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	Leticija Aleksandra Petrova
Student number	5306345

Studio		
Name / Theme	Explore lab	
Main mentor	Roel van de Pas	Architecture, design
Second mentor	Hubert van der Meel	Building technology
Third mentor	Pirouz Nourian	Research, design informatics & generative design
Argumentation of choice of the studio	Explore lab allows to combine multi-disciplinary approaches and ideas and celebrates new methods towards working in architecture. I wanted to combine several ideas from the disciplines of mathematics & computer science & architecture to develop a building system for affordable and scalable housing. This studio gives room for flexibility in designing the actual research process not only the freedom to explore within the topic.	

Graduation project	
Title of the graduation project	Reconfigurable Discrete Architecture for Affordable Housing
Goal	
Location:	Netherlands, Amsterdam, Ijburg, Strandeiland, Muidenbuurt
The posed problem,	The production of homes should be accessible, affordable and the housing units should offer a broad range of variety how the spaces can be configured and what spatial qualities they offer. This brings to the fact that the standard way of building our homes needs to be changed, instead of on average 7000 different parts and processes a building needs a simpler production chain where the complexity of the process is decreased, and more actors can participate in constructing which can help to decrease the housing shortage. The current solutions of modular and prefabricated parts do not offer enough variety and broad range of customization. This research aims to create a method which allows to design a limited set of stackable timber elements that can be configured into versatile affordable housing units using combinatorial design and compression only structures.
research questions and	How to design a small set of stackable timber elements to form both a structure and the inner/outer shells of a building that can be configured into versatile, scalable, and affordable housing units using combinatorial design and a compression-only structure? **Sub questions** • How to design a dimension system of the elements that has a strong relation to people's movement and the internal configurational logic of a home based on ergonomics? • How to ensure that architecturally and ergonomically valid and versatile configurations can be realized by using the proposed limited set of construction blocks? • How to incorporate the manufacturing costs and limitations in the design of the stackable wooden blocks? • How to ensure that the predefined set of building blocks allows for a scalable structure?
design assignment in which these result.	The design project is a combination of 2 single family homes in the yet to be built neighborhood Ijburg, more specifically Strandeiland in Amsterdam. These 2 homes should have the flexibility to be divided in the future into 4 apartments to ensure adaptability to new family structures. As a case study the 3 generation house by Beta office is analyzed and how they treated the circulation and the possibility to change apartment division. (Figure 1)

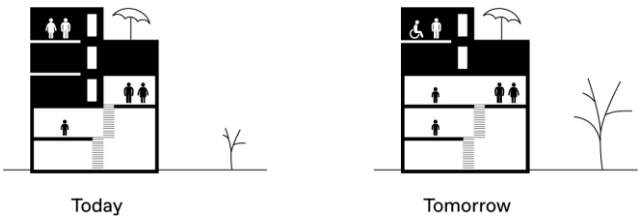
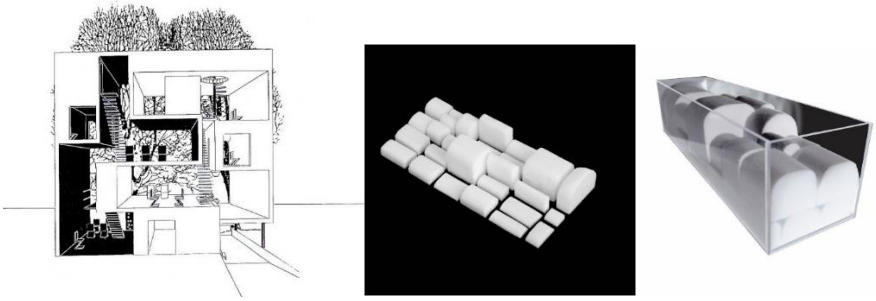


Figure 1: Beta office, 3 generation house

The created building system within the research is necessary to ensure an affordable solution, that brings variety in its possible designs and an easy production and assembly process since the target is young families with children. This should be a part of the process of tackling the housing shortage. In addition to creating new building system new architectural typologies are studied due to the granularity of the building system and due to the goal of adaptability of the floorplan for the future. (Figure 3) Therefore, the project "Double house" by MVRDV is studied to discover new possibilities for boundaries between 2 homes combined into 1. And the project "Vault house" by Johnston Marklee is used as an inspiration for the typology study.



