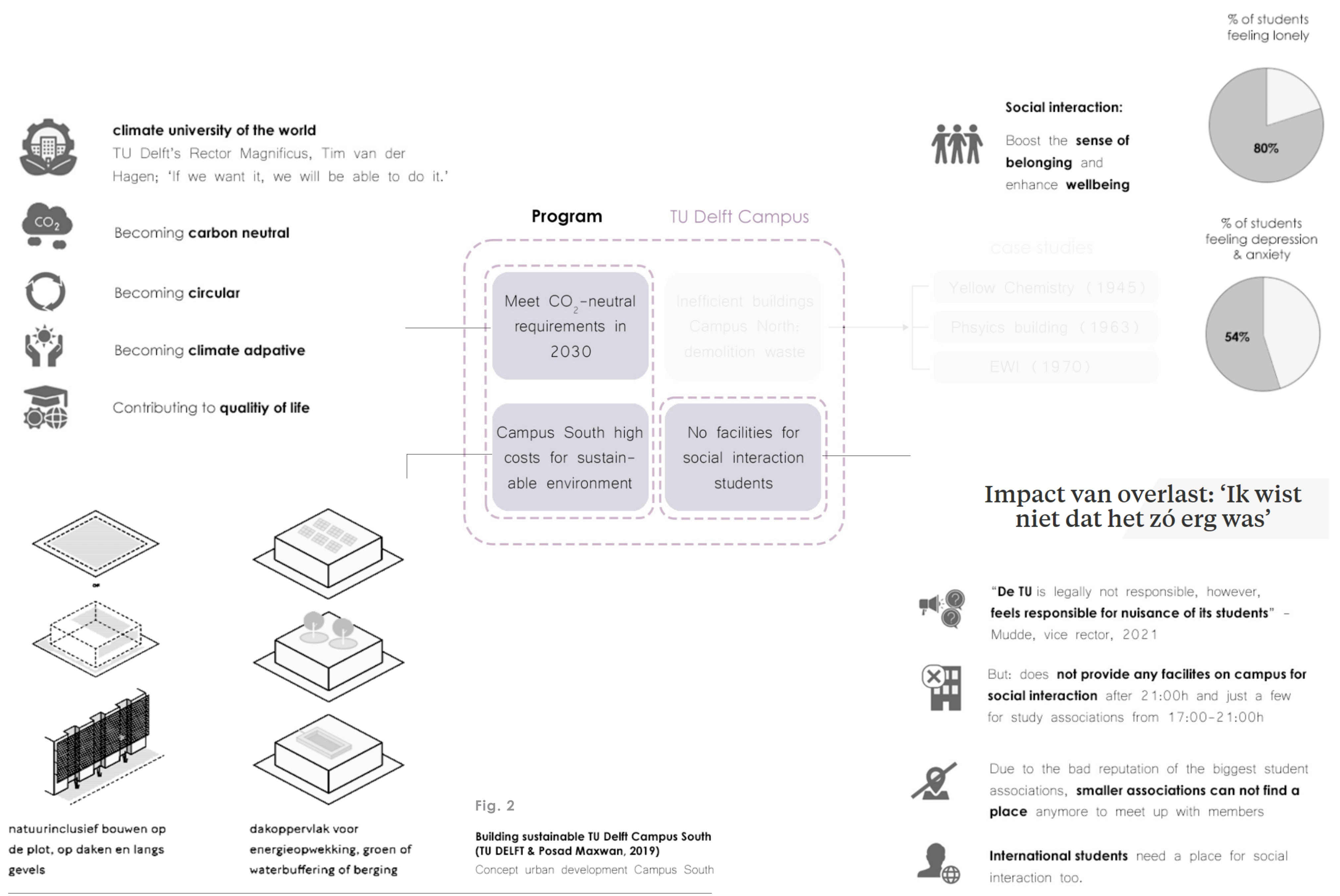
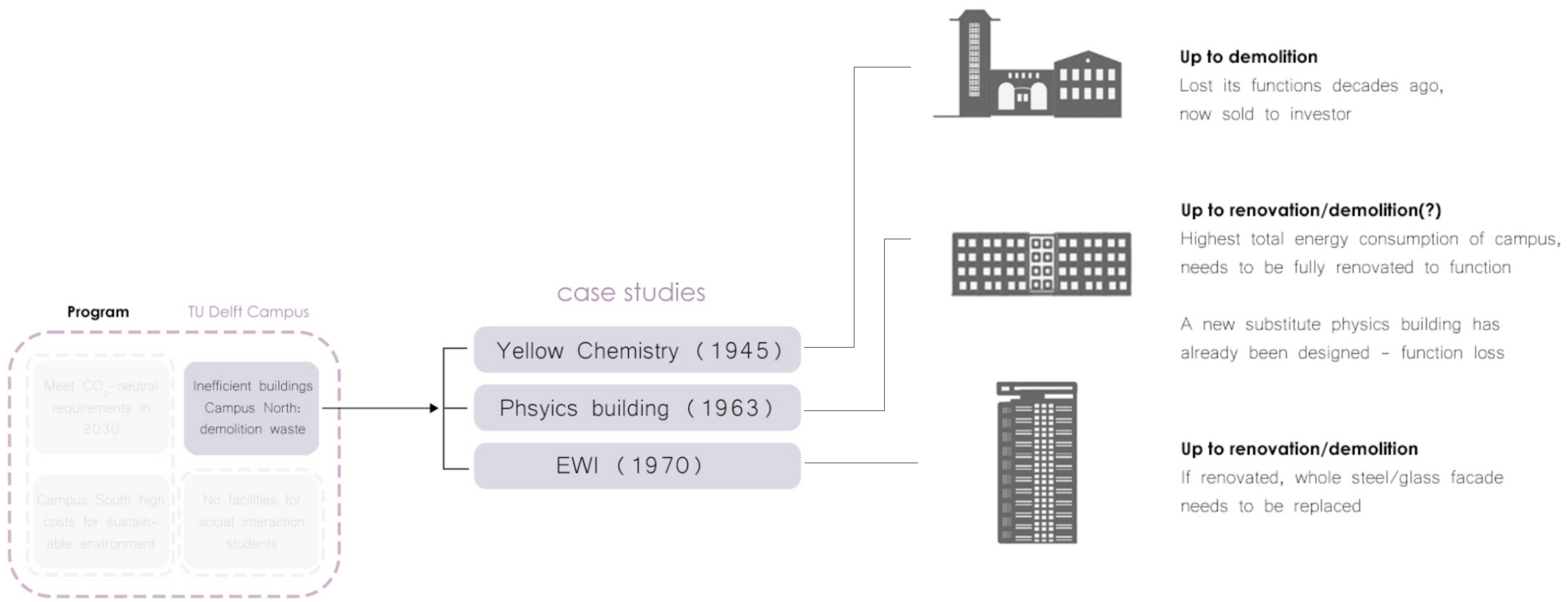


