Graduation Plan

Master of Science Architecture, Urbanism & Building Sciences



Graduation Plan: All tracks

Submit your Graduation Plan to the Board of Examiners (<u>Examencommissie</u><u>BK@tudelft.nl</u>), 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	Marco Daniel Aristizábal Baldeón
Student number	5822874

Studio		
Name / Theme	Building Technology Graduation Studio / 3D printing at	
	large scale prototypes	
Main mentor	Serdar Asut	Design Informatics
Second mentor	Oscar Roomens	Architecture
Argumentation of choice of the studio	In an actuality where the was important for me to social problems as lack of The Design Informatics present an opportuni manufacturing process Furthermore, with an exploration also seeks to from the formal and geor	e 3D printing field is growing fast, recognize how this was addressing f housing in different countries. studio, with the use of robotics, ty for it with the additive and technological concepts. a architectural approach, this push beyond what is being done metrical aspect.

Graduation project	
Title of the graduation project	inhabit3D: 3D printing focused on social housing (large-scale prototypes) using the Kit-of-Parts method.
Goal	
Location:	No specific location. The project will try to develop more than one solution for the project to be replicable within different ground surfaces.
The posed problem,	The global challenge of affordable housing is becoming increasingly urgent due to rapid urbanization and population growth, which exacerbate the shortage of affordable options. Governments and real estate developers are being called upon to find sustainable solutions through innovative technology, community engagement, and investment in affordable housing projects. In this context, 3D printing has emerged as a potential solution.

	With that objective, 3D printing housing projects have been developed worldwide the last years. These projects often feature simple extrusions of specific floor plans, influenced by the limitations of the 3D printer's dimensions and construction crane accessibility. However, it has been observed that the layer-by-layer technique used in 3D printing aligns with the principles of traditional masonry construction. This suggests that 3D printing has the potential to go beyond existing architectural forms, similar to architects like Eladio Dieste and Antonio Gaudi, who have already explored unconventional shapes in walls and roofs, showcasing organic and distinctive aesthetic possibilities. This indicates that current 3D printing constructions are not limited to their present forms and shapes, and it is an opportune time to explore further as the industry continues to develop more dwellings.
	and cost savings, there are weaknesses in constructing dwellings, such as limitations in size and reach, speed compared to traditional construction, inability to modify the form, and difficulties in repairs. Improvements and new manufacturing techniques are needed, especially in the construction industry.
research questions and	To address a complex problem, a strategy involving multiple fields of action is required. That is why this thesis will include the concept of a kit-of-parts and the use of form-finding. Together, they aim to solve the manufacturing challenges of social housing while demonstrating the potential of technology in achieving innovative and formal results in 3D printing manufacturing.
	This raises the question: How can 3D printing, incorporating the 'kit-of-parts' concept, and form-finding techniques enhance construction efficiency, architectural adaptability, and foster innovation in form and shape?
	In the field of the Design Informatics, sub questions also arise, as:

	 What other techniques of 3D printing can be used to enhance the form or shape of the object? What constraints need to be considered in the fabrication of the prototypes? Which techniques of 3D printing can be used to optimize the material, time, and structure of the object?
	On the other side, from the Architectural point of view the interrogations are,
	 Which characteristics in a housing project makes it a social project? How can the interlocking or assembly enhance the shape of the final project?
design assignment in which these result.	The final product of the thesis will be an architectural project for a social housing project. The design will incorporate the concept of a kit-of-parts, enhancing the shape and form of the housing units and the overall building.
	As the kit-of-parts concept is being used, a comprehensive library of the final typologies that encompass all the designed parts will also be introduced. This innovative approach not only ensures the seamless integration of customer needs but also emphasizes a user-centric methodology considering customer satisfaction and engagement.
	Additionally, prototypes of the housing units or parts will be 3D printed using the printers available in the LAMA lab. Depending on the design and time constraints, the prototypes may be printed in either a certain scale or in full scale. Understanding the material which will be use also is a part of the thesis.

Process

Method description

The study within this thesis adopts a pragmatic and scientific methodology, which can be categorized into four primary domains: literature review, design, laboratory experiments, and prototyping.

Phase 1: Literature review

In this phase, extensive research is conducted on current papers and publications to become familiar with the main topics of the thesis, such as 3D printing and its relation

to housing projects. Furthermore, additional research will be conducted on the most important concepts that this study aims to explore, such as kit-of-parts, social housing, and ongoing research projects in the field of form finding in 3D printing.

The most relevant sources of this topics are mainly from researchers as Shajay Boosham, Vishu Bhooshan, from the 3D printing field.

Papers and study cases from distinguish universities as ETH Zurich and IAAC from Barcelona are also taken in consideration, and previous thesis projects from BK at the TU Delft has also been found relevant.

Phase 2: Design

This phase is the most extensive and crucial for achieving final results. It involves applying the findings from the literature review to answer the main research question and sub-questions effectively.

The phase begins with the analysis of a dwelling, breaking it down into smaller components that can be redesigned using 3D printing techniques. Once all the components are identified, various alternatives will be incorporated into the design to cater to different user needs. During this process, issues such as interlocking between the parts and housing units will be addressed. Ultimately, this stage aims to complete the library for the kit-of-parts.

