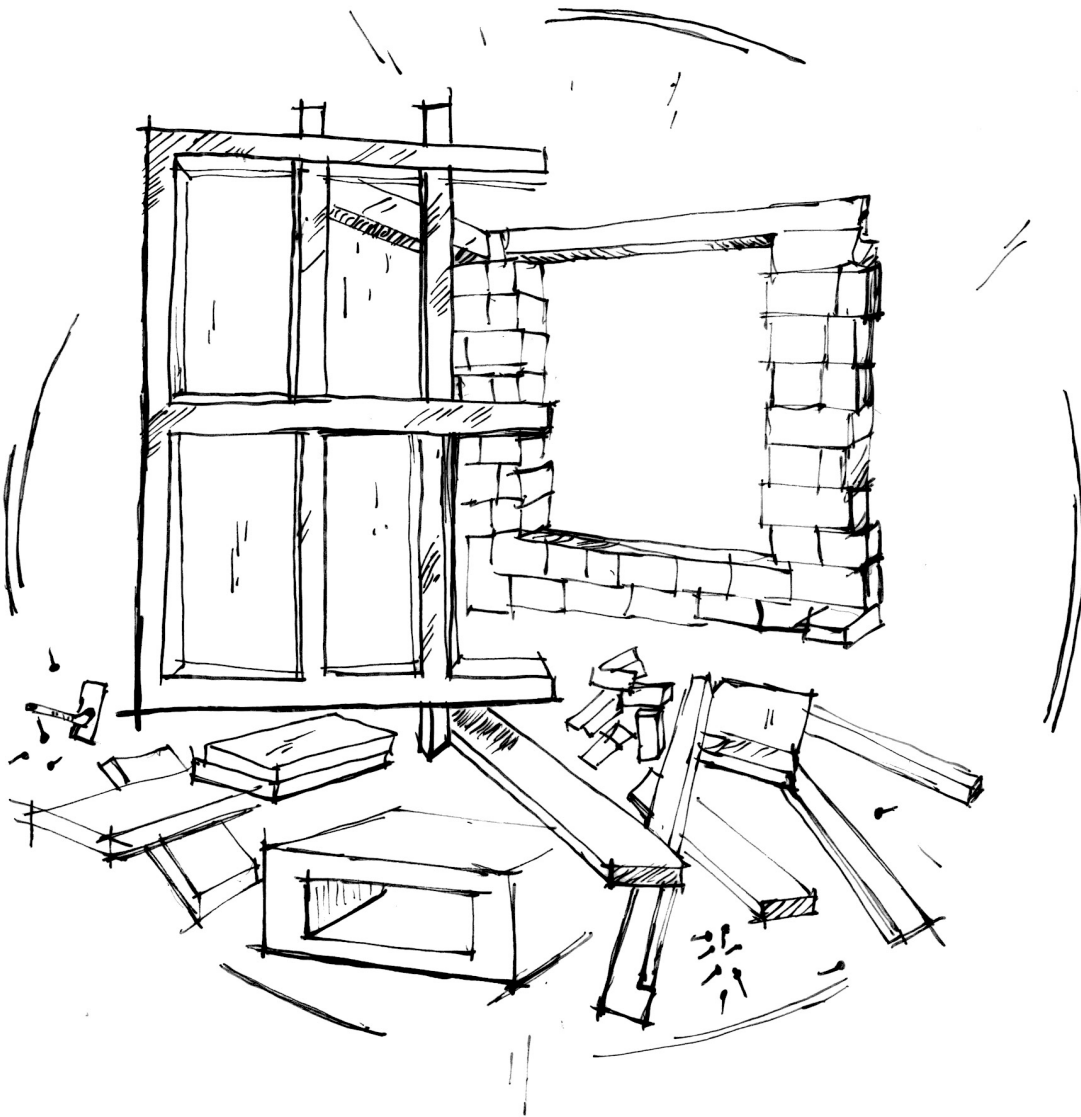


# Filling the gaps in the city

*A circular approach to design with  
optimal material reuse in architecture*



Hein van der Helm  
studentnumber: 4875060  
19-04-2024

Technische Universiteit Delft  
Faculty of Architecture, Urbanism &  
Building Sciences  
MSc Architecture

