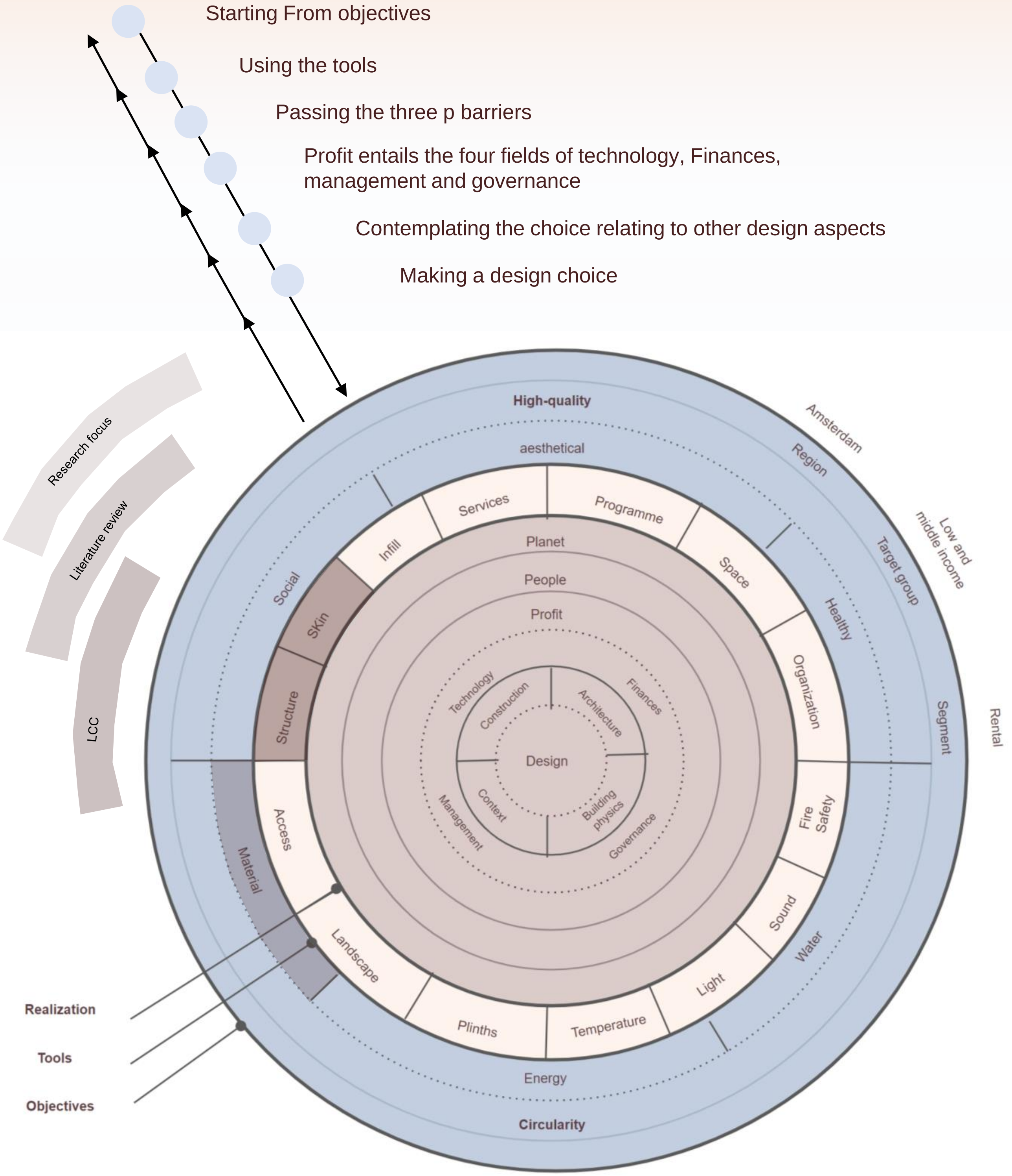
Diagram: Research and Design Plan



Research Plan: Sahar Golchin Far

(1) Introduction

1.1. Problem statement

Today the Netherlands is experiencing a 4.2% shortage in the housing stock which accounts for 331,000 homes that are needed (Lijun, 2020). The market not only has to supply for the current shortage, but it also has to meet future demands. It is estimated that the country should expect 850,000 population growth by 2030 that entails 775,000 extra households that call for a place to live in ten years from now (BPD, 2016). Highly urbanised zones in the Netherlands such as the Randstad cities (Amsterdam, Rotterdam, The Hague and Utrecht) are facing this national issue more severely. Amsterdam will have 18% growth in the number of households by 2030, that is the highest rate compared to the rest of the region (BPD, 2016). The average Amsterdam housing price was 500.000 euros while the nationwide price of a home was 314.000 euros in 2019 (Solanki, 2020). It is getting increasingly harder to find affordable housing, especially for the low and middle-income households (Tasan-Kok & Özogul, 2019).

The ambition of Amsterdam's city government is to construct 52,500 dwellings by 2025 to tackle the crisis (Amsterdam, 2020). The plan is to dedicate 40% of the constructions to social housing and to include mid-priced housing for another 40% (Solanki, 2020). Building this large amount of dwellings in the current traditional and linear building culture has negative consequences on the environment. The construction industry is the most waste-producing sector compared to agriculture, metal, food and textile industries (CBS, 2019). In 2012, 25 million tonnes of waste was produced in the construction sector that was three times more than the total household wastes. In the Netherlands, more than 95% of the demolition waste is recycled and they get used in civil constructions for fillers or base materials of roads. However, in the building industry, only 3 or 4% of construction materials are Secondary. Besides, recently there is a surplus of recycled demolition waste and secondary materials since less infrastructure is needed and constructed in the civil sector. Therefore, the construction industry should transition from a linear way of production to a circular economy as soon as possible. In a circular economy, recycling is one of the last resorts and the aim is high-quality use and reuse of materials (Schut, 2016).

Demolition typically happens to low-quality and inexpensive Dutch houses like the postwar mass housing stock. Between 1995 to 2003 the rate of demolished houses to new constructions was 1 to 7 (Icibaci, 2019). It is important to reuse the products from demolished constructions but the building market still needs to use new building products since second-hand materials are not always available. The industry should stop using building products without considering their environmental impact, deconstruction and the end-of-life scenario. Biobased materials have the potential to be feasible and sustainable alternatives to the deep rooted current construction trend of concrete and brick. However, biobased products are not commonly used in the Netherlands which makes them costly.