(Left to right) Figure 2: MVRDV, Double house Utrecht 1997, rethinking the boundary of 2 homes in 1; Figure 3 & 4: typology massing, Vault house by Johnston Marklee

The system and the building of the family homes seeks to be as simple as laying Lego blocks yet as detailed and customized as any highly detailed architectural project.

Process

Method description

Research methodology

This research project is a Research & Development project since it is within the realm of "Sciences of the Artificial". (Simon, 1996) The methodological approach for the framework of this research is based on design science research which is a way of "structuring research methods as a methodology in the context of developing design or "spatial decision support systems" in the more general context of developing information or decision support systems". (Nourian, 2016) (Peffers, Tuunanen, Rothenburger, Chatterjee, 2007) The more specific framework within the realm of design science research partially used in this research project is the "Go design" framework which is a modular generative design framework introduced by Shervin Azadi & Pirouz Nourian. (Azadi & Nourian, 2021) It is a framework for design processes in the built environment and it provides unification of participatory design and optimization to reach mass-customization and evidence-based design. This framework is articulated mathematically through 3 procedures: 1) space-planning, 2) configuring, and 3) shaping. (See figure 8) It frames typical design problems as multi-dimensional, multi-criteria, multi-actor, and multi-value decision-making problems (Azadi & Nourian, 2021) However, in this research only the 2nd (Configuring) and 3rd (Shaping) procedures of the Go Design framework are undergone, the 1st procedure (Planning) is seen as a given.

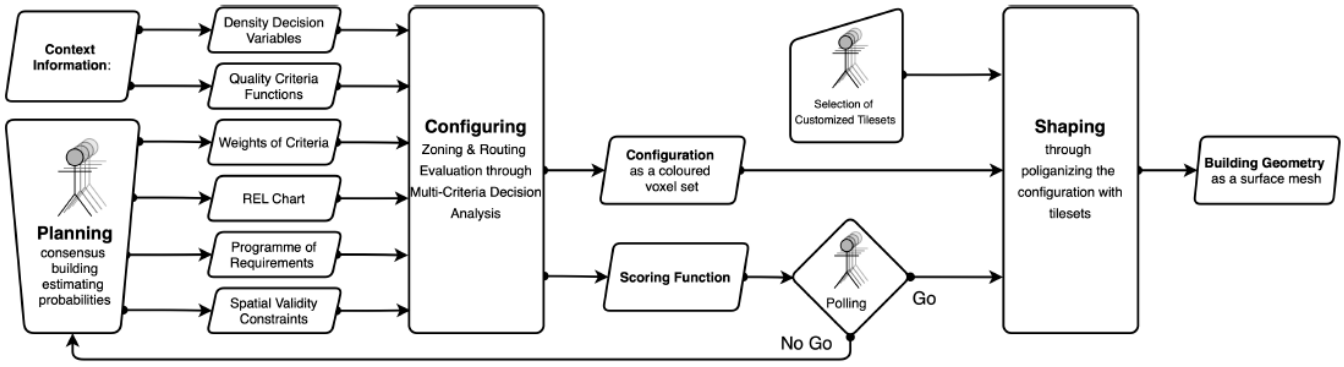


Figure 5: Main flowchart of the Go design framework (Azadi & Nourian, 2021)

