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

<table>
<thead>
<tr>
<th>Name</th>
<th>Astrid Potemans</th>
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</thead>
<tbody>
<tr>
<td>Student number</td>
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<td>0648088144</td>
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## Studio

<table>
<thead>
<tr>
<th>Name / Theme</th>
<th>RE&amp;H / MBE – Circular Economy Lab</th>
</tr>
</thead>
</table>
| Teachers / tutors          | Matthijs Prins  
Ad Straub |

**Argumentation of choice of the studio**

One year ago, at semester start-up of Management in the Built Environment, we were challenged by Niel Slob and Saman Mohammadi to think about our future: the growing world’s population, scarcity of resources and our current linear economy in which we take, make and waste. Alternatively they proposed a model of reuse, remake and recycling – a so called circular economy. Imagining a circular economy for lamps, washing machines or carpets was comprehensible; imagining a circular economy for buildings proved to be much more complex. I was intrigued by the concept and was convinced that this was the answer to save our planet and humankind.

In the first month I realised that a transition towards a circular economy will not save our planet and humankind. There are some fundamental and practical problems, of which the latter are especially hard to tackle in the building industry. The aim of my research is not to forcefully imply a circular economy in the building industry – even if it were possible, the question remains whether it is desirable.

Nevertheless, I believe the building industry has great potential to become more efficient, and thinking and discussing about a circular economy in the building industry is but one of the means to trigger the actors operating in it to take action.

## Graduation project

| Title of the graduation project | Construct, deconstruct, reconstruct  
Towards the reuse of prefab concrete building components in the Netherlands |

### Goal

| Location: | n/a |
The posed problem,

Currently, when a building becomes obsolete, it is either renovated, transformed or demolished, depending on the cause of obsolescence (Thomsen & van der Flier, 2011). However, the possibilities for renovation and transformation are bound to the characteristics of the building and the location, and can therefore not always or only partially meet demand. The option of demolition is becoming less attractive due to several reasons. Demolition waste in the Netherlands is often used as foundation material for roads, yet, this market is becoming saturated (Rijkswaterstaat, 2015). Landfilling results in pollutant emissions and a loss of materials, embodied energy and space and is increasingly costly (Hendriks & Janssen, 2001). Deconstruction and reconstruction of modular buildings can prove to be a good alternative.

Deconstruction and reconstruction need not be limited to relocation of a specific building. Modules designed with carefully chosen dimensions and characteristics could be widely reapplied in dwellings, hospitals, offices, bridges – so to name a few. In this manner, building modules fit within the concept of circular economy. This concept has gained renewed attention as a result of the growing world’s population, consequently an increase in demand for energy and materials (Heilig, 2012; Reh, 2013). These developments are putting pressure on natural resources (Gorgolewski, 2008). In a circular economy, as opposed to a linear ‘take-make-waste’ economy, the extraction of natural resources is reduced, products and components are reused and materials are recycled. Deconstruction and reconstruction of building modules has the potential to reduce the need for new natural resources.

In the Netherlands, one of the most widely used building materials is concrete. Concrete is versatile, affordable and requires low maintenance. The Dutch building industry is tailored the application of concrete. Precast concrete elements, for example beams, columns, staircases, and masonry and building blocks can be dismantled and reused, as long as their connections are not grouted or cast in place (Hurley and Hobbs in Iacovidou & Purnell, 2016).

The advantages of construction of modular buildings during the initiation and construction phase are described in literature and application is found more and more in practice. The potential benefits of
deconstruction, albeit to a lesser extent, also described in literature but application is rare in practise in the Netherlands. Until now the costs of deconstruction have outweighed the costs of demolition, and without deconstruction there is no reconstruction possible. In order to encourage reconstruction it is important to gain insight in the up-to-date major barriers and drivers for deconstruction within the building industry in the Netherlands.

**Main research question:** What are major drivers and barriers for deconstruction and reconstruction of prefab concrete building components for actors in the building industry in the Netherlands and how can a tool be designed to encourage this?

The main goal of this research is to identify the major drivers and barriers for deconstruction and reconstruction of prefab concrete components in building industry in the Netherlands. This is the descriptive part of the research, the ‘basic qualitative research’ (Merriam 2009).

Before a building can be deconstructed and reconstructed, it should be constructed in such a manner that it is possible to deconstruct. An example of such a building is the MorgenWonen dwelling. This is not a unique case – benefits and challenges have been described in literature.