Fig. 2

Building sustainable TU Delft Campus South (TU DELFT & Posad Maxwan, 2019)
Concept urban development Campus South

Several buildings on the TU Delft campus fall short of current sustainability standards, mainly due to outdated construction methods. This inefficiency has led to a need for renovation or demolition, driven by functional decline and economic considerations. For instance, the Faculty of Electrical Engineering, Mathematics and Computer Science (EEMCS) has one of the highest energy consumptions on campus and has been a topic of debate regarding its fate. The Yellow Chemistry (GS) building faces sale to an investor due to its current vacancy and loss of function. The decision of whether to demolish or renovate it, rests with the new owner. The Applied Physics (TN) building ranks lowest in energy performance and requires a comprehensive renovation for improved sustainability (see figure 4) (Blom & Van den Dobbelsteen, 2019). Opting for demolition or renovation of these buildings has the potential to yield reusable steel components. Without a systematic approach to reuse, these components, despite their potential, may likely end up as demolition waste, contributing to larger-scale environmental challenges.

In the Sustainable Vision the goals for new buildings are established. New buildings should consist of 10% of materials harvested from to be renovated or to be demolished campus buildings. Of these to be renovated/demolished campus projects, 80% of the materials that wil become available should be reused in new buildings (figure 3) (Gameren & Van den Dobbelsteen, 2022). To be able to achieve these goals, new reuse methods need to be sorted out. It is not possible to reach this goal only by reusing construction materials, so investigating reusing other components is very important.

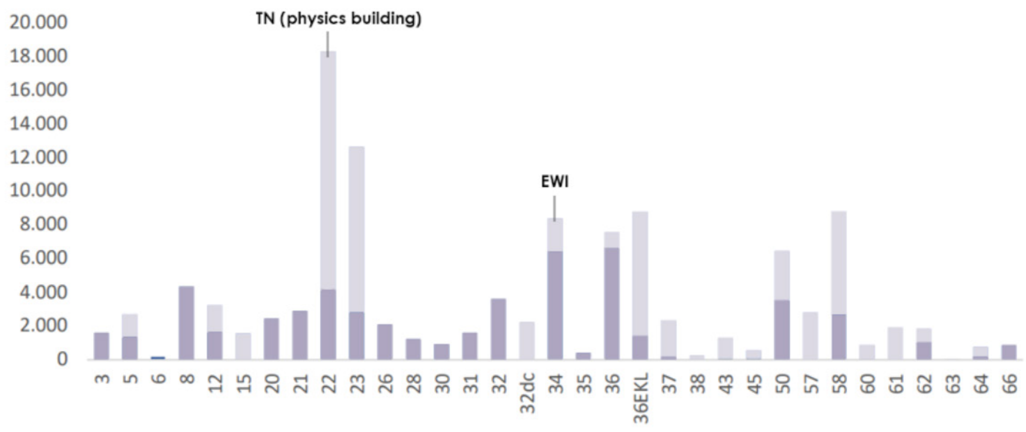


Circulair		Doel
Materiaalgebruik	X% van het materiaal is geoogst uit bestaande gebouwen	10% (Hangt van aanbod af)
Materiaalgebruik	X% van de vrijgekomen materialen vanuit TU Delft Campus worden hergebruikt in het gebouw	80%
Materiaalgebruik	X% van de gebruikte materialen in het gebouw zijn circulair (PM circulair -> definitie nodig)	80%
Materiaal registratie	X% van het gebruikte materialen/producten worden geregistreerd (e.g. materialenpaspoort, centrale database)	100%

Goals new building, circularity TU Delft (Sustainable vision, 2022)

Part of Appendix C of the Sustainable vision TU Delft

Fig. 3



The total energy use of the TU Delft campus buildings monitored in 2018 (Sustainable vision, 2022)

Dark colour indicates educational spaces and offices; light are research functions and labs

Fig. 4

Thematic focus Reclaimed steel components

The construction sector faces obstacles in effectively utilizing secondary materials for building. Barriers to widespread adoption of urban mining include logistics challenges, uncertainties in demand for reused materials, and concerns about performance. The critical issue is the lack of comprehensive information on the availability and potential value of harvestable materials. Notably, progress has been made with the concept of donor steel, exemplified by NTA 8713 released by NEN Connect last summer, aiming to reduce the environmental impact of steel structures. This standard outlines procedures to determine the geometric and material properties of steel profiles for reuse.