Name of studio: Architectural Engineering  
Design tutor: Yannick Warmerdam  
Research tutor: Jos de Krieger

Research Plan

### **Personal information**

Hein van der Helm

studentnumber: 4875060

### **Studio**

Name of studio: Architectural Engineering

Design tutor: Yannick Warmerdam

Research tutor: Jos de Krieger

### **Argumentations of choice of the studio:**

In my opinion, Architectural Engineering lies the connection between technology and architecture, which ultimately are interwoven in the current world. To explore the relationship between technology and innovation on the hand and to bring that into practice in architecture on the other hand is the challenge I would like to take on in the studio Architectural Engineering. This studio enables a hands on approach in a field of experts, where architecture and innovative solutions rely close on the practice. Therefore I am motivated to have a hands on approach in an inspirational environment, instead of producing beautiful visions I strive for making a difference.

# Research Plan

## **Key words**

Reuse, Circular Design, Building Materials, Architecture

## **I. General problem statement**

Currently there is a lack of space in cities for new buildings, moreover the existing space is becoming increasingly scarce in city centres like Rotterdam, according to head of Urban Planning for the municipality of Rotterdam (Maas et al., 2021). A second evolution is that city centres are densified and still new buildings arise, within or on the outskirts of cities. This trend often involves the demolition of existing structures, to make way for larger buildings constructed with new materials (Ter Steege et al, 2023). This demolition goes not only with a loss of materials, but also with the loss of a piece of identity with it. However, overlooked or forgotten spaces offer potential solutions for urban densification within existing city boundaries.

The demolition of buildings comes with waste. According to the European Commission (2020) more than a third of all waste generated in the European Union (EU) comes from construction and demolition waste (CDW). A diverse range of materials is getting lost, including concrete, wood, glass, bricks, metals and plastic (European Commission, 2020). In this traditional linear economy where materials are extracted, utilized and disposed the industry contributes to environmental concerns. According to research 40% of all

materials are used in the construction industry, where at the same time the industry is also responsible for 40% of all waste. Besides, the emissions from buildings are largely influenced by how we build and design. The predominant building materials, such as concrete and metals, have a high CO<sub>2</sub> footprint (Malabi Eberhardt et al, 2020). Despite efforts to reuse and recycle materials, the imbalance between new construction and demolition results in the production of new materials. Even though materials and building components are available, the habit of reusing and designing with those elements is not visible enough in the building industry (Malabi Eberhardt et al, 2020). In contrast to this traditional linear economy, a circular economy strives to close the loop by minimizing waste and promoting the reuse of materials.

The terminology around circularity remains ambiguous in the construction sector. Different definitions arise and different users use it with a different goal. This paper uses the definition for circularity described by the Ellen MacArthur Foundation (n.d.):

*‘The circular economy is a system where materials never become waste and nature is regenerated. Products and materials are kept in circulation through processes like maintenance, reuse, refurbishment, remanufacture, recycling and composting.’*

The principles of a circular economy have been introduced in the construction industry, through projects that reuse constructions or facilitate the future reuse of building elements or integrate renewable materials. While such circular solutions gain in popularity, the reuse of building materials remains a specialized practice in architecture (Kozminska, 2019). This is due to a different design process that is involved with reusing existing materials or enabling future reuse of building elements, which differs from the conventional design approaches. Currently, we face a time with pioneering architects that strive for a circular architecture using mainly reused materials. Multiple strategies arise facing different difficulties: uncertainties about the materials, different design process and lack of experience (Heesbeen et al, 2021).

To conclude, a different perspective on the reuse of materials in architecture is needed in order to stimulate the shift towards a circular building industry. Designers have to rethink the way we use space and materials. The Ellen MacArthur Foundation (2020) describes that design decisions determine how the environment looks like and how materials are used, making them pivotal in shaping the built environment. The task for the new generation architects is to lower the CO<sub>2</sub> emissions and waste in the building industry and focus on reuse in architecture. Therefore, adopting new design principles centred around 'reuse of materials' to contribute to a circular future. This graduation projects investigates the role of the architect incorporating reuse of materials, where form follows material.