→ **Sub question:** What are major drivers and barriers for the construction with prefab concrete building components for actors in the building industry in the Netherlands?

Once a building has been constructed in such a manner that it is possible to deconstruct, this needs not necessarily mean that deconstruction is actually preferred over demolition.

→ **Sub question:** What are major drivers and barriers for the deconstruction of concrete building components for actors in the building industry in the Netherlands?

If the choice is made to deconstruct rather than to demolish, obviously there is another destination in mind for the component than landfilling.

→ **Sub question:** What are major drivers and barriers for the reconstruction of concrete...
<table>
<thead>
<tr>
<th>Design assignment in which these result.</th>
<th>building components for actors in the building industry in the Netherlands?</th>
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<tbody>
<tr>
<td>Currently there are few cases in which components are reconstructed, whilst there are potential environmental, societal and financial benefits to the reuse of components.</td>
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<tr>
<td>The secondary goal is to encourage the building industry towards the reuse of prefab concrete components. The challenge here is to find a way to transfer relevant knowledge to relevant actors in the building industry. This is the exploratory part of the research, the ‘critical qualitative research’ Merriam (2009).</td>
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<tr>
<td>Sub question: How can a tool be designed to encourage deconstruction and reconstruction in the building industry in the Netherlands?</td>
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**Process**

**Method description**

The first three sub questions, regarding the major drivers and barriers, is investigated from a realist point of view, which advocates that there is a reality independent of the mind, which can be observed through the senses. From a realist point of view, it would therefore be possible to formulate drivers and barriers that are observable as facts. To increase credibility, sufficient data needs to be collected (Saunders et al., 2009). This is done through an extensive literature review and in addition, expert interviews. The goal of the expert interviews is to form a comprehensive overview of drivers and barriers that are up-to-date and specific for the Dutch context. A realist perspective would argue for a large amount of interviews to be able to make generalizations, however, given the limited amount of resources available to the researcher, the choice is made to limit the amount expert interviews.

The last sub question, on how to design a tool to encourage actors, is investigated from an interpretivist point of view, which “advocates that it is necessary for the researcher to understand differences between humans in our role as social actors” (Saunders et al., 2009, p. 116).

**Research strategy**
Research strategy linked to assessment periods.

**Sample selection**

Given that the researcher wants to get a comprehensive overview of the current drivers and barriers for deconstruction and reconstruction, samples are selected from which most can be learned – a purposeful, purposive or criterion-based sample (Merriam, 2009). This research comprises of two levels of samples:

- **Sampling of the objects for expert interviews**
  - A critical case which presents a logical inference about the phenomenon of interest (Bryman, 2012)
    - Financial drivers and barriers: VolkerWessels, contractor of MorgenWonen
    - Environmental and social drivers and barriers: Evert Schut, senior advisor Rijkswaterstaat, author of ‘Beleidsverkenning Circulaire Economie in de bouw’, project manager MVO Netwerk Beton & Jack van der Palen, architect and chairman MVO Netwerk Beton
    - Technical drivers and barriers: Westo Prefab Concrete Systems, supplier of columns circular building Alliander
    - Organisational drivers and barriers: Hennes de Ridder, retired project manager and author of ‘Legoliseren van de bouw’
  - Interviewees will not exclusively be interviewed on the specific drivers and barriers above, however, it is expected that they have a specialization in a specific aspect.
  - It is assumed that theoretical saturation will have been reached after these five interviews, however, if this is not the case, snowball sampling will be used to gather more data.

- **Sampling of the objects for focus groups**
  - The goal is to retrieve data in a social context and start discussion
  - Group size is approximately six, participants are preferably strangers to each other (Merriam, 2009)
  - Convenience sample: the tool is aimed at architects and contractors, so a convenient selection is made

**Data collection and analysis**

Data that serve as input for the tool are collected through semi-structured expert interviews. Data analysis and data collection are recursive, allowing the researcher to make adjustments and test emerging concepts. Merriam (1998) describes data analysis as the process of making sense out of the data, in other words, making meaning. The goal of the semi-structured expert interviews is to provide an up-to-date and comprehensive overview of
drivers and barriers within the Dutch context. The goal of the focus group interviews is to provide feedback on the tool.

As data are collected from a single data source, internal validity will be enhanced by member checking during the interview and after data analysis. Furthermore, peer examination will be done by a colleague in the field. To enhance transferability, two experts from each discipline will be interviewed. To enhance external validity thick descriptions will be provided in text (Merriam, 1998).