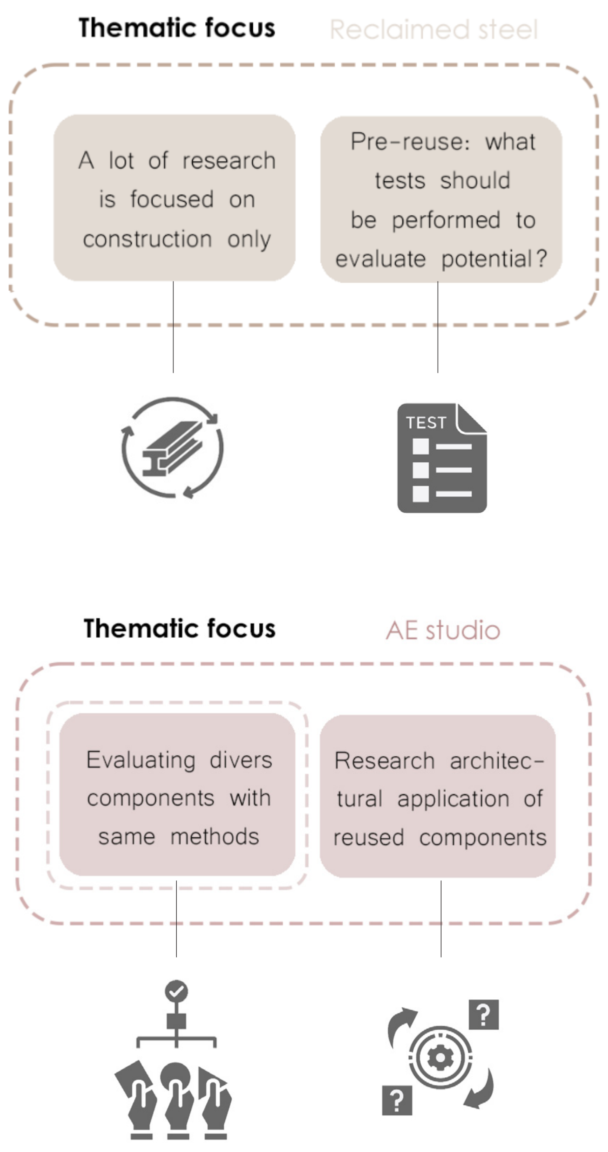
While existing studies mainly focus on primary structural steel, construction methods from the last century reveal diverse applications of steel in buildings, such as reinforcing steel, secondary construction, facade construction, cladding, pipes, windows, and doors. Studies by Pottgieser (Ayon & Pottgieser, 2019) and Geboes (2020) address the reuse of windows with steel frames, while Andersen, Ravn, and Ryberg (2022) offer a method to assess the better reuse of steel cladding compared to recycling. However, literary sources on the reuse of these components are fewer compared to primary structural steel. A clear approach to various steel components' reuse could enhance current knowledge.

Investigations to the reuse potential of components examine the factors that are influencing these potential, like the research of Dronkers (2020). However, in some research to the evaluation potential, the practical testing methods of components are not included. Research like Fujita en Kuki (2016) shows that differences between destructive and non-destructive tests are of great influence on reuse potential and should be included. Another important factor is the architectural application possibilities. If a component has technical-functional application options, rather than one with only aesthetic options, its has more potential to be reused.

Thematic focus AE Studio

In past studio years, students researched methods to assess and harvest components from old buildings for reuse in new constructions. They developed schemes for evaluating components, considering factors like dismantling costs, testing, transport, energy emissions (reuse vs. new production), and lifespan. The schemes offer a broad view of factors influencing reuse, outlining what to evaluate (category, components), although specific evaluation methods for each element are not always specified.

This research will build on the framework established in the previous studies conducted in this studio. However, it will distinguish itself by delving deeper into the analysis of specific building components. The primary focus will be on components predominantly or entirely made of a specific material, namely steel. This targeted approach will enable a more precise examination and understanding of the factors and circumstances influencing the reuse of these components. Perhaps it may provide more focused insights and practical, efficient solutions.



