Graduation Plan: Building Technology

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3 Title of the graduation

Design for Disassembly for façade components in the Circular Economy

4 Background

This master thesis is part of an ongoing research program on Façade Leasing, which is developing a business-to-client product-service system (PSS) for resource efficient facades. The initiative was actually another master thesis in Building Technology, the one of Juan Azcarate-Aguerre (Azcarate-Aguerre, 2014) that turned into a Climate KIC H2020 research program involving both the Façade Research group as well as the department of Real estate and Housing. The program is called Integrated Façade as a Product-Service System (IFPSS).

It should be noted that a mock-up testing the possibilities of this research in 1:1 scale is going to take place in spring 2016. More specifically four (4) panels of the **EWI low rise building** on **TU Delft campus** are going to be replaced with panels that provide different services within the leasing façade concept.

From selling products to selling performances

Before getting into my own role in this program I will try to explain what the basic idea of the business model is. A shift has lately been observed in the market regarding the way products are made available to clients. More and more companies are nowadays focusing on providing services instead of delivering products. While this practice is gaining more and more space in other industries (i.e. car leasing or using laundry services) it has not yet been established in the building industry.

Juan Azcarate-Aguerre, in his graduation project proposed to follow a similar approach with buildings, and more specifically with facades. The idea is to think of the skin as a sum of performances. Obviously there are the most basic ones like weather proofing and visibility or privacy. But why stop there? Think of media facades, or green facades or energy facades. There are no limits.

The concept is profitable for all the stakeholders. Clients within the leasing concept have the opportunity to decide which kind of functions they wish their façade to have. More importantly the choice of leasing and not buying the façade gives them the chance to change those functions during the façade's lifetime, or upgrade them as new technologies are made available (or even downgrade them if that is their wish).

Suppliers on the other hand have an opportunity to increase their profits. A building skin according to Stewart Brand (Brand, 1994) has a lifetime of 20 years. However most office spaces change tenants within 3 years after the building's realization. Within this concept suppliers can redistribute the façade components into new facades and when worse comes to worst they always have the opportunity to recycle the building materials.

This is in fact a win situation for everyone. Not only for the client and the supplier but also for the environment. Within this new circular economy we can achieve less waste, less energy use and less CO_2 emissions.

5 Problem statement

Currently the building sector contributes up to 35% of waste in the E.U. and consumes more than 40% of all energy, resulting in an urgent need for buildings to reduce their environmental impact over their entire life cycle (European Commission, 2011). The facade of a building typically represents 25-30% of its embodied energy and would have previously been sent to the local landfill along with the rest of the building at the end of its useful life. Leasing facades as a new business model could make facades more sustainable during their lifetime, by introducing a circular way of building as opposed to the existing linear one that goes straight from extracting resources to demolishing buildings directly to landfills.

Current design strategies cannot however support this model. In order to make leasing facades a feasible concept and not just a business plan, a new design strategy has to be introduced: one that involves a fourth dimension: time. There is absolute demand for a design strategy that allows for disassembling the façade into parts and reclaiming those that are suitable for reuse while distributing the rest into other sustainable end-of-life scenarios.

6 Objectives

The general objective of this project is to:

Investigate the possibilities and impacts of Design for Disassembly strategies for façade components in the Circular Economy.

The sub-objectives are to:

- Develop an understanding of how principles of the Circular Economy can be applied to facades.
- Find out to what extend the concept of DfD in the Circular Economy can be applied on existing façade components
- Propose ways to improve the potential of existing façade components in the Circular Economy by using DfD strategies.

7 Limitations

The above objectives will be met by using the existing design of the IFPSS mock-up as a case study. Due to time limitations, this study will focus on the analysis and design of three (3) of the components used in the mock-up, that can be regarded as components usually found on a large number of facades, as opposed to less conventional components. The selected components are:

- Alcoa window frames (RT 72 and RT 72 HI)
- Trox decentralized air handling unit (FSL-B-ZAB-SEK)
- Renson external sunshade (Fixscreen 100^{EVO})

8 Research question

The research question that I will try to answer is:

How can Design for Disassembly improve the potentials of façade components in the Circular Economy?