## **II. Overall Design Objective**

This project aims to explore the feasibility and implications of reuse in architecture and how this affects the design process. The goal is to understand how reuse in architecture can be optimized in the design in order to build more circular and limit the amount of CO<sub>2</sub> a building emits. To reduce and reuse the amount of waste and CO<sub>2</sub> in the building industry, a prominent and vital step lies in the design stage. For the long term we also have to rethink other aspects, since reducing waste is one aspect of this circular economy. However, this graduation project will mainly focus on the aspect of reuse and material driven design and how this transforms the design process.

The theoretical research focuses on exploring design principles and factors that influence the potential for material reuse in architecture. The requirements and design principles identified in this research will be applied to the design project centered on the 'residual' spaces in Rotterdam. The design part will illustrate how these principles are used in a different design process (see fig. 2) and demonstrate how architects can reuse existing materials into new buildings.

The aim of the design project, besides applying the design principles focused on reuse, is to transform the existing residual spaces in the inner city centre of Rotterdam. A defined research into the residual spaces withing

the city centre of Rotterdam will be worked out in a categorization and map of existing urban spaces that are forgotten and/or have potential. A design for multifunctional buildings for at least two of these residual spaces in Rotterdam will showcase the use of reused materials and how architects can design for reuse in the future. A combination between housing and public programm will be combined to create a multifunctional and mixed use building.

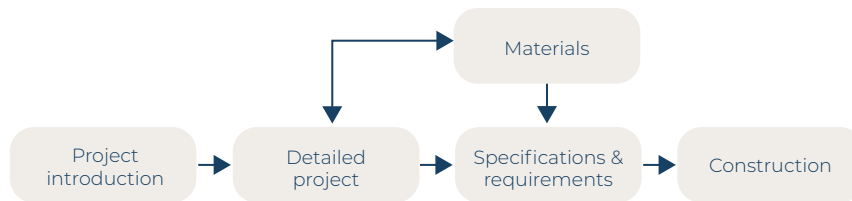


Fig. 1. Current design & construction process (simplified)

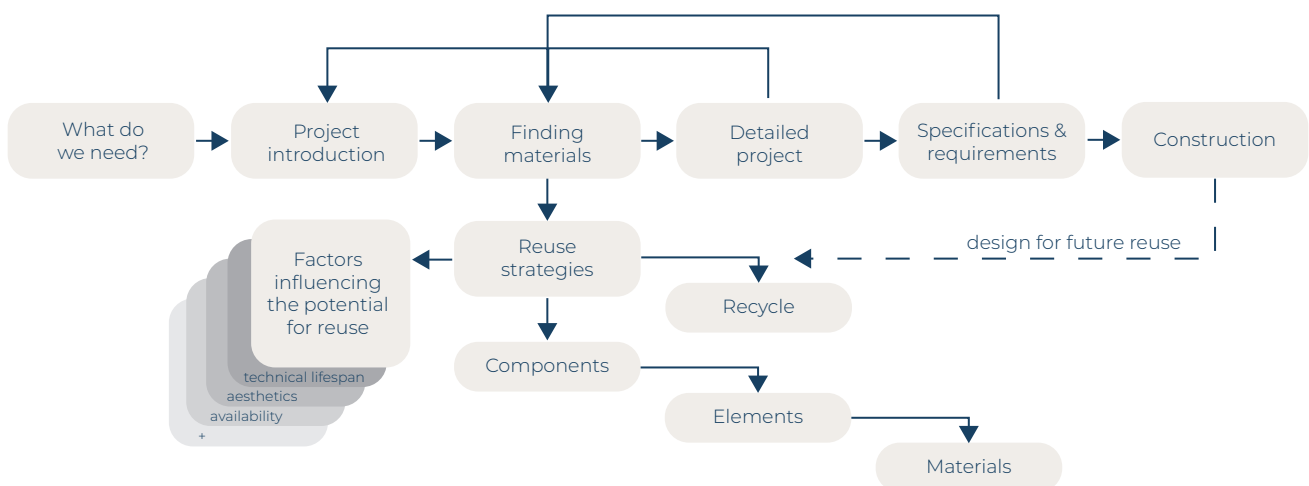


Fig. 2. Design & construction process implementing reuse (simplified visualised)