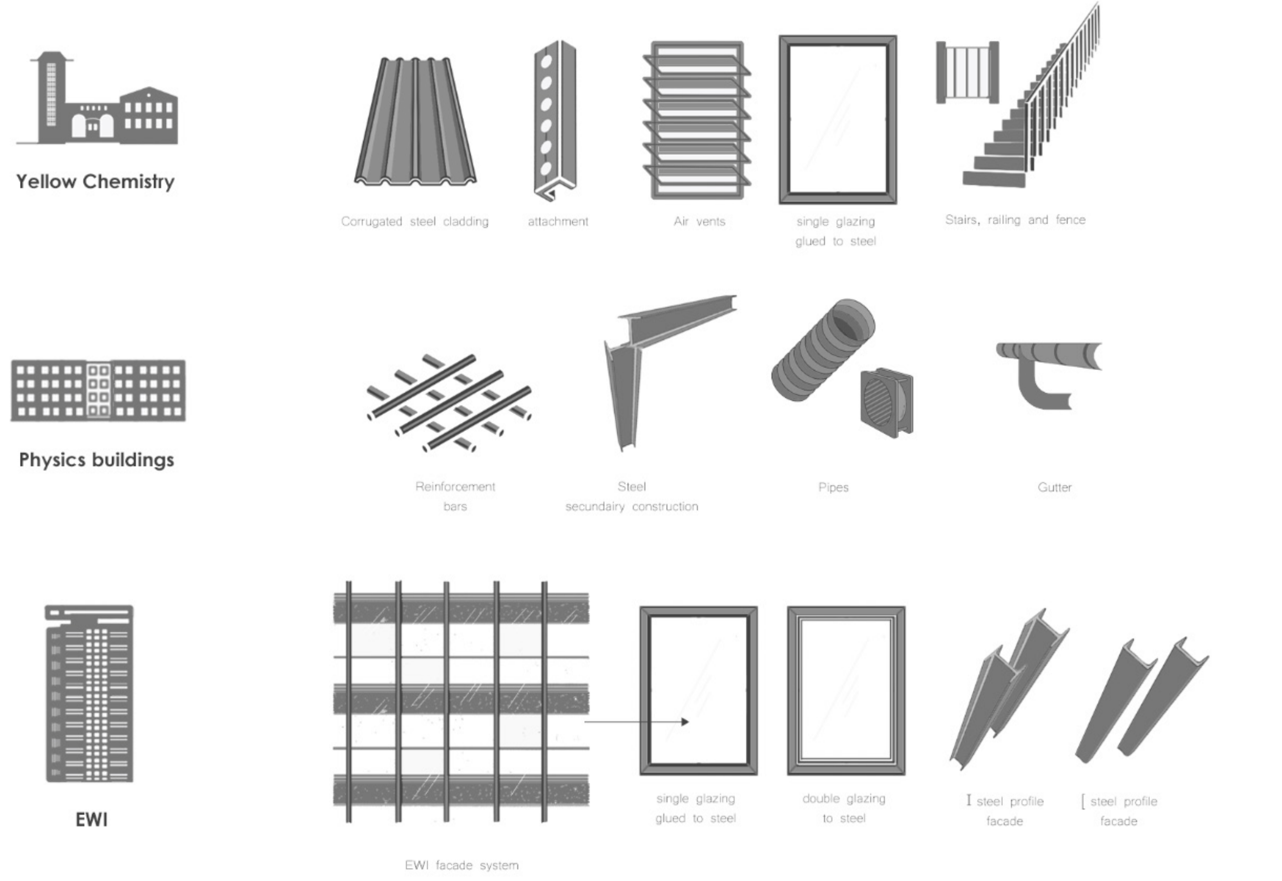


Fig. 5

RESEARCH ⊱ DESIGN

The paper focuses on what the process of reusing steel components could mean for material consumption in the context of campus redevelopment. The aim is to investigate which steel components from the outdated EWI, TN and GS campus buildings are suitable for reuse in order to prevent demolition waste. How the component should be evaluated for reuse will be closely examined; the potential for reuse will be determined by investigating influential factors. Here, not only the influences on the component are determined, but also its measuring method is taken into account in the potential. Possibilities for application after harvesting are also explored.

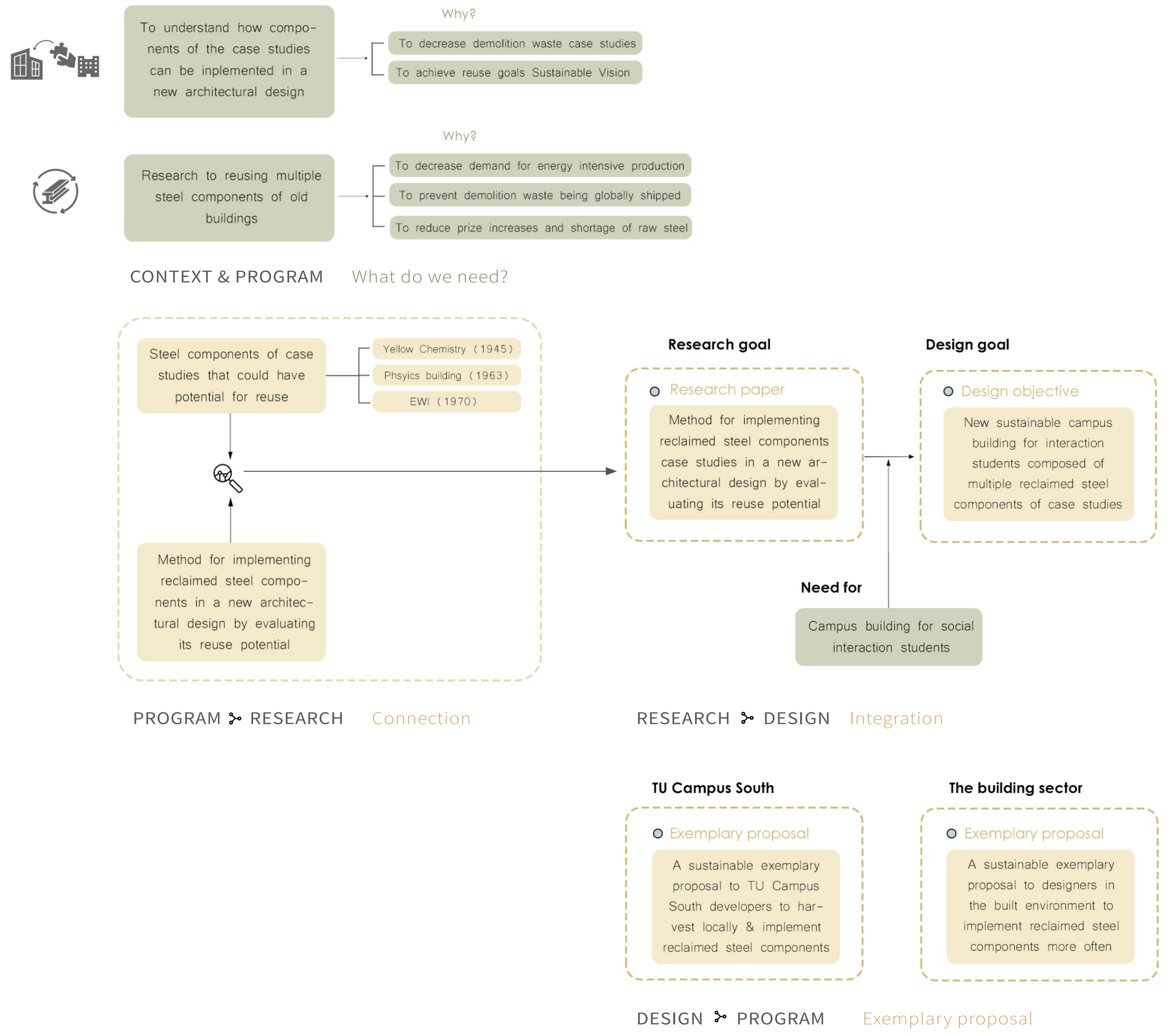
By determining whether the component has enough potential to be reused, it can be decided whether or not to use it in a new project. The goal of the final project is to apply as many useful components as possible in a new project. The building's function will be to improve social interaction between students, due to the absence of this facility on campus. A program of requirements will be drawn up for this in the coming period. The final project will be a sustainable building constructed as much as possible from reused steel components from the case study buildings. The diagram on the right page shows an overview of connections between context, program, research and design.

