Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences

Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (Examencommissie-BK@tudelft.nl), Mentors and Delegate of the Board of Examiners one week before P2 at the latest.

The graduation plan consists of at least the following data/segments:

Personal information	
Name	Thijs Koeleman
Student number	4371909
Private e-mail address	thijskoeleman@gmail.com

Studio	
Name / Theme	Robotic Building
Main mentor	Henriëtte Bier
Second mentor	Arwin Hidding
Argumentation of choice of the studio	I chose the studio architectural engineering, and specifically the studio robotic building, because throughout the entire master programme I gained a great interest in the construction of architecture. The construction of a building is what makes architecture and the architecture is what makes the construction. So in the search for innovative and sustainable architecture there must be innovation in the construction industry. This innovation can be brought by introducing robots as a new way of producing and possibilities, hence the choice for the robotic building studio. In my opinion these new technologies have a great potential and will undoubtedly have a considerable amount of influence on the current and future architecture

Graduation project	
Title of the graduation project	The construction industry of tomorrow implemented today
Goal	
Location:	Rotterdam, The Netherlands
The posed problem,	One of the biggest problems in the world of architecture right now is the demand for new houses because of the growing population. The Netherlands alone has a target of building one million homes before the year 2030. The houses that are available are mostly very expensive to buy, but also to rent. There is a gap between what people can afford and what the market offers. People are leaving cities to live somewhere else where rent is within their budget. Almost all different income types feel the consequences of this ongoing trend. The group of people who have the most

	difficulties are the students and young professionals (age 18-34). More high quality dwellings are needed within the price range of these people but the construction industry is not building fast enough to even reach the target of 2030. How come that the industry takes such a long time to build a building. One of many reasons are the amount of materials used in a single building. Over the past decennia we started to add all sorts of systems and new/extra components such as insulation and aesthetic elements to ensure the comfort of the end user and keep sustainability in mind. But we almost come to a point where you can ask yourself if it is sustainable to put more and more materials into a building. Is all the embodied energy in these materials small enough to establish a sustainable lifetime of a building. Because all the single materials are produced/harvested in different regions of the world, meaning they all should be transported via different routes to the building site. The process of both producing and transporting materials in the construction sector alone contributes for about one fifth of the total carbon dioxide emissions. Another disadvantage of using large amounts of different materials is that it is very time consuming to put these together and compose a building. Nowadays these materials are mostly put together by human workforce with the help of machinery. The products that create this building are often not very sustainable. The industry still produces lots of materials in linear cycles. After use it is hard to separate the materials and components because of the way they were made. A large amount of waste also appears at the end of a lifespan of a building, because these buildings were not designed to be disassembled, but rather demolished. The total amount of waste is not recyclable and mostly used for landfills and incineration which are both not very sustainable options.
research questions and	*Design Question* How to design an *affordable, highly performative* and *high quality* **tiny house** (casco) that can be **3D printed** on site and fits in a *circular construction economy*? Sub Questions What is an affordable qualitative tiny house? How to design a highly performative tiny house? How to design with the 3D printers opportunities/potentials and constraints/negativities? What are the limitations of a 3D printer? How to 3D print on the construction site? How do people and robotic components relate to each other?

	Research Question The research question should concern the new possibilities in architecture that can be made through 3D printing: How to **integrate** multiple *functions* and *systems* into a single, *mono material* **envelope** of a building? Sub Questions What functions and systems should be integrated? What materials are suited for this integration? What is the relation with the end user? What is the tradeoff for integrating functions and systems into one element? How to produce this integrated envelope element?
design assignment in which these result.	To address the need for housing for students and young professionals cities should densify. This should be done with high quality tiny houses, because those can be quickly made in a large amount while still maintaining quality. If designed parametrically they can be added throughout the city on different available and still unused plots. There is also room to improve in the construction industry to produce more high quality homes. By introducing robotics, such as 3D printers and robotic assembly machines, the building process can be more integrated, performed quicker, have a higher accuracy and provide the same if not higher quality (see figure 1) . Therefore should the typology of current tiny houses be questioned because those were based on old construction techniques. Lastly, the material usage in the construction industry should be reconsidered. The now linear way of producing and using construction materials is no longer suitable for sustainable architecture. Fewer materials should be used to produce a building, while still maintaining the interior quality for the end users, but also the sustainable ambitions. Designing a building with raw materials that can be reused should be encouraged (see figure 1).