### III. Overall Design Question

*How can design principles based on reuse in architecture be applied to transform the existing residual spaces in Rotterdam's city center into multifunctional mixed-use buildings?*

Sub questions:

- *What is defined as 'residual' space in Rotterdam - focusing on the concept of gaps in the city introduced by architecture firm Kühne & Co - and can these spaces be categorized?*

- Which locations within the city of Rotterdam - based on the analysis of 180 possible sites by Kühne & Co and the municipality of Rotterdam - offer potential solutions for the design project?

The design part of the research will be conducted alongside the thematic research. The methodology for identifying the context and design location for this graduation project will be based on earlier studies by Tillie et al (2018) and general research on ‘infill locations’ in Rotterdam. The approach for selecting and identifying the specific places will be based on the same approach used in a research by architecture firm LIAG for densification places in the Hague, ‘100 plekken, 1000 kansen (2019)’.

Additionally, a map will be worked out with locations for the neighbourhood ‘Oude Westen’ in Rotterdam. Besides, a list will be made to categorize these ‘residual’ spaces suitable for densification.

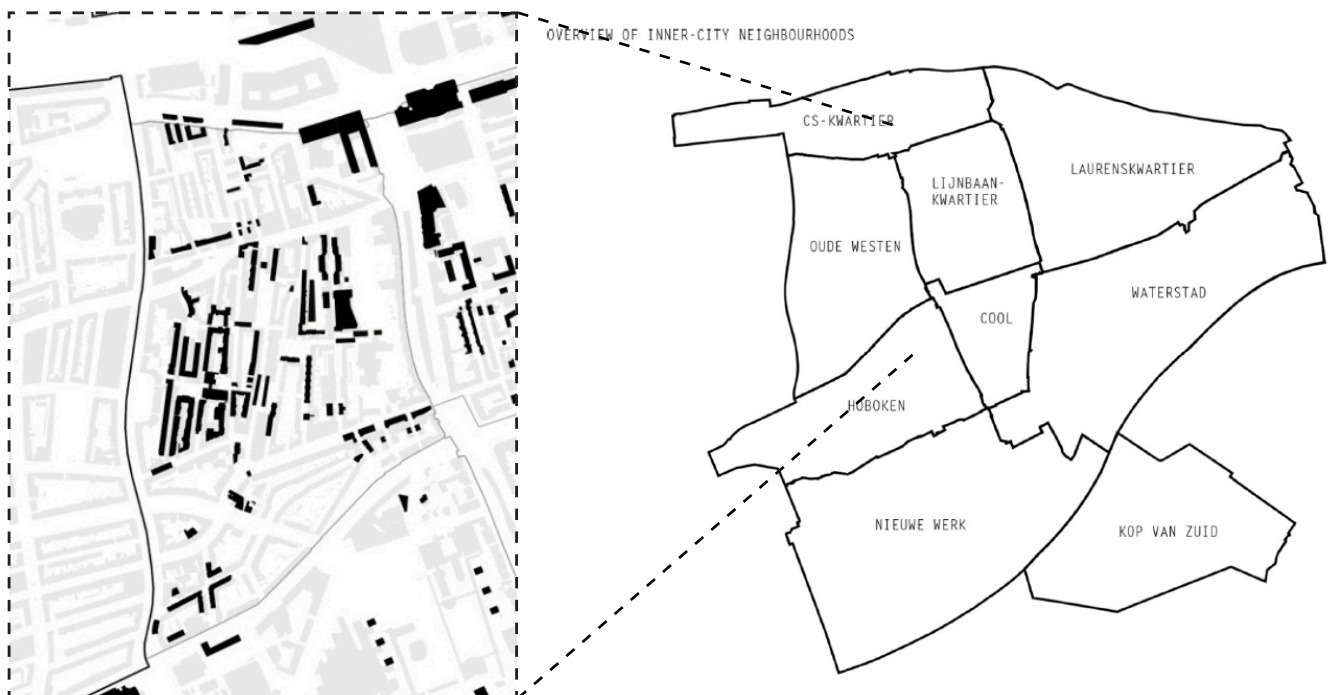


Fig. 3. Potential places for densification for neighbourhood ‘Oude Westen’ in Rotterdam (original drawing by Doepel Strijkers Architects, 2019)

#### IV. Relevance

The Dutch government aims for the economy to be fully based on reused resources by 2050 (Rijksoverheid, 2024). In this desired circular economy, there is no waste. Already in 2030 the Dutch building industry should

be halfway on the move to a circular building economy. Circular design should hereby lead to the optimization of value preservation and minimize environmental impact.

