

# 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](mailto: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 |               |
|----------------------|---------------|
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| Student number       | 4607643       |

  

| Studio                                |                                                                                                                                                                                                                                                                                                                                      |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Name / Theme                          | Structural design: Discrete Timber                                                                                                                                                                                                                                                                                                   |
| Main mentor                           | Stijn Brancart                                                                                                                                                                                                                                                                                                                       |
| Second mentor                         | Hans Hoogenboom                                                                                                                                                                                                                                                                                                                      |
| Argumentation of choice of the studio | I'm interested in creating a construction configurator. It uses a discretized 3D grid to place components and includes a structural analysis to assess different configurations. The modular components aren't necessarily timber products, but the essence of the Discrete Timber topic is captured in a construction configurator. |

  

| Graduation project              |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Title of the graduation project | Construction configurator: aligning the customer's preference with the manufacturer's capabilities                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| Goal                            |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| Location:                       | The Netherlands                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
| The posed problem,              | <p>The design process in BIM software is convoluted and requires advanced technological skill from the user.</p> <p>Moreover, a lack of integration between the phases and stakeholders involved in construction causes design issues. Resolving these issues requires extra reorganization efforts, leading to delays, higher costs, and potentially lower quality buildings.</p> <p>Integrated construction configurators offer a solution to these issues. However, most of the existing configurators lack flexibility. Instead, they provide the selection of predefined</p> |

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|                                          | room sized modules or adaptive parameter values. Few research studies explore the flexible spatial arrangement of components to achieve design variations.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| research questions and                   | <p>Main research question:<br/>How can the design space of integrated construction configurators be enlarged?</p> <p>Sub research questions:</p> <ol style="list-style-type: none"> <li>1. What is missing in current construction configurators?</li> <li>2. What are the theoretical frameworks that can inform the architecture of the proposed software?</li> <li>3. What is the workflow and system design of the proposed software?</li> <li>4. What is the configuration process of the proposed software?</li> <li>5. How is the system grid organized?</li> <li>6. What grid size is appropriate to be compatible with as many building elements/products as possible?</li> <li>7. How can building components and assemblies be organized into a categorical hierarchy?</li> <li>8. How can module size or opening variations be facilitated in the proposed software?</li> <li>9. How does the structural analysis work in the proposed software?</li> </ol> |
| design assignment in which these result. | Develop an integrated construction configurator. The configurator should act as proof of concept. While it should portray the main system/structure of the software, it doesn't need to include all features required for integrating from design to manufacture. The minimum is an immersive experience that allows the configuration of structural elements on a 3D grid. Additionally, the structural configuration is analyzed to give feedback on required profiles or products and material use. Next steps would be to include additional building                                                                                                                                                                                                                                                                                                                                                                                                               |

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| <b>Process</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |                                                                                                                                                                                                                 |
| <b>Method description</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                                                                                                                                                                 |
| <p><b>Literary research</b></p> <p>First, literary research is conducted on current construction configurators and research on construction configurators. This literary research is utilized to understand what a construction configurator is, how it compares to BIM, how they can be categorized, which ones are currently available, and what is missing in current construction configurators.</p> <p><b>Software proposal</b></p> <p>Secondly, the literary research is used to propose a new construction configurator with features and improvements over current construction configurators. The proposal includes a theoretical framework, a workflow and system design, a configuration process, a framework for a system grid, a framework for a kit-of-parts, and a framework for structural analysis.</p> <p><b>Software development</b></p> <p>Lastly, the theory and plan for the proposed construction configurator will get translated into code and software. For this step Unreal Engine will be used to serve as the backbone for the software, it is the 3D environment in which the project can get developed. Within Unreal Engine, code specific to the project will get written. This code can be separated into a data, application, and presentation tier, also called the database, backend, and frontend. It is essential for each tier to get developed to some degree.</p> <p>The first step will be to write the code for a uniform 3D system grid. Then, a database of structural elements needs to be developed. This database should contain one column, one beam, one structural wall or bracing, and one floor/roof system. Next, the code needs to be developed for the interaction of the user with the software. This includes the orientation and movement in the 3D environment, the selection of an item from the database, and then the placement of that item on the 3D system grid. The final step will be the structural analysis of the configuration.</p> <p><b>Supplementary software development</b></p> <p>After these steps the software should work with limited features, only including structural design and assessment. The next steps will implement more features to make the software relevant for more project phases, projects, and stakeholders. The first of these next steps would be to allow size variations in the 3D system grid and the (structural) elements in the database. Next, the inclusion of additional building products, such as partition walls and façade elements. Next, allowing opening variations in the planar elements in the database. Next, developing the code which</p> |                                                                                                                                                                                                                 |