**Practical considerations**
This research is conducted as part of the graduation from the master track Management in the Built Environment. As a consequence, this research is conducted within a limited amount of time and within a limited budget. The research design is drawn up according to progress and assessment dates of the Faculty of Architecture.

**Ethical considerations**
Following ethical guidelines, participants will be informed about the aim of the research. Informed written consent shall be obtained at the interviews. Participants may chose to participate anonymously. Data will be treated with confidentiality.

**Literature and general practical preference**

**Theoretical framework**

**Circular economy**
In the past few years, an increasing amount of publications, academic as well as non-academic, have appeared on the concept of circular economy. The concept was recently promoted by the Ellen McArthur Foundation, founded in 2010 to “inspire a generation to rethink, redesign and build a positive future” (Ellen MacArthur Foundation, 2013, p. 96). However, the concept can be traced back much further, to the mid-sixties, when Boulding (1966) argued in *The economy of the coming spaceship earth* that our planet is a closed, rather than an open system, in which raw materials and energy are finite.

“The closed earth of the future requires economic principles which are somewhat different from those of the open earth of the past. For the sake of picturesqueness, I am tempted to call the open economy the ‘cowboy economy,’ the cowboy being symbolic of the illimitable plains and also associated with reckless, exploitative, romantic, and violent behavior, which is characteristic of open societies. The closed economy of the future might similarly be called anything, either for extraction or for pollution, and in which, therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy” (Boulding, 1966, p. 7).

In his essay, Boulding (1966) puts forward that his considerations relate to the very long run—“at least beyond the lifetimes of any now living” (p. 10). One can be inclined to think that this very long run has come sooner than Boulding could ever expect, that the end of this very long run is now.

Ever since 1966, many different authors have written about the concept of a so-called closed or circular economy. However, what constitutes a circular economy has never been unambiguously agreed upon. In a recent review of over 155 articles on circular economy, Ghisellini, Cialani & Ulgiati (2016) found that the majority of articles concern industrial ecology and technical innovation rather than economic aspects.

Planing (2015) argues that the increased interest in circular economy is driven by the three major changes: an increase in price and volatility of the price of raw materials as of 2000; the rapid development of information technologies, enabling new business models; and a shift in consumer behaviour. The increase in prices would form the most important financial driver for parties to employ circular business models. Stahel (2012) suggests that selling performance, rather than products, is the most profitable business model in a circular economy.
Stigter (2016) designed the financial section of a performance-based business model for a supplier of a steel beam in a circular economy. Stigter concluded that, albeit under the set of conditions of his study, growth in resource prices based on scarcity determines the financial feasibility of the business model.

Even though prices for steel have dropped tremendously since 2008, as a result of the world credit crisis, Stigter makes the assumption that the prices will rise again with the increase of the world’s population. However, not steel, but concrete is the single most widely used material in the world (Crow, 2008). Cement, the binding agent in concrete, is the most important basic material used in building engineering (Supino, Malandrino, Testa, & Sica, 2016). There is currently no shortage of raw materials to make new cement (Allwood, 2014). The other components of concrete, sand and gravel, are also far from scarce (Rijkswaterstaat, 2015).

The above does not mean that a circular economy in the building industry is impossible nor undesirable, for the actual problem is not material scarcity, but the amount of energy used and the amount of waste produced in the sector. Furthermore one may argue that a circular economy should not be used to “boost global competitiveness, foster sustainable economic growth and generate new jobs” as proposed by the European Union (European Commission, 2015). The solution to the problem is not a matter of linear or circular use of materials, but rather the attitude towards consumption.

“The difference between the two types of economy becomes most apparent in the attitude towards consumption. In the cowboy economy, consumption is regarded as a good thing and production likewise; and the success of the economy is measured by the amount of tire throughput from the "factors of production," (...) By contrast, in the spaceman economy, throughput is by no means a desideratum, and is indeed to be regarded as something to be minimized rather than maximized” (Boulding, 1966, p. 9)

Reduce, reuse or recycle

Circularity in the building industry

Building obsolescence: renovate, transform, deconstruct or demolish?
Obsolescence of buildings can be defined as “a process of declining performance resulting in the end of the service life” (Thomsen & van der Flier, 2011, p. 352). The cause of building obsolescence largely determines whether a building can best be reused, deconstructed or demolished. Thomsen & van der Flier (2011) conceptualized the causes of building obsolescence into four quadrants, as shown in figure 2.4.1a,b. The conceptual framework entails the major variables and their relations.