According to the architectural firm Popma Ter Steege (2023), who studied reuse in architecture, it is time that architects have to shift their mindset and have to become material gatherers again. In order to gain a circular economy and to reduce the amount of CO<sub>2</sub> in the building sector a big step lies in the design phase, since this is the first step in the whole building process. Moreover, multiple architecture firms are pioneering in designing and building with reused materials. Therefore this project will investigate the current possibilities and challenges. The design for selected residual spaces in Rotterdam will create spaces that improve and enhance the liveability and contribute to a sustainable densified city centre.

## **V. Thematic Research Objective**

The circular economy allows no waste. Circularity becomes both a challenge and simultaneously allows for new innovative solutions. It is architects that have the key role in the first step to design a circular built environment.

According to professor Gorgolewski (2019) it is the starting point for architects and designers to often identify the potential for reused materials and building components in new projects involving reuse. Afterwards, they develop their concept and ideas depending on these materials. However issues arise around this concept of using reused materials.

The conventional design approach starts with designing the main elements of the buildings, which will be followed by picking the right materials, tools and installations to meet the required specifications (see fig. 1). To design new buildings with existing materials, it is important to understand how these materials are suitable for reuse in a new building. A distinction between already existing research into reuse potential can be made and the newly pioneering architectural approaches that appear in the field. Issues of where to find the materials, also referred to as harvesting, ownership, detailing, irregularities, imperfections and time can all influence the design.

The theoretical research aims to generate a framework with design principles



that showcase the requirements and important decision-making principles of how to design with reused materials and how to design for future reuse. The focus on reused materials will not mean that other solutions like building with biobased materials or the transformation of existing stock of structures are of less importance.

## **VI. Thematic Research Question**

*What design principles can be developed to create a circular framework that effectively integrates reused materials into new building projects for architects during the design phase?*

Sub questions:

- *How can reused and reclaimed materials be defined in the building industry?*
- *What are the main factors that influence the potential for reuse of the predominant building materials?*  
Material availability; history of the product; aesthetics; condition; technical performance; quantity; dimensions; flexibility; lifecycle assessment
- *How is the technical lifespan of used building materials measured?*
- *What are the challenges of using reusable materials in architecture for architects?*
- *How can we design with the imperfections of materials in architecture?*
- *What physical connection methods can be used for future reuse in the façade?*

## **VII. Thematic Research Methodology**

The research will be conducted by studying academic and non-academic literature and performing interviews with architects. The literature study will result into a deeper understanding of the most important factors that influence the reuse potential of building materials. Since the use of reused materials in architecture started in the last years in The Netherlands all these buildings can be seen as individual unique cases. Instead of looking at individual case studies, this research focuses on the approach and design principles that were taken into account by architecture firms to come to the

final design. How can we learn from existing strategies applied by pioneering architecture firms that have successfully designed a circular building using mainly reused materials.

To narrow down the research, the interviews will be held with 3 architecture firms and experts that have applied a circular design strategy in the Dutch practice. These architecture firms are: Architekten Cie., Door Architecten, Popma ter Steege Architecten (architecture firms that can be added to this list if more information is necessary: Superuse & Apto Architects Amsterdam). The same question in relation to their design process will be asked to find similarities and differences. The overall methodology in relation to the subquestions is visualized in fig. 4.