However, it's important to note that subsequent phases may lead to changes in the design, making the process iterative.

Phase 3: Laboratory experiments

In this phase the first experiments will be done in the LAMA lab with the supervision of Paul de Ruiter. The chosen material for this study will be clay -why can me mentioned-. It is important to understand the properties of the material and the printer tool -robot arm or the smaller 3d printers- as it will influence in the result of the prototyping. The composition of the material is the most important problem to address viscosity, humidity, printing velocity, among others. The final result of this stage will be first printed, partially or completed, iterations of the design which can prove that a bigger or complex test can be performed. This will be the first advice if the design might need to considerate some changes.

Phase 4: Prototyping

The final phase will involve printing the prototype or prototypes of the design on the larger scale possible. The changes and improvements from the previous stage will be taken into consideration finishing with the conclusions, final comments, and further research suggestions.

Literature and general practical references

- Quintero Segura, D. F. (2016). Vivienda social alternativa: criterios de inserción de vivienda social alternativa en áreas consolidadas de la ciudad de Cuenca: modelo en zona Yanuncay (Bachelor's thesis). Retrieved from <u>http://dspace.ucuenca.edu.ec/handle/123456789/26214</u>
- [2] Forcael, E., Ferrari, I., Opazo-Vega, A., & Pulido-Arcas, J. A. (2020). Construction 4.0: A Literature Review. *Sustainability*, *12*(22), 9755. MDPI AG. Retrieved from <u>http://dx.doi.org/10.3390/su12229755</u>

- [3] Zhang, J., Wang, J., Dong, S., Yu, X., & Han, B. (2019b). A review of the current progress and application of 3D printed concrete. *Composites Part A: Applied Science and Manufacturing*, 125, 105533. <u>https://doi.org/10.1016/j.compositesa.2019.105533</u>.
- [4] De Schutter, G., Lesage, K., Mechtcherine, V., Nerella, V. N., Habert, G., & Agusti-Juan, I. (2018). Vision of 3D printing with concrete — Technical, economic and environmental potentials. *Cement and Concrete Research*, *112*, 25–36. <u>https://doi.org/10.1016/j.cemconres.2018.06.001.</u>
- [5] Howe, A., Ishii, I., & Yoshida, T. (1999). *Kit of Parts—A Review of Object-oriented Construction Techniques*.
- [6] Bhooshan, S., Bhooshan, V., Dell'Endice, A. et al. The Striatus bridge. Archit. Struct. Constr. 2, 521–543 (2022). https://doi.org/10.1007/s44150-022-00051-y
- [7] Douroudi, E. (2020). *Implicit Representation for 3D-Printing Aware Shape Design*.
- [8] Burger, J. (2019). *Eggshell: Design and fabrication of non-standard, structural concrete columns, using 3D printed thin-shell formwork.* (MSc thesis)

Reflection

1. What is the relation between your graduation (project) topic, the studio topic (if applicable), your master track (A, U, BT, LA, MBE), and your master programme (MSc AUBS)?

The chosen studio in the Design Informatics field is highly relevant to the thesis topic. It not only focuses on additive manufacturing techniques but also provides the necessary technology to fabricate samples and prototypes for testing the results. Additionally, the incorporation of the kit-of-parts concept aligns with the technological and production aspect.

The second field of research explores the Architectural perspective, which will contribute conceptually and practically to the thesis by shaping the design and form of the project. Furthermore, the inclusion of the social housing concept expands the scope beyond the BT chairs.

By taking this interdisciplinary approach for the thesis, beyond the confines of the BT chairs, the outcome is expected to be innovative and reflective of the MSc AUBS programs.

2. What is the relevance of your graduation work in the larger social, professional, and scientific framework.

The social problems of today, especially those in my immediate environment, city, and country, have always concerned me throughout my career as an architect. Now, with better knowledge and access to technological tools, I have an opportunity to propose

a solution to a problem like the lack of quality housing for people. When I moved to the Netherlands, I realized that housing shortage is not only a problem in my country but also in many other places.

Therefore, the topic of my thesis addresses a current problem and aims to propose a solution, or at least attempt to do so, by combining technology and architectural innovation. Also, by including the topic of the "social" housing, different strategies and solutions will be addressed and proposed. Overall, the focus is on an urgent global problem: the need for affordable and sustainable housing solutions, giving a contribution for the society.

From a professional point of view, there are currently several 3D printing companies dedicated to printing houses. However, the existing offer is not sufficient in terms of scale and production to address the housing issue and provide an innovative solution to the formal aspect, which was a concern in the previous study. If a successful proposal is developed, it could serve as a solution for real-life applications and contribute to the field of technology. Undoubtedly, one of my professional interests is also the opportunity to work with 3D printing and robotics.

As the thesis aims to combine architectural and technological inquiries, working with each proposed concept will be a challenge which deep research and study are needed. Specially in the field of the additive manufacturing and robotics, where testing the prototypes will conform an important part of the result.

Other universities and entities such as ZTE Zürich, IAAC Barcelona, and the ZHA department of computational design research are also actively researching new techniques. They focus not only on optimizing the printing process but also on seeking beauty and exploring new shapes. This demonstrates the relevance of this academic and scientific study and its ongoing process.