Figure 2.4.1a,b: Major causes of building obsolescence after Thomsen & van der Flier (2011, p. 352) and assuming most effective actions.
In practice, building obsolescence is mostly caused by a interwoven multiplicity of reasons. Furthermore, decision-makers do not base their choice of action solely on causes of obsolescence. Demolition is considered a loss of value, but can outweigh the costs of renovation, transformation or deconstruction (Thomsen & van der Flier, 2011). Obviously, not all buildings allow for deconstruction, for example in situ cast structures. However, it can be concluded that deconstruction is most rewarding if the building is left obsolete for exogenous causes.

Langston, Wong, Hui, & Shen (2008) distinguish between physical, economic, functional, technological, social and legal obsolescence. Deconstruction is most rewarding if the building is left obsolete for economic, functional or social reasons, as shown in table 2.4.2.

<table>
<thead>
<tr>
<th></th>
<th>Renovate</th>
<th>Transform</th>
<th>Deconstruct</th>
<th>Demolish</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical obsolescence</strong></td>
<td>Natural or accelerated decay over time while all buildings experience natural decay over time</td>
<td>x</td>
<td></td>
<td>x</td>
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<tr>
<td><strong>Economic obsolescence</strong></td>
<td>The cost of continuing to use building (component) outweigh the expense of substituting some alternative</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Functional obsolescence</strong></td>
<td>Change in owner objectives and building requirements</td>
<td></td>
<td>x</td>
<td>x</td>
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<tr>
<td><strong>Technological obsolescence</strong></td>
<td>Building (component) cannot technologically compete with alternatives</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td><strong>Social obsolescence</strong></td>
<td>Fashion or behavioural changes</td>
<td></td>
<td>x</td>
<td>x</td>
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<tr>
<td><strong>Legal obsolescence</strong></td>
<td>Revised regulations</td>
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<td>x</td>
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</table>

Table 2.4.2: Types of obsolescence after Langston, Wong, Hui, & Shen (2008) distinguish and assumingly most effective actions.

The building as a collection of interrelated components

Prefab concrete building components

Findings

Research

→ **Sub question:** What are major drivers and barriers for the construction with prefab concrete building components for actors in the building industry in the Netherlands?

→ **Sub question:** What are major drivers and barriers for the deconstruction of concrete building components for actors in the building industry in the Netherlands?

Drivers and barriers are categorised after Iacovidou & Purnell’s *Mining the physical infrastructure: Opportunities, barriers and interventions in promoting structural components reuse* (2016) and include financial, environmental, social, technical and organisational factors, as shown in figure 3.1.1.
Table 3: Benefits and constraints of deconstruction.

<table>
<thead>
<tr>
<th>Environmental</th>
<th>Economic</th>
<th>Social</th>
<th>Technical</th>
<th>Organizational</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduction in the use of virgin raw resources</td>
<td>Higher costs compared to conventional demolition</td>
<td>Mitigation of noise, dust, and odours associated with conventional demolition</td>
<td>Buildings and building components not designed for deconstruction</td>
<td>Lack of standard specifications and building codes to order the reuse of building components</td>
</tr>
<tr>
<td>Reduction of waste generated</td>
<td>Creation of local markets for materials recycling and components reuse</td>
<td>Creation of new jobs in deconstruction sector</td>
<td>Performance guarantee for reused materials - tests needed to certify performance</td>
<td>Intensive effort and time required</td>
</tr>
<tr>
<td>Proper removal and handling of hazardous materials</td>
<td>Lack of regional markets for reclaimed components</td>
<td>Preservation of low-cost material to low income communities</td>
<td>Lack of experience and capability on construction techniques used, and available tools to implement deconstruction</td>
<td>Lack of infrastructure for refurbishment and repaired components</td>
</tr>
<tr>
<td>High recovery of components for reuse and materials for recycling</td>
<td>Opportunities for small and medium-size enterprises (SMEs) development to handle secondary components for reuse</td>
<td>Job training in use of basic tools and deconstruction techniques</td>
<td>Vast variety in quality of extracted components from buildings</td>
<td>Tight scheduling of deconstruction projects</td>
</tr>
<tr>
<td>Conservation of embodied energy and carbon of materials and components</td>
<td>Generation of revenue through selling salvaged components</td>
<td>Cultural preservation and retention of historical significance of community infrastructure</td>
<td>Vast variety in the size of extracted components from buildings</td>
<td>Large number of parties involved in deconstruction</td>
</tr>
<tr>
<td>Reduction of environmental impacts from maximization of the need for</td>
<td>Reduction of cost in transport and storage of components</td>
<td>Opportunities for self-employment and small business development</td>
<td>Existence of hazardous substances (fire retardants, coatings, etc.)</td>
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<tr>
<td>recycling of materials</td>
<td></td>
<td>Consumers prejudice in using second-hand materials and preference to new</td>
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<td>Ancestry and commercial desirability</td>
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Figure 3.1.1: Major drivers and barriers of deconstruction (Iacovou & Purnell, 2016).