Research sub themes	What data is needed	Method of collecting data	Method of analysing
<b>Understanding reused/ reclaimed building materials</b> -How can reused and reclaimed materials be defined in the building industry? -What are the main factors that influence the potential for reuse of the predominant building materials? How is the technical lifespan of used building materials measured?	Qualitative data on definitions and current factors according to research.	Literature study, Interviews (practice), Looking at specific data in Rotterdam	Literature review: Study academic and non-academic literature to gain insights into factors influencing reuse potential, existing strategies, and challenges faced in circular building design.
<b>Challenges and design considerations for architects</b> -What are the challenges of using reusable materials in architecture for architects? How can we design with the imperfections of materials in architecture? -What physical connection methods can be used for future reuse in the façade?	Qualitative data on design principles used in practice and information on different methods and opinions regarding reuse.	Literature study, Interviewing min. 3 experts: - Architekten Cie. - DOOR architecten - Popma Ter Steege Architecten - (Apto Architecten Amsterdam, Superuse)	Conduct interviews with architects and experts from selected firms to gather firsthand information and perspectives on circular design strategies, challenges, and successful approaches.  Comparative analysis between strategies. Analyze buildings and approach to extract conclusions learned and best practices in using mainly reused materials.

Fig. 4. Methodology related to subquestion of thematic research.



Architekten Cie.  
Circl  
Amsterdam - 2017



Popma ter Steege Architecten  
Paviljoen The Field  
Leiden- 2020



Door Architecten  
het PIT lab  
Amsterdam - 2021

Fig. 5. Architecture firms and projects where design process in relation to project will be researched, other projects are also included in research.

## **VIII. Expected results**

The result of the research will showcase design principles in framework that architects can apply during the design of a circular building with high material reuse goals. Architects have to encompass the lifecycle of the material and have to be creative in the way of finding the right material. Besides, future projects should have a clear list of the used materials and what future waste or components are defined. In that way, future disassembly is not one of the methods, but becomes a standard in the circular economy. Another aspect that is expected is that the research shows that reuse will be chosen before recycling, since we strive to minimize the energy and waste streams in the building industry. Recycling will have a bigger chance to lead to smaller elements that have no future use, whereby future reused elements should be designed more flexible and for disassembly.

The analysed approach from the three architecture firms showcase successful opportunities, however an optimal approach will be formulated. Thereby, reuse and principles for disassembly for future architectural design should be implemented. A research in the 'residual' spaces in Rotterdam to densify the city centre will lead to one or two contexts that will be worked out for the final design after P2. A changing role of the architect and how to design with reuse will accelerate the circular economy.

The main limitation is that the focus on reused materials will not always be the best solution for every design. Other solutions like building with biobased materials or the transformation of existing stock of structures offer also potential circular solutions. Besides, investigating a design process and asking questions to architects can give subjective results.

# Schematic visual of research plan

**Filling the gaps in the city:** A circular approach to design with optimal material reuse in architecture

## Limited urban space and densification challenges

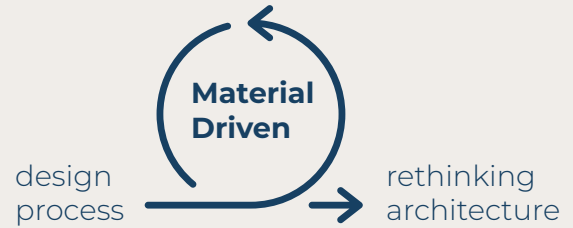
City centers, including Rotterdam, face scarcity of space for new constructions, leading to densification efforts. However, this often involves demolishing existing structures, resulting in material loss and loss of cultural identity. At the same time city centres still have space, but these spaces are forgotten and or not sufficient used. A need for smarter densification.

## Construction and demolition waste (CDW)

The construction and demolition process generates a significant amount of waste, contributing to environmental concerns. Despite efforts to reuse and recycle materials, the imbalance between new construction and demolition results in the production of new materials. There are plenty of materials and building components available, however the habit of reusing and designing with those elements is currently not visible.

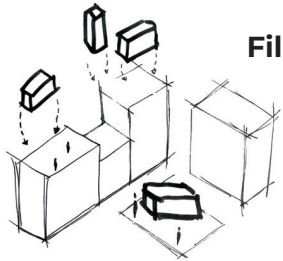
## Transition to a circular built environment

There is a need for a fundamental shift from the linear system to a circular system in the building industry. This requires rethinking design approaches to prioritize the reuse and recycling of materials. The process of material driven design needs systemic changes and a shift in mindset of architects in promoting and working with circular architectural practices.