RELEVANCE

Research on the reuse of steel building components, beyond structural elements, remains underexplored. This research has the potential to contribute to the attainment of the new sustainability objectives outlined in the TU Delft's sustainable vision for new buildings. Given that a substantial portion (80%) of campus buildings will undergo renovation or demolition, and considering that the selected case study buildings contain numerous steel components, the development of an assessment method for the reuse potential of these elements could be highly valuable. The findings of this research could serve as a exemplary proposal for project developers at TU Delft Campus, aiding in the achievement of the targeted 10% reuse rate. On a broader scale, establishing a clear protocol for handling these components can inspire designers to harvest locally & implement reclaimed steel components, effectively reducing the volume of steel demolition waste.

OVERAL DESIGN QUESTION

“ How can **reclaimed steel components** from unsustainable TU Delft campus buildings dating from 1930-1970's **be implemented in the architectural design** of a **new** circular campus **building?** ”



RESEARCH QUESTION

“How can **reclaimed steel components** from **campus buildings** dating from 1930-1970's **be implemented** in **architectural design**?”

SUB-QUESTIONS

Chapter 1: **Reuse, recycling and demolition**

Why is it important to reuse steel components?

Chapter 2: **Inventory of steel components**

Which components of the case studies will be investigated and why?

Chapter 3: **Factors affecting usability of reclaimed steel components**

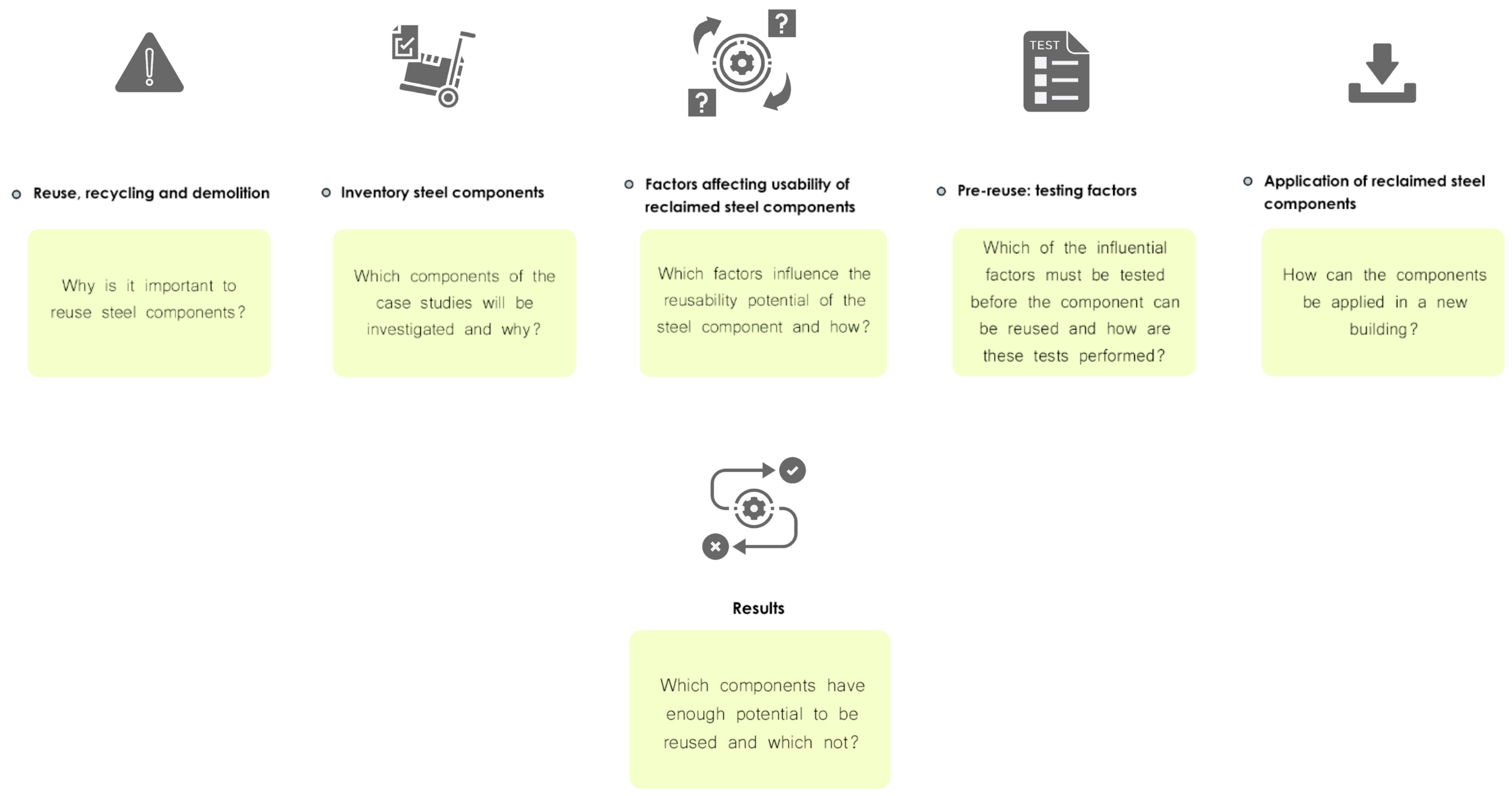
Which factors influence the reusability potential of the steel component and how?