→ **Sub question**: What are major drivers and barriers for the reconstruction of concrete building components for actors in the building industry in the Netherlands?

**Design**

→ **Sub question**: How can a tool be designed to encourage deconstruction and reconstruction in the building industry in the Netherlands?

The tool to encourage construction with, deconstruction and reconstruction of concrete building components in the building industry is an online platform inspired on the harvest map in figure 3.2.1.
The harvest map provides an overview of second-hand building materials, however, it is intended as a customer-to-customer platform. Furthermore products are offered in small quantities, and the category of concrete is missing.

**Reflection**

**Relevance**

*Societal relevance*
As of the Industrial Revolution mankind generally has, on a large scale, extracted raw materials from the earth to turn them further into products. Ever since world’s population is growing steadily and simultaneously it is expected that the average wealth of individuals will increase in the coming years (Heilig, 2012; Reh, 2013). These developments are resulting in an increasing demand for energy and materials and are putting enormous pressure on natural resources (Gorgolewski, 2008). At a certain point in time the costs of extracting non-renewable raw materials will exceed their utility value (Allwood, Ashby, Gutowski, & Worrell, 2011). The extraction of raw materials places not only a burden on the economy but also on the environment.

On December 2nd, 2015 the European Commission presented the Closing the loop - An EU action plan for the Circular Economy (European Commission, 2015). The construction and demolition sector is considered a priority area in the action plan. The building industry consumes an estimated 40% of the total flow of raw materials in the global economy (Roodman, Lenssen, & Peterson, 1995). Furthermore building construction and demolition waste accounts for approximately 40% of the total waste flow in developed countries (United Nations Environmental Programme, 2014). There is an urgency and a potential for the building industry to become more material efficient. Deconstruction of components at a building’s end-of-life can reduce waste streams, whilst reconstruction of components can reduce the need for raw materials.

*Scientific relevance*
In 2005, Dorsthorst & Kowalczyk provided an overview of the state of deconstruction in the Netherlands and concluded the following:
A decade after publication circumstances have changed: the market for road foundation material is becoming saturated (Rijkswaterstaat, 2015). This gives rise to a new financial incentive to consider deconstruction over demolition. More recent research in the field of component reuse in the building industry is based upon case studies in among others Brazil (da Rocha & Sattler, 2009), Canada (Gorgolewski, 2008) and Portugal (Coelho & de Brito, 2011). However, drivers and barriers for component reuse are found to be dependent on geographical factors, and research on the topic in the Netherlands is lacking. Additionally, the propelled interest in the concept of circular economy indicates that the building industry may have altered its view on component reuse.

**Practical relevance**

The results of this research are useful for the supply side of the building industry. The need to reduce raw material extraction and waste flows in the building industry is becoming more apparent to society and clients. By mapping the drivers and barriers for component reuse and their importance to individual actors within the supply side of the building industry, the topic becomes more open for discussion and negotiation for these actors. Furthermore a tool will be designed to encourage component reuse, aimed at architects and contractors. For depending on the type of building contract, it is either the architect or the contractor on the supply side that can make the decision to reuse components.

**Time planning**

<table>
<thead>
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<tr>
<td>June 14th, 2016</td>
<td>P2 Assessment</td>
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<tr>
<td></td>
<td>P2 Graduation plan, P2 Report</td>
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<td>June 22nd, 2016</td>
<td>P2 Assessment</td>
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<td></td>
<td>Presentation</td>
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<tr>
<td>August 10th, 2016</td>
<td>Retake WM0312CT</td>
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<td></td>
<td>Possible retake ‘Philosophy, Technology Assessment and Ethics for Civil Engineering’, 4 ECTS</td>
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<td>September 5th, 2016</td>
<td>Start WM0201TU-Eng</td>
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<td>‘Technical writing’, 2 ECTS</td>
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<td>P3 Progress</td>
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<td>Draft reflection, research report</td>
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Important dates and deliverables.

**Bibliography**