Proposed methodology
Process overview

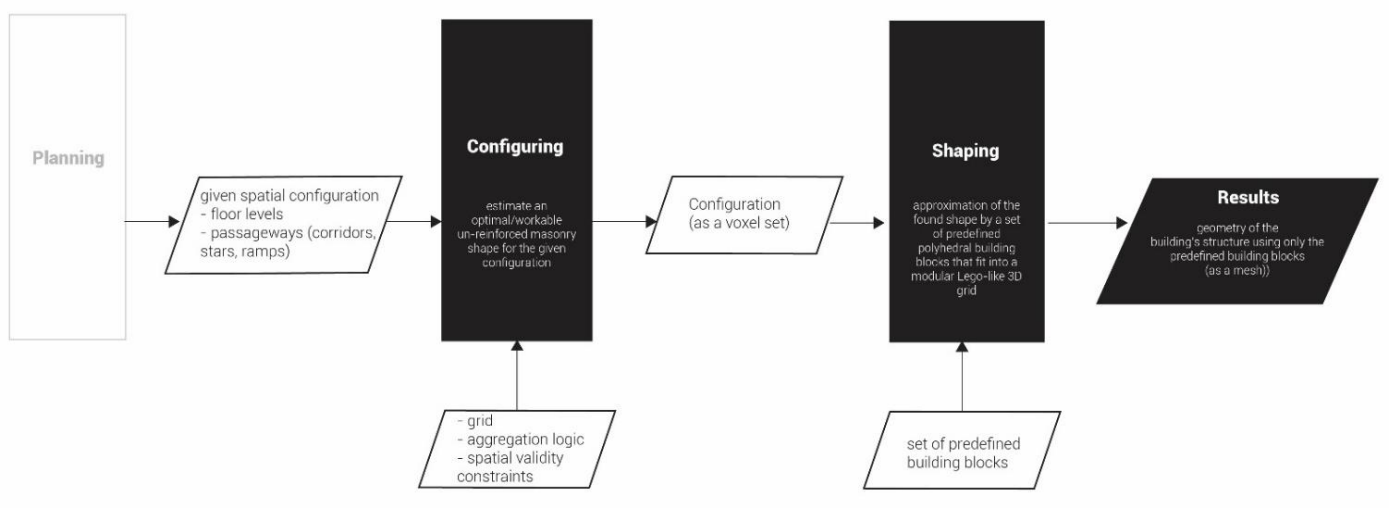


Figure 6: General flowchart for this research, Author

0. The input of the process within the Configuring procedure is a given spatial configuration, therefore the Planning procedure is not a part of this research. The spatial configuration is meant to be a set of floor levels connected with a set of passageways - corridors, stairs, and ramps. See below an example:
1. The next step is to design/estimate an optimal/workable un-reinforced masonry shape for the given configuration, possibly separated according to the separate floor levels/rooms. (Voxel set)

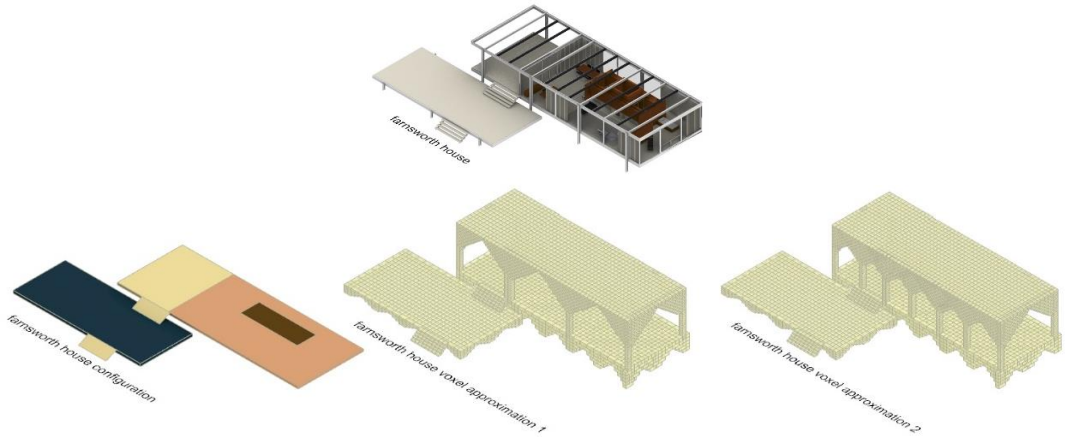


Figure 7: (Top) Farnsworth house 3D , (Left) Configuration of floor levels and stairs, (Middle & right) configuration approximation wih a voxel set 2 options

2. The final step is the approximation of the found shape by a set of predefined polyhedral building blocks that fit into a modular Lego-like 3D grid.

Figure 9: final possible spaces after shaping with predefined blocks (from left to right: (1) gothic vault, , (2) gothic vault viewed from bottom, (3) diamond vault, (4) diamond vault viewed from bottom)

The result of the procedures is a mesh surface geometry for the desired housing project based on the created building blocks and inputted spatial configuration. Additionally, all procedures together create a methodology, a meta level game, which are steps that can be taken, and another solution can be found to have a set number of blocks with which variety of valid solutions can be created.