Housing associations (or woningcorporaties) are private non-profit organizations that provide rent regulated social housing to the vulnerable populations in Dutch cities (Hoekstra, 2013). Housing associations can play a significant role in overcoming these housing and environmental crises. The housing stock of the Netherlands consists of 33% of social housing that is the highest rate among European countries (Czischke & van Bortel, 2018). However, today it takes an average waiting time of 15 years for people to access social housing units in Amsterdam (Tasan-Kok & Özogul, 2019). It can be an impactful step for the Dutch construction industry if social housing associations replace their current linear practice with circular construction methods. Besides, housing associations often oversee the housing units during the entire lifecycle, therefore the residual value of the building products in a circular construction can be a good incentive for them. On the other hand, some of the social housing associations are having financial struggles. They are assigned to make their outdated units more sustainable, and their income from the rent collection is now divided between renovation and building new dwellings (Capital Value, 2019). This might hinder their choice to adopt circular practices in the new constructions. This project aims to analyse the existing opportunities and barriers in the path of circular, biobased and affordable housing production.

1.2. Design objective

The goal of this project is designing a housing complex for a social housing association. The challenge lies in finding a balance between creating a circular and high-quality result and making it as cost-effective as possible. Circularity in this design will focus on using biobased materials that are designed for disassembly. It also entails circular use of other resources such as energy and water. High-quality in this context stands for a space that aesthetically and socially is pleasant and healthy for the inhabitants.

There are four aspects of context and landscape, architecture, building physics and construction that need to be developed in the design. The thematic research paper is focused on the construction since it is an extremely influential aspect on the ultimate cost of the building. This topic is also intriguing for me since the financial aspect brings the project very close to reality. Therefore, the three aspects of planet, people and profit should all be a concern for this design.