Problem Statement

## Filling the gaps in the city



Transform 'residual' spaces in circular buildings in Rotterdam.

## Overall Design Question

*How can design principles based on reuse in architecture be applied to transform the existing residual spaces in Rotterdam's city center into multifunctional mixed-use buildings?*

## Thematic Research Question

*What design principles can be developed to create a circular framework that effectively integrates reused materials into new building projects for architects during the design phase?*

A defined research into 'residual' spaces within the city centre of Rotterdam will be worked out in a categorization of existing urban spaces to make the design principles more generic applicable.

Research Questions

material  
function  
form follows

### What data is needed

- Understanding reused/reclaimed building materials
- Harvesting and investigation of available building materials
- Challenges and design considerations for architects

### Method of collecting data

- Literature
- Literature + Interviews + Looking at specific data in Rotterdam
- Interviews (min. 3)
  - Architekten Cie.
  - DOOR Architecten
  - Popma Ter Steege Architecten
  - Apto Architects Amsterdam
  - Superuse

### Method of analysing

- Literature review > base for decision-making.
- Comparative analysis with existing ways and applied methods.
- Comperative analysis in approach and newly applied methods with existing methods.

Methodology

## Desired impact: the new architect

Filling the gaps in the city with a new architecture that consists mostly of reused materials. This way we bring back and maintain the identity of individual building materials and strive for a circular built environment. Instead of starting from scratch, we design using the already existing materials and employ newly developed design principles.

**New perspective on architecture**



## Basic planning for graduation project during MSc3

Date	Deadlines	Planning	Notes
10 26 feb 1.4		Research phase	
11 4 mar 1.5		Design phase	
12 18 mar 1.6			
13 25 mar 1.7			
14 1 apr 1.8			
15 8 apr 1.9	P1	Developing graduation plan	
16 15 apr 1.10	deadline GP	FB	Feedback to finalize GP.
17 22 apr 2.1		Searching literature + collecting data	
18 29 apr 2.2		Research architecture firms	Design phase will start later, but materials need to be searched in order to start design phase.
19 6 may 2.3		Comparative analysis	Design and program follow after research
20 13 may 2.4	final draft RP	Conducting interviews	Jos gives final feedback.
21 20 may 2.5	deadline RP	Create results	
22 27 may 2.6		Finalize RP	
23 3 jun 2.7		Research context	Presentation and initial drawings will be added in elaborated planning.
24 10 jun 2.8	P2	Define program / use	
25 17 jun 2.9		Find materials / harvest	Extra time to continue design and to if needed improve research paper.
26 24 jun 2.10	End MSc 3	Concept design	
		Sketch design	

## Bibliography

### Books

Addis, B. (2006). *Building with Reclaimed Components and Materials: A Design Handbook for Reuse and Recycling* (1st ed.). Routledge. <https://doi.org/10.4324/9781849770637>

Baker-Brown, D. (2017). *The Re-Use Atlas: A Designer's Guide Towards the Circular Economy*. RIBA Publishing.

Gorgolewski, M. (2018). *Resource Salvation: The Architecture of Reuse*. Wiley Blackwell.

Maas, W., Mvrdv, & Van Manen, S. (2021). *Dakencatalogus*. Flamand.

Pit, M., Edens, C., Sladoljev, I. (2021). *Lessons in Circularity*. Cie.

Stricker, E., Brandi, G., Sonderegger A., Angst, M., Buser, B., Massmünster, M. (2022). *Reuse in Construction: A Compendium of Circular Architecture*. Parks Books.

Ter Steege, J.W., Betsky A., Van Leeuwen, M., Popma, J. (2023). *Reuse to reduce: Architecture within a Carbon Budget. The Case of BioPartner 5*. Jap Sam Books.

### Research papers / reports

Circle Economy Foundation. (2024). *The circularity gap report 2024*.

Cirkelstad. (2022). *Niet (meer) normaal! – Van symptoonbestrijding naar systeemverandering*.