The deriving sub-questions are:

- What are the different end-of-life scenarios for the façade components in relation to Circular Economy?
- What are the available guidelines for DfD for façade components?
- How can façade components be disassembled functionally?
- How can façade components be disassembled physically?
- Which end-of-life strategies are currently applied to the selected façade components and what are the alternatives?
- What is the expected lifetime of the selected façade components?
- How can the façade components be evaluated for their suitability for DfD in the Circular Economy?
- How can the selected façade components be improved in terms of DfD in the Circular Economy?
- What are the benefits of improving façade components in terms of DfD in the Circular Economy on a greater scale?

9 Design question

The design question is:

How can resource efficient façade components be designed with the implementation of Design for Disassembly strategies?

The deriving sub-questions are:

- What is the impact of DfD strategies on production processes of façade components?
- What is the impact of DfD strategies on the architectural quality of façade components?

10 Approach and Methodology

The first step of the research will be conducting a **literature review** for the general subject of *Design for Disassembly*. The purpose of that is to understand the theoretical background and get an understanding of the general guidelines. This will also help in evaluating the design strategy and determining how ready the building industry is for such a transition.

Part of the literature review will be focused on *Circular Economy* so as to define the multiple end-of-life scenarios for façade components. This is a necessary step as the final outcome aspires to give direct answers to what the alternative end-of-life scenarios will be for each component of the design.

A thorough **state-of-the art investigation** is also needed. This will help me gain a better understanding of the assembling methods for facades (which is a pre-requisite for the disassembly method). Also, this is a necessary step in understanding the materialization of each component and their expected lifetime. For this purpose a series of interviews with professionals from the industry will follow during the evaluation phase.

Around the beginning of 2016 the final design for the **case study** of the IFPSS mock-up will be selected. After conducting an analysis and understanding of the design I wish to have **interviews** with representatives of the involved companies. In these I wish to discuss among others the materialization of their products, their expected lifetime, the necessary maintenance and the possible end-of-life scenarios. This information will be

collected in a detailed database that will serve as an evaluation tool for the existing design.

From that point on I can move on into proposing changes and improvements in that **design** to make it more sustainable and more suitable for Design for Disassembly, by using the knowledge acquired in the first phase of literature review. This translates into a detailed list of which components can be reused and the alternative end-of-life scenarios for the rest of them.

Last but not least, I wish to have a look at the greater picture of flows of materials that are commonly used in the built environment in order to understand the consequences of improving the suitability for DfD in the Circular Economy of façade components on a greater scale.

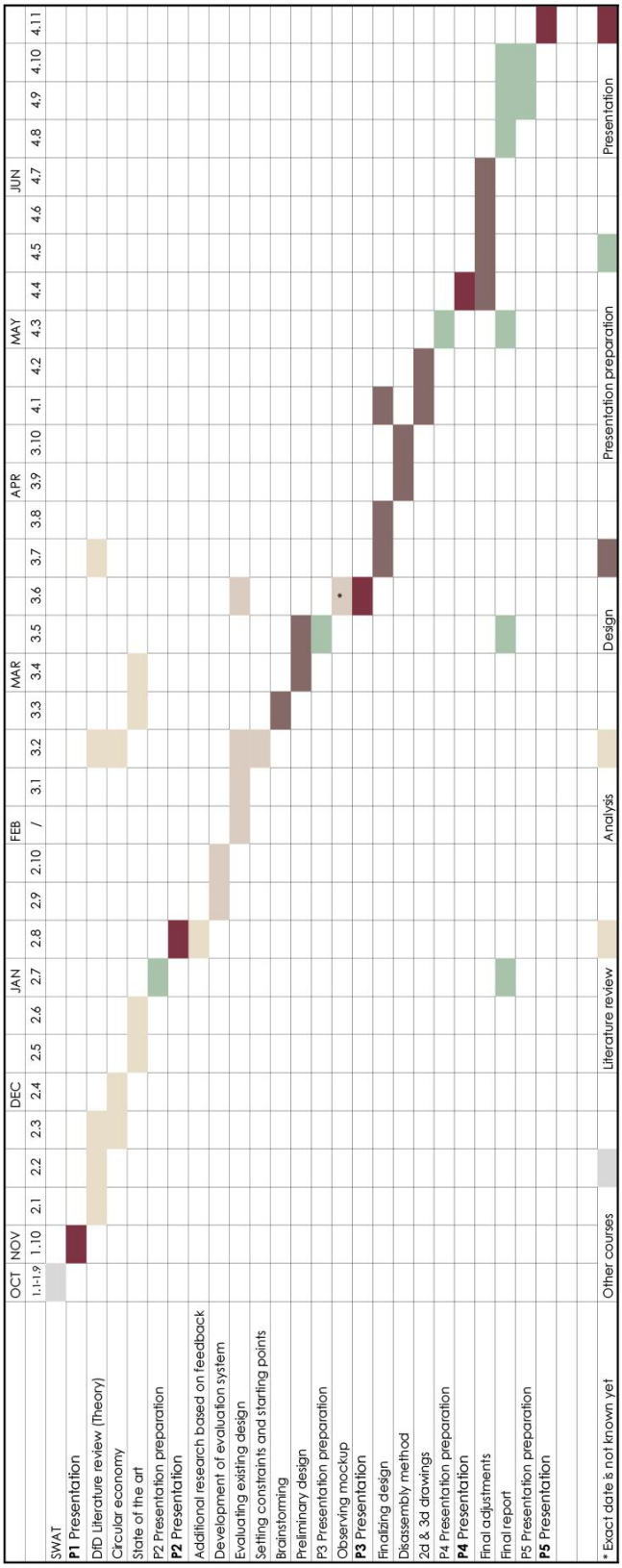
Every chapter of the final report will address one or more of the research and design sub-questions.