Chapter 4: **Pre-reuse: testing factors**

Wich of the influential factors must be tested before the component can be reused and how are these tests performed?

Chapter 5: **Application of reclaimed steel components**

How can the reclaimed steel components be applied in a building?



METHODOLOGY

To answer the research/sub questions, first a literature study will be done, while looking for reference projects consisting of reclaimed steel components. Later on in the research process, interviews will be conducted, for information about components where the literature is lacking. In figure 6 it is noticeable that the literature study, reference analysis and interviews are overarching methodologies. It will be used in many stages in the design process for different subjects and needed for both the case study analysis and circular flow analysis. The case study analysis consists of a site study, material analysis, archive drawing analysis and only if the time permits, executing one or a few non-destructive tests myself to experience putting theory into practice. After the case study analysis, while making use of literature study, interviews and references, components will be chosen to test by executing a circular flow analysis. For the definition of circular flow analysis, see page 3. The circular flow analysis consist of making an inventory of components, analyze factors that influence the components in the inventory, analyze methods evaluating performances of components and application possibilities when reusing component. The circular flow analysis will be made visual into schemes, with the assistance of decision charts and balance sheets. The feasibility analysis shows the end result: if the component has enough reuse potential and is suitable for being applicated in a new project.

From research to final project, three phases can be distinguished: investigation phase, experimentation phase and integration phase (see figure 7). The investigation phase is the research. The results of the research will be a list of components that have enough reuse potential to be applicated in a new project. The experimentation phase, will be making compilations of ways to applicate these components in a new building. Technical drawings will be made and for complex applications, digital and physical models will be made to examine the application. Site investigation, program of requirements, and implementation of components into design, influence each other. Making schemes of how these influence the possibilities, could help understand the design choices. A concept of the design project should be made, integrating the best combinations of site, program and application of compilations of experimentation phase. The program of requirements for the final project should be clear in the experimentation phase. The goals for how many reusd components should be set, to determine when to be satisfied with the end result in the integration phase.