1.3. Research question

The question that the thematic research paper is aiming to answer is how can the use of circular building products and construction by social housing associations impact the costs of the project? Transitioning toward circular products requires a thorough understanding of four fields of technology and design, finances, management, and governance (TUDelft CESBE2x, 2020). Therefore, the following sub-questions are asked:

- How is the current construction method of social housing units and what are the circular alternative construction methods?
- What is the financial impact of choosing circular or conventional building products?
- Who are the stakeholders and what are the relevant laws and policies?

These questions can clarify the alternative circular scenario, so the research question is answered by having the system's entirety in mind.

(2) Research framework

2.1. Key terms, concepts, theories

The main concepts that are related to this design project are social housing, affordability, circularity, Design For Disassembly (DFD) , Open Buildings and Prefabrication.

<u>Social Housing:</u> Social housing in the Netherlands is a public service offered by housing associations to households conforming to some strict criteria such as having an income lower than 35.739 euros per year. The rent of these homes is 710,68 euros per month (Czischke & van Bortel, 2018).

<u>Affordability</u>: Affordability is a relative term that expresses the relation between the cost and the customer's ability to pay (Definitions, n.d.). In this paper, the goal is to design a cost-effective building

for an association. As a result, the dwelling should be affordable for the low and middle-income household.

Circularity: Ellen MacArthur Foundation (2017, para. 1) defines circular economy as "... a systemic approach to economic development designed to benefit businesses, society, and the environment. In contrast to the 'take-make-waste' linear model, a circular economy is regenerative by design and aims to gradually decouple growth from the consumption of finite resources."

Design For Disassembly (DFD): Design for disassembly is a strategy that enables the reuse of building materials through planning the deconstruction in the design phase. There are several aspects to the implementation of DFD such as elaborating materials, documenting deconstruction methods, designing the connections, designing standardised components, detaching non-reusable and non-recyclable parts and paying attention to labour procedures (Rios et al., 2015).

Open Buildings: Open Building is a concept defined by John Habraken that has adaptability at its centre. The idea was developed in 1972, and it was a response to the top-down monotonous mass housing after the Second World War. According to Open Building, different layers of the construction would be independent of each other, and the user will have the potential to customise the space plan. The concept also calls for embracing new business models and ownership strategies (Geldermans, 2020).

Prefabrication: Prefabrication or off-site fabrication in architecture is a concept that entails the production and assembly of building components usually in a factory rather than at the building's location. Afterwards, these assemblies get to be mounted and connected on site. This method is known to create precise, sustainable and affordable buildings through a process that develops rapidly and emits minimal material waste (Schneiderman, 2012). Prefab products can be categorised into groups based on the degree of their completion before being mounted on-site. Therefore, the classes are materials, components, panels and modules (Smith, 2010).

The main focus of this project is to enable circularity by designing a construction suitable for disassembly and reuse in a reasonable price. This brings the primary topic of the project to the Make domain of aE Studio. Circularity of energy and water also play a role in this design which relates to the Flow domain.

2.2. Methods

This paper studies the effect of circular building products on housing constructions through qualitative and quantitative strategies:

A literature review was done to find the most common structure and skin techniques. Plus, Dutch building product market was analysed to collect circular and prefabricated construction opportunities. The cost of these products was collected from the suppliers and De BouwkostenWijzer. For answering the second sub-question, available literature on building materials cost comparison was studied, and the LCC (Life Cycle Cost) of a few hypothetical cases was compared. Boundaries are defined for the LCC layers and scope to fit in the time frame of the research.

The LCC is performed on 12 models of structure, five types of skins and 16 cases that show a combination of different structures and skins forming a 10x10m space in the middle of an apartment. The circular products are picked from Cirkelstad's online product catalogue. LCC can consider all the costs throughout the life cycle phases of a building: the initial phase, the construction phase, operational phase, and end of life phase (Braakman et al., 2021). It is also useful to assign a goal, stakeholder, scope, and a period for the costs (TUDelft CESBE2x, 2020). Here the goal is a comparison to find the most cost-effective combination, the stakeholder is the social housing associations, and the scope is the entire cycle except for some of the omitted costs. The LCC is done for a period of 70 years. The Third question regarding the management and governance was shortly reviewed through literature.