11 Relevance

Adapting a circular economy is an urging necessity not only in the building industry, but other industries as well. This is a required step we need to take towards a sustainable way of life. Introducing design for disassembly in façade systems serves the first rule of Cradle to Cradle philosophy which is "Waste=Food".

While this is a common practice in other product industries, the façade industry is quite behind in research and has little to none practical examples to demonstrate. This suggests a need for systematic research towards this direction in order to investigate the feasibility of the concept and the potential benefits.

12 Time Planning



13 Literature

13.1 Reviewed literature

Books

Bakker, C., Hollander, M., Hinte, E. and Zijlstra, Y. (2014). *Products that last*. Delft: TU Delft Library.
Brand, S. (1994). *How buildings learn*. New York, NY: Viking.
Herzog, T., Krippner, R. and Lang, W. (2004). *Facade construction manual*. München: DETAIL - Institut für internationale Architektur-Dokumentation GmbH & Co. KG.
Knaack, U., Auer, T., Klein, T., & Bilow, M. (2007). *Facades: Principles of Construction.* 2nd ed. Basel: Birkhäuser.
McDonough, W., and Braungart, M. (2002). *Cradle to cradle*. New York: North Point Press.

Conference proceedings

Eekhout, M. (2006). The Management of Complex Design & Engineering Processes. In: *Adaptables 2006, International Conference of Adaptable Building Structures*. [online] Available at: http://www.irbnet.de/daten/iconda/CIB10949.pdf [Accessed 1 Dec. 2015].
Geraedts, R., Remøy, H., Hermans, M. and Van Rijn, E. (2014). Adaptive capacity of buildings: A determination method to promote flexible and sustainable construction. In: *International Union of Architects Worlds Congress UIA2014*.