Proposed glossary

- Voxel grid – 3-dimensional grid based on ergonomics on which all the predefined building blocks are based

- Tessellation - or tiling is the covering of a surface, using one or more geometric shapes, called tiles, with no overlaps and no gaps.
- Building block - predefined element, mesh surface (part of the set of the final blocks)
- Configuration - an arrangement of elements in a particular form or combination.
- Spatial configuration – A set of floor levels and connecting spaces – corridors, stairs, and ramps

Configuring & Shaping procedure specification

The Configuring and Shaping procedures can be broken down into specific steps that create the logic of the configurator and the predefined building blocks.

Configuring

1. Defining an underlying grid for the whole system within the context of housing
   - ➔ Relation to people's movement,
   - ➔ Constraints based on ergonomics and standard space sizes
2. Defining the aggregation logic and the interface between many elements to create a variety of solutions
   - ➔ Possibility to extend each element upwards in the z direction (and some also in the x and y)
   - ➔ Possibility to customize the scale of the building (ceiling height, room width etc)
3. Defining spatial validity constraints within the context of housing
   - ➔ Access, Daylight & Structure

Shaping

4. Defining the structural approach for the building to be scalable
   - ➔ Repetition
   - ➔ Compression only structure
5. Incorporating the limitations and costs of manufacturing within the design of the elements
   - ➔ Trace the production of the material, for example, wood comes in standard size sheets
   - ➔ Manufacturing of the pieces: The elements can be created through the process of CNC milling
6. Choosing an element creation approach
   - ➔ Topological Polyhedralization
   - ➔ Tessellation & extrusion
7. Adapting final space desired aesthetics to each building block