allows importing of BIM families, so they can extend the database. It is unlikely that more features than this can be implemented in the timeframe of this thesis. However, other possible features include connections between elements, non-orthogonal system grids, importing of custom (complex shaped) elements.

## Literature and general practical references

Benjamin, S., Christopher, R., & Carl, H. (2022). Feature modeling for configurable and adaptable modular buildings. *Advanced Engineering Informatics*, 51.

<https://doi.org/10.1016/j.aei.2021.101514>

Cao, J., Bucher, D. F., Hall, D. M., & Lessing, J. (2021). Cross-phase product configurator for modular buildings using kit-of-parts. *Automation in Construction*, 123. <https://doi.org/10.1016/j.autcon.2020.103437>

Cao, J., & Hall, D. (2019). AN OVERVIEW OF CONFIGURATORS FOR INDUSTRIALIZED CONSTRUCTION: TYPOLOGIES, CUSTOMER REQUIREMENTS, AND TECHNICAL APPROACHES. *Proceedings of the European Conference on Computing in Construction*, 295–303. <https://doi.org/10.35490/ec3.2019.145>

Louth, H. D., Fragachan, C., Bhooshan, V., & Bhooshan, S. (2024). Configurator: A Platform for Multifamily Residential Design and Customisation. In *Lecture Notes in Mechanical Engineering: Vol. Part F1562* (pp. 769–805). Springer Science and Business Media Deutschland GmbH. [https://doi.org/10.1007/978-3-031-36922-3\\_40](https://doi.org/10.1007/978-3-031-36922-3_40)

Potseluyko, L., Pour Rahimian, F., Dawood, N., Elghaish, F., & Hajirasouli, A. (2022). Game-like interactive environment using BIM-based virtual reality for the timber frame self-build housing sector. *Automation in Construction*, 142.

<https://doi.org/10.1016/j.autcon.2022.104496>

Wikberg, F., Olofsson, T., & Ekholm, A. (2014). Design configuration with architectural objects: Linking customer requirements with system capabilities in industrialized house-building platforms. *Construction Management and Economics*, 32(1–2), 196–207. <https://doi.org/10.1080/01446193.2013.864780>

## 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 development of a construction configurator is a very interdisciplinary undertaking. Configurators originate from the realm of product design or industrial design. Creating a platform like a configurator is in the realm of software development or computer science. The approach in user interaction and the engine used in the platform is based on the gaming industry. This specific configurator is meant to serve as an interface between the end user and architect, therefore the field of architecture is also involved.

However, the content of the configurator is mainly based on knowledge from the architecture, engineering, and manufacturers domain. Building technology is the field that bridges the gap between these domains. This knowledge is incorporated in the project by orchestrating the configuration process, this includes managing how

building elements come together, but also analyzing and evaluating configurations. An important way of evaluating a configuration is by means of a structural analysis, which is a core part in this project.

For this reason, this project fits into the Structural department, but it also fits in the Computational Design department. The studio topic is Discrete Timber, the configurator uses a discretized grid to structure the configuration process. The building blocks aren't limited to timber products, but can be included.