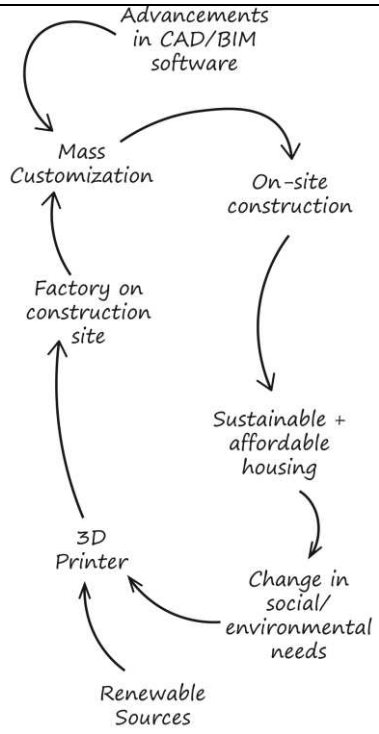

Figure 1: Improve Construction Industry

The design assignment can be concluded in the following: design a tiny house that can be 3d printed and robotically assembled for students/young professionals as an act of urban densification.

[This should be formulated in such a way that the graduation project can answer these questions.
The definition of the problem has to be significant to a clearly defined area of research and design.]

Process

Method description

In order to investigate the 3D printers potentials and limitations and transforming those to several design principles different types of methods will be used. These methods will, together with the research report, create a base from where I can make decisions towards designing new types of spaces for the final design. They will each be listed with their intended use and target.

Case studies

Most of the case studies that are conducted provide information for the design assignment of a new tiny house. Factors include the placement of the tiny house within the city, the spatial configuration and the relation between the tiny houses and the users. Other case studies provide information about the 3D printers

potentials/opportunities and the constraints/negativities. With this information several decisions can be made for both the construction site and the architectural design.

Computational design
A generative design script is used to generate the apartment and building layout on a plot in the city. This is used because of the complex spatial puzzle of different apartment types. Computational design will also be used in the integration of different functions and systems in the building envelope and intern structure. Concepts are sketched before entering them into the computer, the machine will only be used to test and optimize the ideas.

Workshops
The workshop provides hands on information about the design to robotic production process. By conducting generative design skills on envelope functions that should be integrated one can see the possibilities and limitations. This results in both a virtual model as well as a scaled prototype of the design. An analysis of the outcome of this workshop should be conducted in order to use this prototype for my thesis wisely.

Literature research
The literature research is mostly aimed at the possibilities of the 3D printer within the field of architecture, so I can make well founded speculations for the future. The 3D printing aspects that are researched are materials, fireproofing, printing techniques and on-site 3D printing

Literature and general practical preference

Bier, H. (2018). Robotic Building (Springer Series in Adaptive Environments). (H. Bier, Ed.) (1st ed. 2018). Cham, Switzerland: Springer.

Bier, H., & Mostafavi, S. (2015). Structural Optimization for Materially Informed Design to Robotic Production Processes. American Journal of Engineering and Applied Sciences, 8(4), 549–555. https://doi.org/10.3844/ajeassp.2015.549.555

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Helm, V., Ercan, S., Gramazio, F., & Kohler, M. (2012). Mobile Robotic Fabrication on Construction Sites: dimRob. Presented at the IEEE/RSJ International Conference on Intelligent Robots and Systems, Vilamoura, Algarve, Portugal. https://doi.org/10.1109/IROS.2012.6385617

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self-sufficient robotic fabrication on architectural scales. *Science Robotics*, 2(5), eaam8986. https://doi.org/10.1126/scirobotics.aam8986

Lussi, M., Sandy, T., Dörfler, K., Hack, N., Gramazio, F., Kohler, M., & Buchli, J. (2018). Accurate and Adaptive In situ Fabrication of an Undulated Wall using an On-Board Visual Sensing System. Presented at the IEEE International Conference on Robotics and Automation (ICRA), Brisbane, Australia. https://doi.org/10.1109/ICRA.2018.8460480