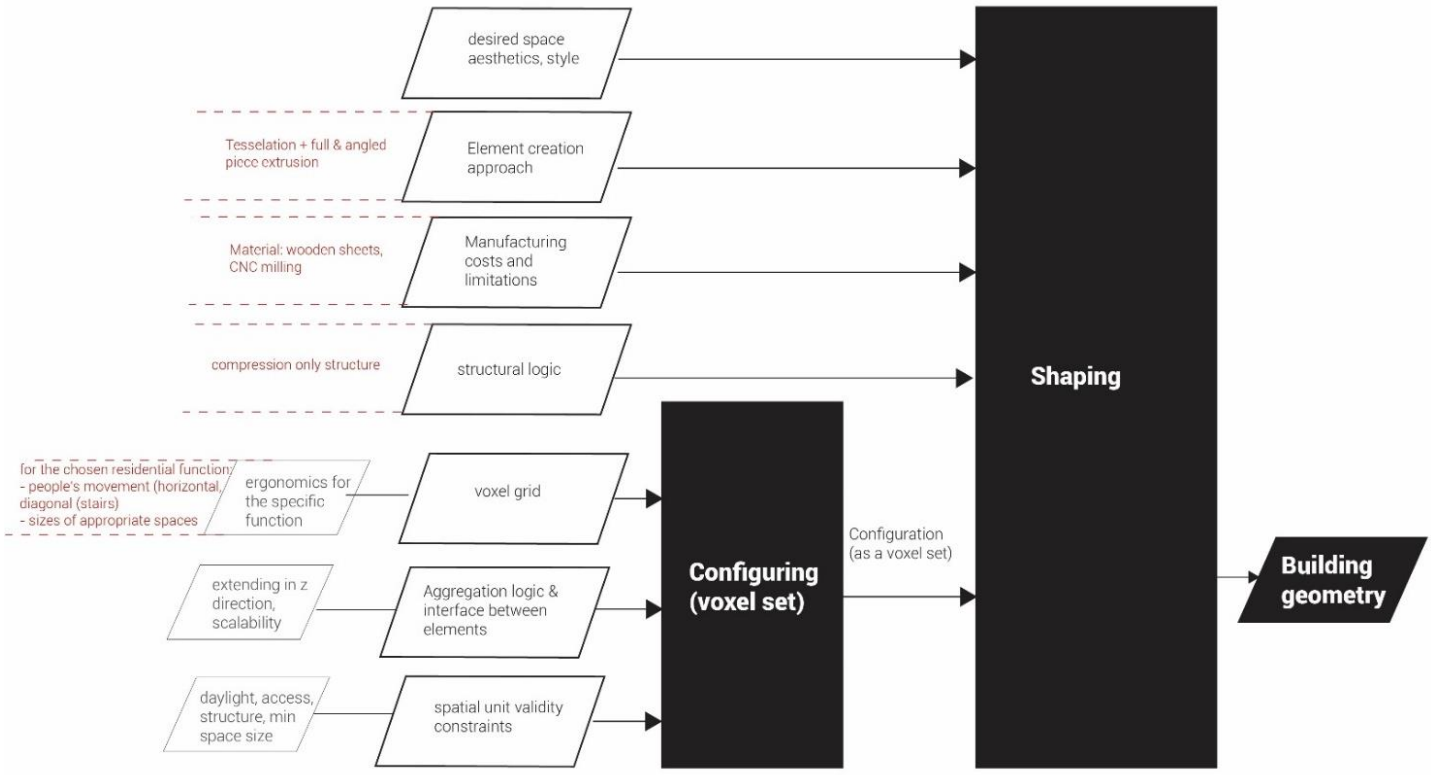


Figure 10: Configuring and Shaping procedure flowchart, Author

Design methodology:

The design consists of case studies, typology studies and analysis of how to position the infill of a building, the façade, the structure etc. See below the specific themes, steps, and case studies planned to be undergone.

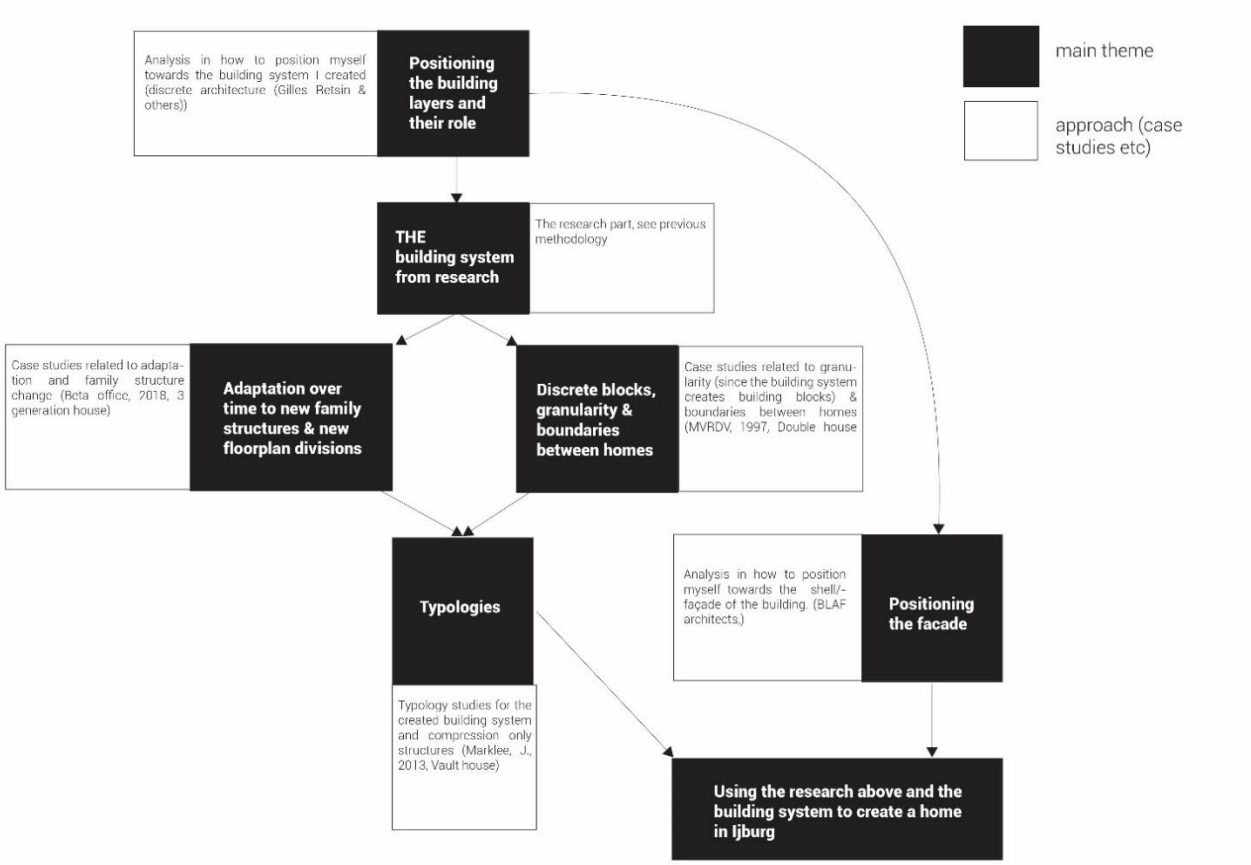


Figure 11: Design methodology, Author

Literature and general practical preference

Books, journals, articles

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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)?