Journals

Crowther, P. (2005). Design for Disassembly - Themes and Principles. *RAIA/BDP Environment Design Guide*, [online] DES31. Available at: http://eprints.qut.edu.au/2888/1/Crowther-RAIA-2005.PDF [Accessed 14 Dec. 2015].
Deniz, O. and Dogan, E. (2014). Building Façade System for Deconstruction. *Journal of Sustainable Architecture and Civil Engineering*, 8(3).
Durmisevic, E. and Yeang, K. (2009). Designing for Disassembly (DfD). *Architectural Design*, 79(6), pp.134-137.
Ellen MacArthur Foundation (2015). *Towards a Circular Economy: Business Rationale for an Accelerated Transition*. [online] Ellen MacArthur Foundation. Available at: http://www.ellenmacarthurfoundation.org/assets/downloads/TCE_Ellen-MacArthur-Foundation-9-Dec-2015.pdf [Accessed 11 Dec. 2015].
European Commission (2011). *Roadmap to a Resource Efficient Europe (571 final)*. [online] Available at: http://ec.europa.eu/food/safety/food_waste/library/docs/com2011_571_en.pdf [Accessed 25 Nov. 2015].
Guy, B. and Ciarimboli, N. (2005). *Design for Disassembly in the Built Environment*. [online] Seattle: Hamer Center for Community Design, The Pennsylvania State University. Available at: http://www.lifecyclebuilding.org/~lifecyc6/docs/DfDseattle.pdf [Accessed 16 Dec. 2015].
JRC-IES (2011). *Supporting Environmentally Sound Decisions for Construction and Demolition (C&D) Waste Management*. [online] Luxembourg: Publications Office of the European Union. Available at: http://publications.jrc.ec.europa.eu/repository/bitstream/111111111/22585/2/d4b%20-%20guide%20to%20lctlca%20for%20c%26d%20waste%20management%20-%20final%20-%20on%20line.pdf [Accessed 10 Dec. 2015].
Schmidt, R., Deamer, J. and Austin, S. (2011). Understanding adaptability through layer dependencies. *Impacting Society Through Engineering Design*, [online] (10-11). Available at: http://adaptablefutures.com/wp-content/uploads/2011/11/Schmidt-et-al.-2011.pdf [Accessed 30 Nov. 2015].
Schmidt, R., Eguchi, T., Austin, S. and Gibb, A. (2010). What is the meaning of adaptability in the building industry?. *CIB*, [online] W104(paper 21), pp.233-242. Available at: http://adaptablefutures.com/wp-content/uploads/2011/11/Schmidt-et-al.-2010b.pdf [Accessed 30 Nov. 2015].
Slaughter, E. (2001). Design strategies to increase building flexibility. *Building Research & Information*, 29(3), pp.208-217.
Stahel, W. (2007). Sustainable Development and Strategic Thinking. *Chinese Journal of Population Resources and Environment*, 5(4), pp.3-19.
Ulrich, K. (1995). The role of product architecture in the manufacturing firm. *Research Policy*, 24(3), pp.419-440.

Van de Westerlo, B., Halman, I. and Durmisevic, E. (2012). Translate the Cradle to Cradle Principles for a Building. *CIB*, [online] W115(paper 5), pp.33-38. Available at: http://www.c2c-centre.com/library-item/translate-cradle-cradle-principles-building [Accessed 30 Nov. 2015].

Master and PhD Theses

Azcarate-Aguerre, J. (2014). *Façades as a Product-Service System: The potential of new business-to-client relations in the facade industry*. Master thesis. Delft University of Technology.
Barkkume, A. (2008). *Deconstruction and Design for Disassembly*. Research Report. New Jersey Institute of Technology.
Beurskens, P. and Bakx, R. (2015). *Built-to-rebuild*. Master thesis. Eindhoven University of Technology.
Bloemen, M. (2011). *Design for Disassembly of Facades*. Master thesis. Delft University of Technology.
Bzdyra, W., Etienne, E., Takla, B., and Toma, L. (2011). *Building Deconstruction: Principles, Practice and Impact on Sustainability*. Research Report. City University of New York.
Durmisevic, E. (2006). *Transformable building structures*. Ph.D. Delft University of Technology.
Hovels, J. (2008). *Open modular facade concept*. Master thesis. Delft University of Technology.
Inda, T. (2014). *Design for Disassembly in Practice.* Master thesis. University of Manchester.
Kakolyri, T. (2015). *Sustainability and Service Life of Curtain Walls*. Master thesis). Delft University of Technology.
Kim, M. (2013). *Efficiency and feasibility of the disassembly process for curtain wall systems* Master thesis. Delft University of Technology.
Klein, T. (2013). *Integral Façade Construction.* (Ph.D). Delft University of Technology.
Roosenschoon, A. (2014). *Deconstructive Re-use.* Research report. Delft University of Technology.

Other

CircularX: CIrcular Economy - an Introduction, offered by TU Delft. (https://www.edx.org/course/circular-economy-introduction-delftx-circularx).

13.2 Literature to be reviewed

Books

Bryan, T. (2010). *Construction technology*. Chichester, West Sussex, U.K.: Blackwell.
Charlett, A., and Maubery-Thomas, C. (2013). *Fundamental building technology.* 2nd ed. London: Routledge.
Emmitt, S., and Gorse, C. (2010). *Barry's introduction to construction of buildings*. Chichester, West Sussex: Wiley-Blackwell.
Watts, A. (2014). *Modern Construction Envelopes* 2nd ed. Vienna: Ambra.
Watts, A. (2013). *Modern Construction Handbook.* Basel: Birkhäuser.

Master and PhD theses

Heesbeen, C. (2010). *Materializing the life cycle of the façade.* Master thesis. Delft University of Technology.
Quinn, K. (2010). *Improving the Feasibility of Building Deconstruction and Adaptability.* Master thesis. Massachusetts Institute of Technology.