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

Integrated construction configurators are relatively new, under researched and underdeveloped. However, they offer tremendous potential, with many benefits over conventional BIM. Especially the ease of use and improved integration between stakeholders and phases are promising aspects of integrated construction configurators. The ease of use can mostly be accounted to the immersion and limiting of the solution space caused by the discretized system grid, reducing the time spent for task completion and reducing the number of errors. The improved integration comes from a tool that is easy enough for the end-user to use and embeds expert knowledge and products from manufacturers in the tool as configuration rules and building blocks. This prevents design issues and therefore saves time, costs, and potentially results in higher quality buildings.

To conclude, integrated construction configurators have the potential to revolutionize, not the way we build, but the way we design our buildings.

|                                                                     | P2     |         |        |        |        |        |        |        |        |        |        |        |        | P3     |        |        |        |        |        |        |        |        | P4     |        |        |        |        |        |        | P5     |        |        |        |  |  |  |  |
|---------------------------------------------------------------------|--------|---------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--|--|--|--|
| Start date                                                          | 13-Nov | 20-Nov  | 27-Nov | 04-Dec | 11-Dec | 18-Dec | 25-Dec | 01-Jan | 08-Jan | 15-Jan | 22-Jan | 29-Jan | 05-Feb | 12-Feb | 19-Feb | 26-Feb | 04-Mar | 11-Mar | 18-Mar | 25-Mar | 01-Apr | 08-Apr | 27-Apr | 28-Apr | 29-Apr | 06-May | 13-May | 20-May | 27-May | 03-Jun | 10-Jun | 17-Jun | 24-Jun |  |  |  |  |
| Week year                                                           | 46     | 47      | 48     | 49     | 50     | 51     | 52     | 1      | 2      | 3      | 4      | 5      | 6      | 7      | 8      | 9      | 10     | 11     | 12     | 13     | 14     | 15     | 18     | 18     | 18     | 19     | 20     | 21     | 22     | 23     | 24     | 25     | 26     |  |  |  |  |
| Task \ Week academic                                                | 2.1    | EXTREME |        |        |        | 2.6    | Break  | Break  | 2.7    | 2.8    | 2.9    | 2.1    | Break  | 3.1    | 3.2    | 3.3    | 3.4    | 3.5    | 3.6    | 3.7    | 3.8    | 3.9    | 4.2    | 4.2    | 4.2    | 4.3    | 4.4    | 4.5    | 4.6    | 4.7    | 4.8    | 4.9    | 4.10   |  |  |  |  |
| P1 presentation                                                     | 20-Nov |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| LR: construction configurators research/products                    |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| LR: theoretical frameworks for configurators                        |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| LR: structure and sizing of the system grid                         |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| LR: categorical hierarchy of building components and assemblies     |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| LR: structural analysis                                             |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| Graduation plan                                                     |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P2 report: develop                                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P2 presentation: develop & prepare                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P2 presentation                                                     |        |         |        |        |        |        |        |        |        |        |        |        |        | 29-Jan |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: getting familiar with Unreal Engine                             |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop uniform 3D system grid                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop database of 'generic' structural elements               |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for orientation and movement                       |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for selection of items in database                 |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for placement of selected items                    |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for connecting structural elements                 |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| Draft reflection                                                    |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P3 report: develop                                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P3 presentation: develop & prepare                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P3 presentation                                                     |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        | P3     |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for applying imposed loads to floors/roofs         |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: extend structural database with profiles/products               |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for recommending structural floor/roof products    |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for structural analysis of linear/bracing elements |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for recommending structural profiles/products      |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for calculating material use and cost              |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop database of 'generic' interior/exterior partition walls |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for size variations in 3D system grid (maybe)      |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| SD: develop code for size variations in structural elements (maybe) |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| Reflection                                                          |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P4 report: develop                                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P4 presentation: develop & prepare                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P4 presentation                                                     |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        | P4     |        |        |  |  |  |  |
| SD: cleaning up code and visualisation/presentation                 |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P5 report: develop                                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P5 presentation: develop & prepare                                  |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |  |  |  |  |
| P5 presentation                                                     |        |         |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        |        | P5     | ?      |        |  |  |  |  |