RESEARCH METHODOLOGIES

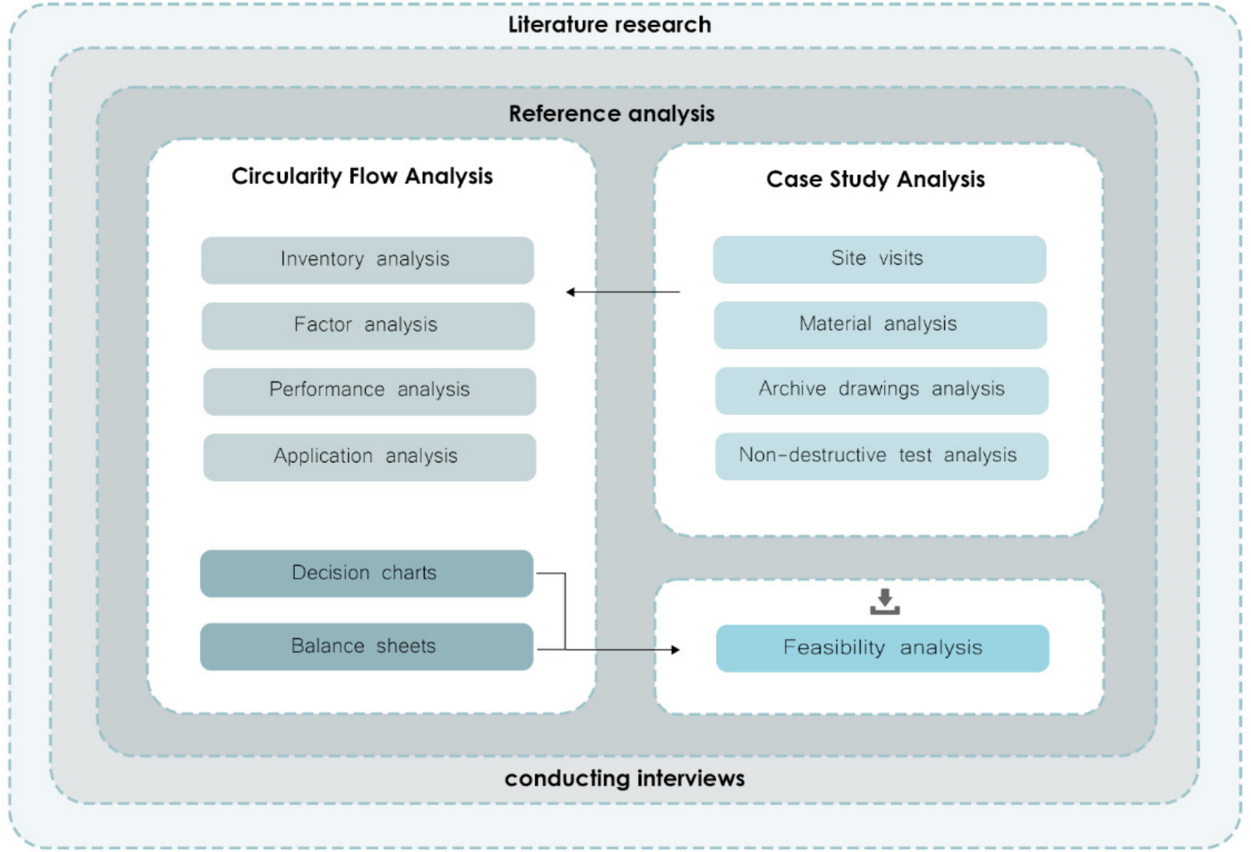


Fig. 6

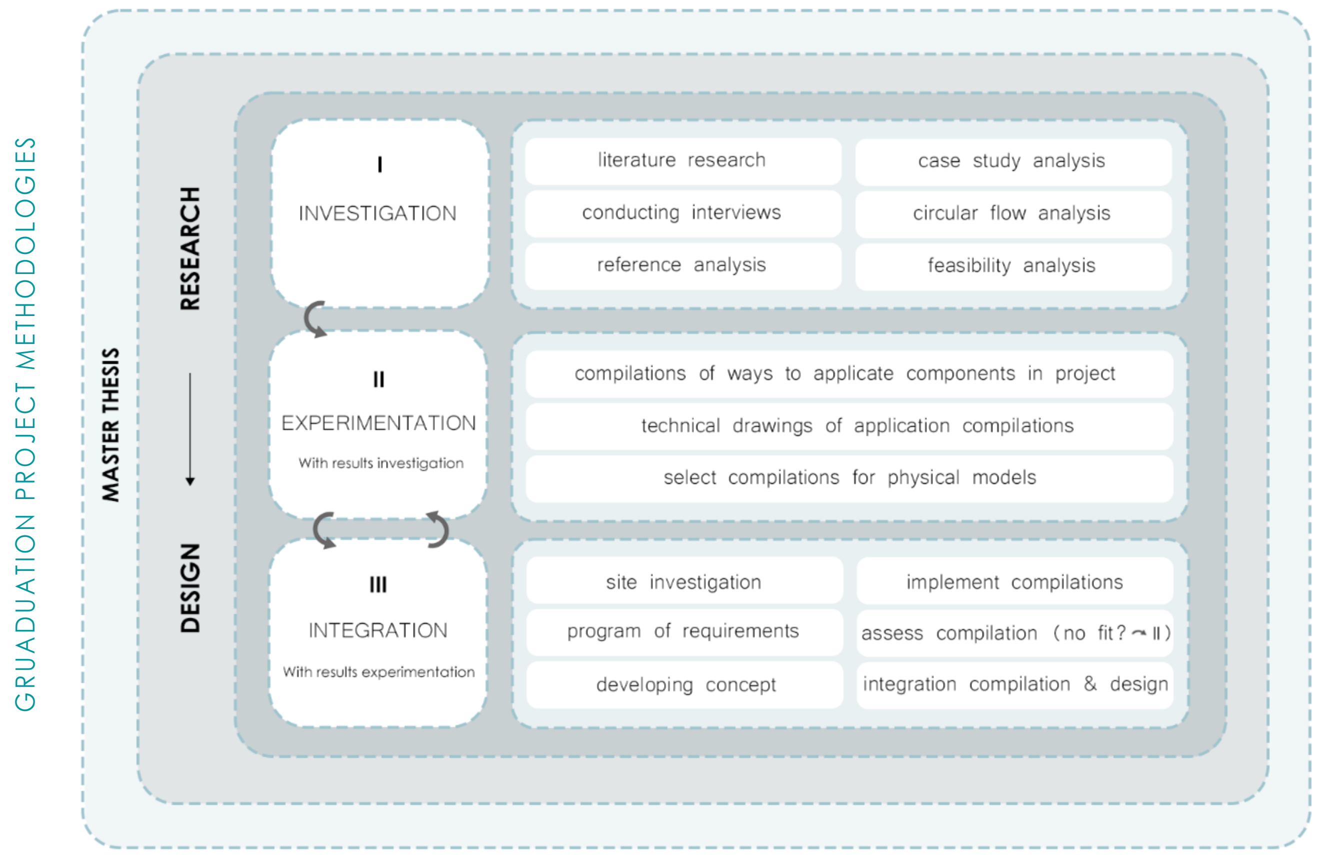


Fig. 7

CHALLENGES

The advantage of investigations from other AE students is that many diverse components of different materials have been researched for reuse: it offers a lot of design flexibility. Specifying multiple components of the same material requires creative thinking to ensure the design remains unique and innovative, rather than resembling a standardized structure like the Eiffel Tower.

Some components may not have extensive information available in existing literature, asking for in-depth interviews and primary research. Finding and scheduling meetings with the right experts for interviews can be a logistical challenge. Interviews may reveal that some unexamined steel components cannot be reused, potentially reducing the diversity of available design resources.