My graduation topic, my Master track (A) and my Master programme (MSc AUBS) are highly interconnected and related. The graduation project tries to rethink the DNA of architecture to find affordable housing solutions. It rethinks the structure of a building, the assembly of it and the customization of the final design. The building block is in between a brick and a whole room. It is a continuation of the ideas of modularity and prefabrication; it is the next step - discrete architecture. Creating a building system directly relates to other design aspects such as sequence of spaces, variety of solutions and customization to clients needs. Even though it is a multi-disciplinary project intertwining Architecture, Maths, a bit of Computer science, in its core it tries to solve an architectural problem and asks questions which arise in every single architecture project, the difference is that it tries to encapsulate many answers in 1 system.

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

Societal relevance

Due to a very slow and expensive process of construction the act of building is accessible only to a few actors, therefore the housing supply is limited and leads to a housing shortage. Firstly, housing solutions are necessary, for example, in the Netherlands to take control of the situation, "845,000 homes need to be built by 2030" (Lalor, R. (2021)). Secondly, a home is one of the biggest investments in most people's lives where a considerable amount of time is spent, therefore a sense of identity and variety within the housing supply is necessary for user's to be able to customize their spaces. By redefining the spatial configuration problem through mathematics and using combinatorial design enough repetition and low costs can be reached yet also variation within the housing units can be offered. Through intertwining design, fabrication & automation a more accessible and open-ended built environment can be created.

Scientific relevance

Research in digital design has moved beyond engaging the field not only through sophisticated forms but also through the politics and economics of fabrication. (Sanchez, 2021) Current discourse moves beyond modularity and prefabrication and demonstrates a higher degree of variability, versatility through only a limited set of building parts. In addition, it goes a step further using these building parts and exploring the possible patterns that can be created and provide variety and differentiation at a lower cost compared to custom made elements. The combination of a predefined set of elements and thinking in patterns is redefining the way how architectural production chains work, however, there is still a gap between these ideas and physical housing solutions. Most work has been done either on different indoor or urban furniture (Retsin, 2019) or pavilion designs (Retsin, 2017), only with a few attempts to create a closed space. (Retsin, 2021)

There have been a few examples from building structures such as the Belgian "Gablok" (Gablok.be, 2022) for wall systems, but many of the examples can be found within game design such as the Lego (Lego.com, 2022) blocks. "Gablok" has achieved an architectural "Lego" piece that lays walls as easily as a Lego structure. The strength of the Lego logic is how simple it is to stack the blocks to create a structure and the grid on what all the elements are based on. The grid is rigid enough for everything to fit and create valid structures, yet it is small and open enough to not predetermine the result. The limitation of Lego is the fact that the structures are made to be viewed from the outside similarly as most sculptures. However, in architecture that would only represent the facade, a small part of the whole building. The most important part is the interior space that is created which people can use for living, working etc. Therefore, the missing elements additionally to the walls are ones that create floors, roofs & ceilings in order to create an interior space. The Gablok system shows potential with the wall creation and the lego logic, therefore, there is room for shaping new elements to create complete architectural spaces.

This project, firstly, aims to use the ideas of reconfigurable discrete architecture, combinatorial design and compression-only structures to apply them to a limited set of stackable timber elements to reach a large design space and variety within the configurations that the elements offer. Secondly, the goal is to move beyond furniture and pavilions and to provide complete housing structures. To create floor, ceiling, and roof elements in addition to the "Gablok" wall system. Thirdly, to create a set of elements that work as smoothly as Lego blocks within the context of housing the size and shape of the elements need to be related to several aspects: ergonomics, people's movement, the size of the spaces that are used and the standard elements used in such spaces, as well as the material and production of such elements to tackle the decrease in productivity. Finally, it also needs to provide variety within the solutions offered for clients to have the possibility to customize their homes.