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Zhang, X., Li, M., Lim, J. H., Weng, Y., Tay, Y. W. D., Pham, H., & Pham, Q.-C. (2018). Large-scale 3D printing by a team of mobile robots. *Automation in Construction*, 95, 98–106. https://doi.org/10.1016/j.autcon.2018.08.004

Reflection

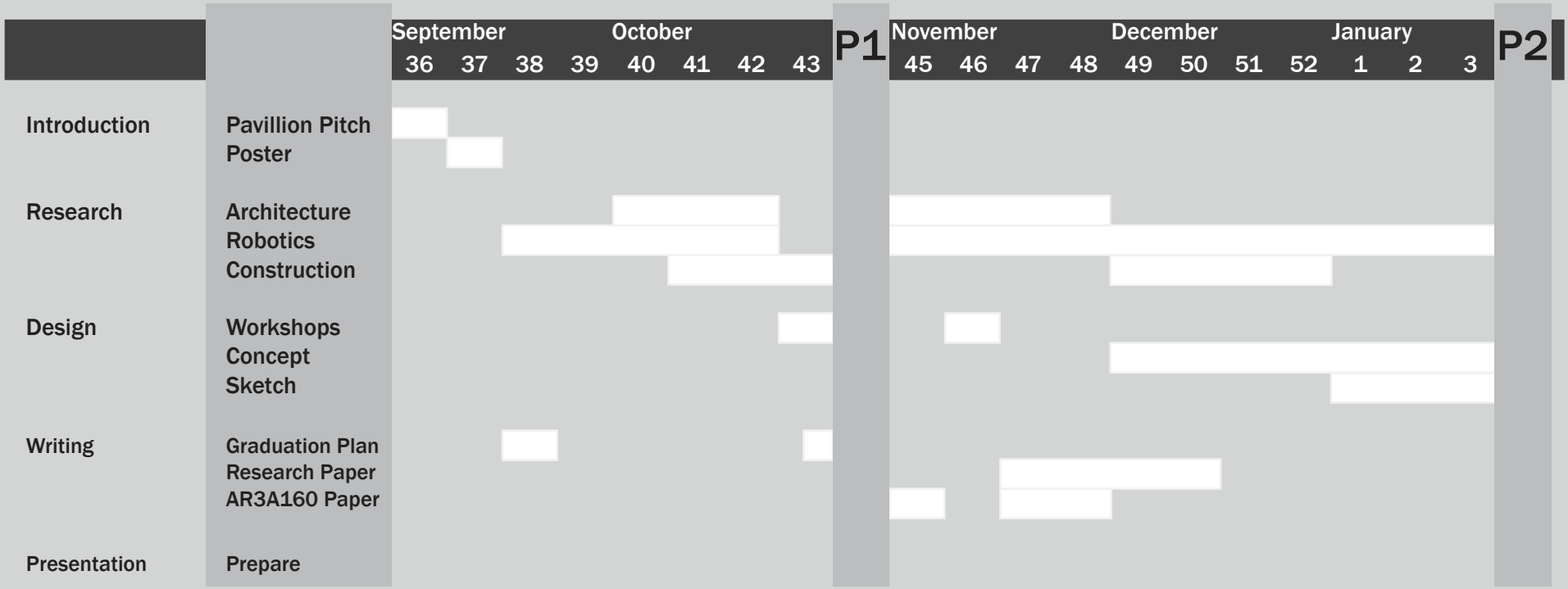
The graduation project topic is mostly about adapting and implementing the use of 3D printers on the construction site. The introduction of robotics in architecture is one of the main drivers of the Robotic Building studio. The Robotic Building studio is part of the architectural engineering programme of the master at the TU Delft. In the architectural engineering programme the focus relies primarily on the design with and for construction, but also on the makeability of a building. In my graduation project this focus is also very present because of the 3D printer. The 3D printer is just a production technique like layering bricks to create a house. This machine is also one of the drivers in my graduation project in the search for sustainable innovation. I see the need for sustainable innovation as something the Master of Architecture encourages in every single design and design decision. It has therefore been an important part in the creation of the design assignment.