Copper 8, Metabolic Consulting. (2023). *Circulaire Bouw 2035: aanzet tot een toekomstperspectief*.

Gorgolewski, M. (2019). The architecture of reuse. *IOP Conference Series: Earth and Environmental Science*, 225(012030), 10.1088/1755-1315/225/1/012030

Guy, B., Shell, S., & Esherick, H. (2006). Design for deconstruction and materials reuse. *Proceedings of the CIB Task Group*, 39(4), pp. 189-209.

Heesbeen, C., Zabek, M., & Hildebrand, L. (2021). A Definition of Essential Characteristics for a Method to Measure Circularity Potential in Architectural Design. In T. Auer, U. Knaack, & J. Schneider (Eds.). *Proceedings of the 9th*



*PowerSKIN Conference*, pp. 165-173.

Hobbs, G., Adams, K. (2017). Reuse of building products and materials: barriers and opportunities. *HISER International Conference on Advances in Recycling and Management of Construction and Demolition Waste*.

Irwin, T. (2018) The Emerging Transition Design Approach, in Storni, C., Leahy, K., McMahon, M., Lloyd, P. & Bohemia, E. (eds). Design as a catalyst for change - *DRS International Conference 2018*, pp. 25-28. <https://doi.org/10.21606/drs.2018.210>

Kozminkska, U. (2019). Circular design: reused materials and the future reused of building elements in architecture. Process, challenges and case studies. *IOP Conference Series: Earth and Environmental Science*, 225(012033). doi 10.1088/1755-1315/225/1/012033

Malabi Eberhardt, L.C., Van Stijn, A., Rasmussen, F.N., Birkved, M., Birgisdottir, H. (2020). Towards circular life cycle assessment for the built environment: A comparison of allocation approaches. *IOP Conference Series: Earth and Environmental Science*, 588(032026). <https://doi.org/10.1088/1755-1315/588/3/032026>

PBL Netherlands Environmental Assessment Agency. (2017). *Circular economy: Measuring innovation in the product chain* (PBL publication number 2544).

Platform CB'23. (2023). *Circulair ontwerpen 2.0* (Werkafspraken voor een circulaire bouw).

Tillie, N., Borsboom-van Beurden, J., Doepel, D., & Aarts, M. (2018). Exploring a Stakeholder Based Urban Densification and Greening Agenda for Rotterdam Inner City - Accelerating the Transition to a Liveable Low Carbon City. *Sustainability*, 10(6). <https://doi.org/10.3390/su10061927>

### **Internet sources**

Ellen MacArthur Foundation. (2019). *Circular design guide*. <https://www.circulardesignguide.com/>

Ellen MacArthur Foundation. (n.d.). *Circular economy introduction*. <https://www.ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview> retrieved on 4th of April 2024.

European Commission. (2020). *A New Circular Economy Action Plan for a Cleaner and more competitive Europe*. [https://ec.europa.eu/commission/presscorner/detail/en/ip\\_20\\_420](https://ec.europa.eu/commission/presscorner/detail/en/ip_20_420)

Footprint Network. (2024). *Press release Dutch Overshoot Day*

2024 – *Earth Overshoot Day*. [https://overshoot.footprintnetwork.org/newsroom/press-release-dutch-overshoot-day-2024/?\\_ga=2.155863806.436721494.1712167062-164008722.1712167062](https://overshoot.footprintnetwork.org/newsroom/press-release-dutch-overshoot-day-2024/?_ga=2.155863806.436721494.1712167062-164008722.1712167062) (retrieved on 3-4-24)

Rijksoverheid. (2024). *Nederland circulair in 2050*. <https://www.rijksoverheid.nl/onderwerpen/circulaire-economie/nederland-circulair-in-2050>

## **Visuals**

De Wit, R. (2020). Paviljoen The Field. [Photograph]. <https://pts.nl/paviljoen-the-field-concept/>

DOOR Architecten. (2021). PIT lab. [Photograph]. <https://doorarchitecten.nl/pit-lab/>

Van Duivenbode, O. (2017). Circl / de Architecten Cie. [Photograph]. <https://architizer.com/idea/2649591/>