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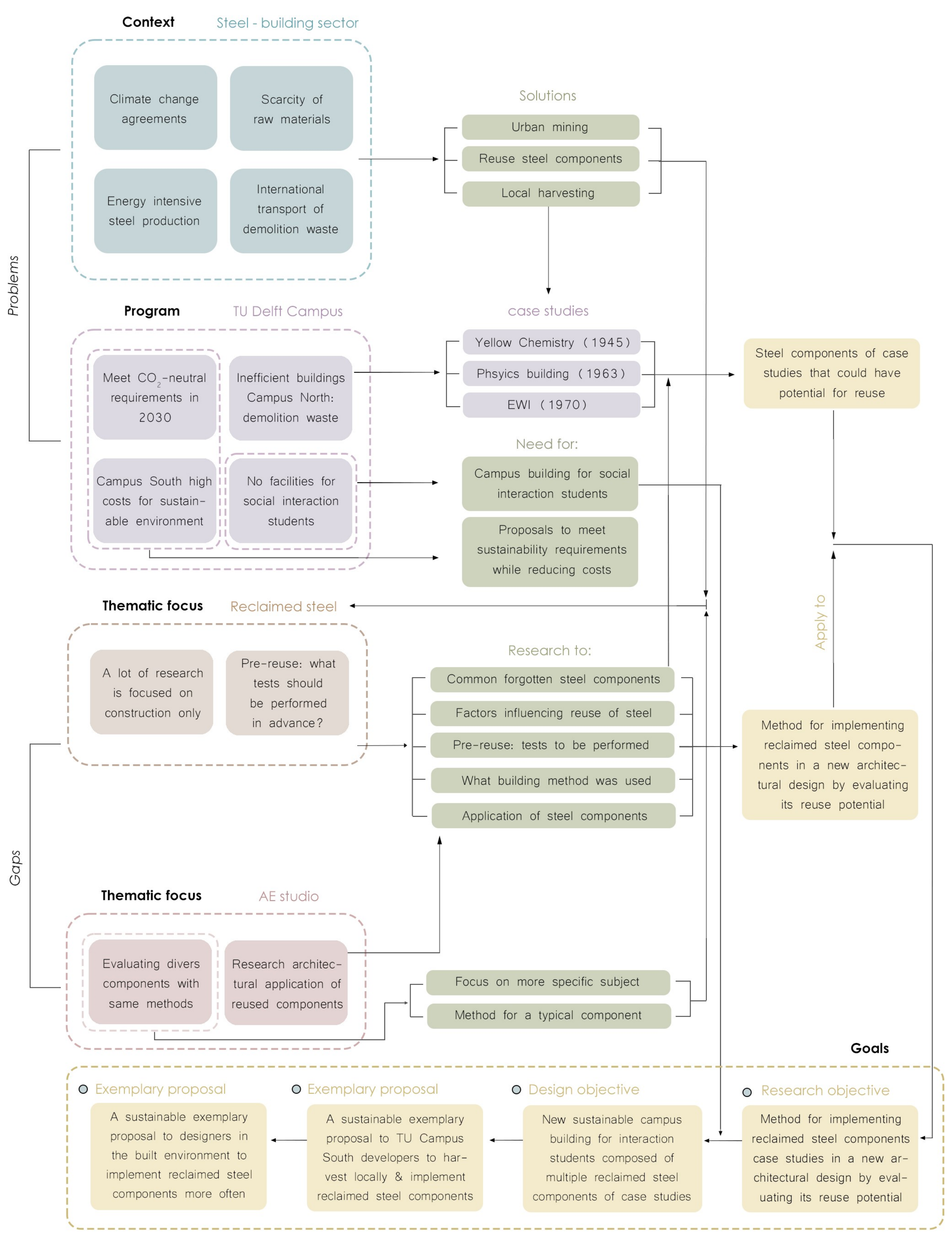
RESEARCH DIAGRAM



PROGRAM PLANNING

WHAT TO EXPLAIN/INVESTIGATE		WHAT TO DO TO ARCHIEVE THIS	SEQUENCE WHEN
Introduction Explanation context, program, thematic focus and methodology	How?	Literature research problem statements and thematic focus	Phase A
		Explanation methodolgy and case study	Phase A
Reuse, recycling and demolition **Why** is it important to reuse steel components?	Why?	Literature research importance of reuse steel components	Phase A
		Reference study project indicating importance of reuse steel	Phase A
Inventory steel components **Which** components of the case studies will be investigated and **why?**	Which?	Site visits case studies, document pictures	Phase B
		Analyse archive drawings	Phase B
		Component analysis (material) qualities	Phase B
	Why?	Literature research building method of component	Phase B
		Literature research/reference analysis to understand environmental performance or advantages of reuse of component	Phase B
		Reference study to find buildings with similar components	Phase B
Factors affecting usability of reclaimed steel components **Which** factors influence the reusability potential of the steel component and **how?**	Which?	Literature research to factors influencing a component in general	Phase D
		Literature research to factors influencing the specific component	Phase D
		Interviews to find factors that influence specific component	Phase C
	How?	Literature research to find out how factors influence the specific component	Phase D
		Interviews to find out how factors influence specific component	Phase C
Pre-reuse: testing factors Which of the influential factors must be tested before the component can be reused and **how** are these tests performed?	How?	Literature research to methods how to test the factor that influences the component	Phase D
		Interviews to methods how to test the factor that influences the component	Phase C
Application of reclaimed steel components **How** can the components be applied in a new building?	How?	Reference analysis of projects with similar solution (details?)	Phase E
		Interview with building technology tutor	Phase F
Results With help of decision charts to evaluate potential, is component applicable or not? If yes, show endresult flow diagram	How?	Make final decision charts to evaluate potential of components	Phase G
		Enough potential? Make flow diagram of whole process of reuse of component	Phase G
		Conclude if reuse of component is reusable or not	Phase G

PROGRAM PLANNING

	P1										P2													P3
Dates	4-10 sep	11-17 sep	18-24 sep	25 -1 okt	2-8 okt	9-15 okt	16-22 okt	23-29 okt	30-5 nov	6-12 nove	13-19 nov	20-26 nov	27-3 dec	4-10 dec	11-17 dec	18-24 dec	25-31 dec	1-7 jan	8-14 jan	15-21 jan	22-28 jan	29-4 feb	5-11 feb	12-18 feb
Week	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	HOLIDAY	HOLIDAY	Week 7	Week 8	Week 9	Week 10	HOLIDAY	Week 1
Deadlines										Presentation + Delivery final research plan P1						Concept research plan -> Jos					Final research plan P2	Presentation P2		
Phases	Phase A	—	—	—	—	—	—	—	—	—	—													
							Phase B	—	—	—	—	—	—											
											Phase C	—	—	—	—									
													Phase D	—	—	—								
																	Phase E	—	—					
																			Phase F					
																				Phase G	—			
Structure											Introduction + Chapter 1 Reuse, recycling and demolition	Fin. Chapter 1/Chapter 2 Inventory steel components	Chapter 2	Chapter 3 Factors affecting usability of reclaimed steel components	Chapter 3/4	Chapter 4 Pre-reuse: testing factors			Chapter 5 Application of reclaimed steel components	Results/ Conclusion	Presentation preparation	Refine-time		Start experimentation Experimentation phase