The graduation project is relevant because it addresses the worldwide housing demand by introducing a new insight and approach to the existing construction sector. This specific graduation project will investigate a possible solution for a generic problem. New technologies could be the answer to cheap, standardized and unilateral housing solutions that are offered right now. These new technologies are

way more customizable for dwellings and they can meet the demands of current target groups, but can also be easily adjusted for future generations.

The need of building one million homes may be the catalysator of improvements and shifts in both the architectural and construction industry. This graduation work will provide information about the future and potential of 3D printing in both of those industry fields

Planning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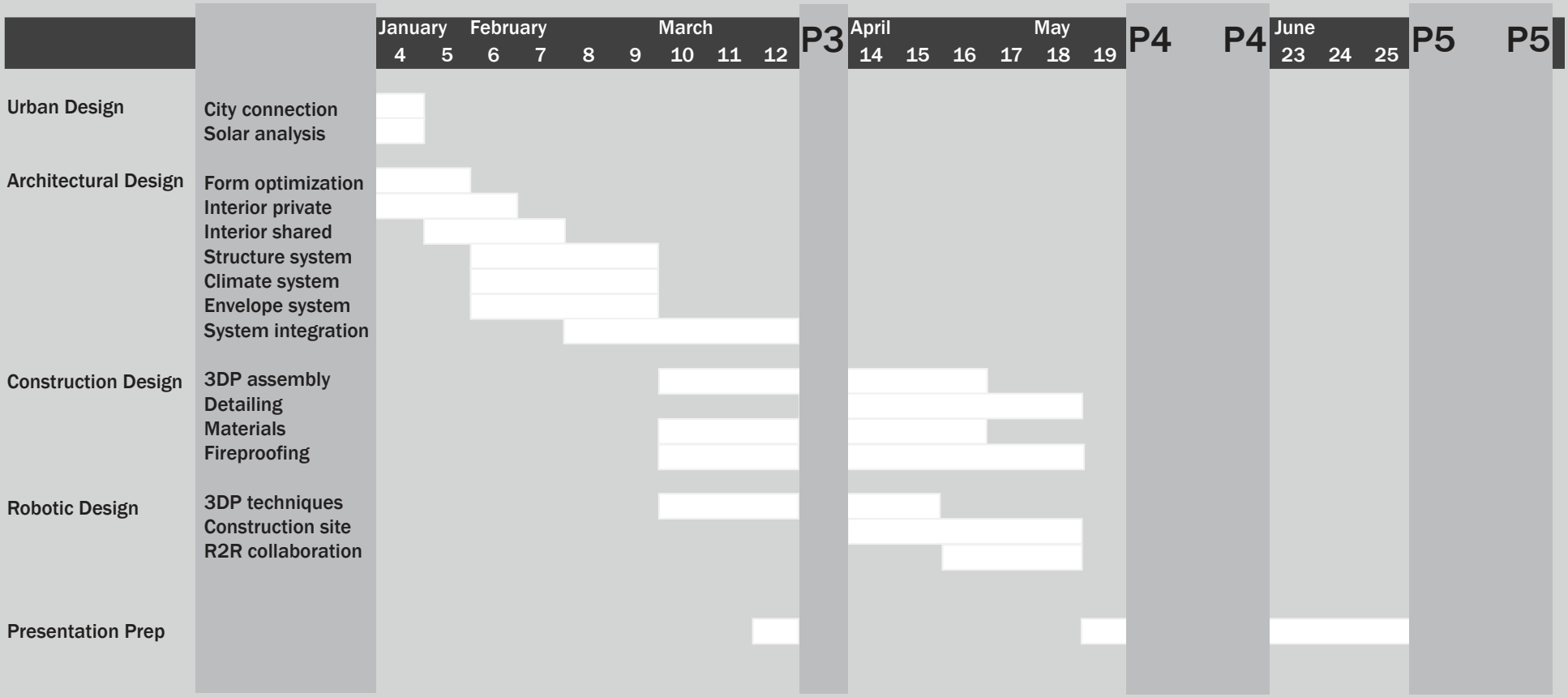
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Urban Design
City connection
Solar analysis
Architectural Design
Form optimization
Interior private
Interior shared
Structure system
Climate system
Envelope system
System integration
Construction Design
3DP assembly
Detailing
Materials
Fireproofing
Robotic Design
3DP techniques
Construction site
R2R collaboration
Presentation Prep