Among the 16 cases, four are out of conventional concrete and brick systems, two are a combination of concrete and biobased products, and ten are made of biobased building products. These products are at different prefabrication levels, so the cost impact of components, panels, and modules is also being compared. These cases are covering both skeleton and load-bearing wall structural systems. This LCC result will help in choosing a structural and skin system for the final design of the project. Learning about a cost assessment tool and having a list of available products is useful for the later design stages.

(3) Preliminary conclusions, choices and design strategies

The research showed that depending on the availability of the products, the purchasing cost differs in every context. Timber buildings are not common in the Netherlands, and the LCC shows concrete products to be at least 20% cheaper than circular products. Even considering the residual value could not prove the affordability of biobased options since the dismantling costs would neutralise their effect. At the same time destructing and dumping concrete at the end of life is very cheap. Increasing the dumping cost, material purchasing tax of concrete or property tax can balance LCC calculations.

Furthermore, prefabrication can reduce construction costs, marginal sub-contractor costs and dismantling costs. They also create safe and organised construction sites that does not disturb the neighbours. The construction time is also short for these systems and manufacture of the modules can take place alongside the on-site foundation work. However, they are only profitable if repetition is high in the design. Ultimately prefabricated LVL modules showed to have the same LCC as precast concrete. CLT construction is more expensive (even in the form of modules) and the load bearing walls makes them less flexible. The LVLs are stronger materials and their modules can also form skeleton structures that enables open buildings and flexibility through the life cycle. Therefore, investing in the prefabrication industry by social housing associations can be the boost that circular and biobased products need.

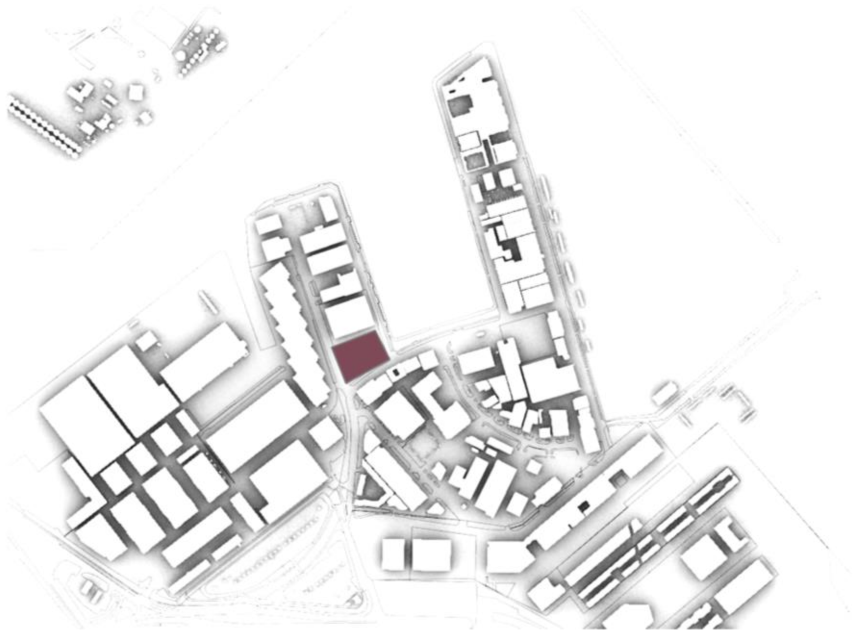


Figure 1 Context of Minervahaven in harbour city

According to the research conclusion, I will design a housing complex with the help of the highest level of prefabrication (modules). This calls for attention to details for assembly and disassembly as well as the relationship of each module to the larger picture of a building and context.

The design of this affordable housing project will be on a 6.000 square meter empty plot on Minervahaven. Minervahaven is a part of the harbour city that is dedicated to multifunctional use of companies and dwellings. Minervahaven was also a part of Houthavens and was used for timber shipment and wood processing industries. It is a pity that most of the buildings made on this timber harbour are made of concrete, and this design project is trying to change that.

The programme is 100 dwelling units that include studios, one-bedroom, two-bedroom and three bedrooms. Besides, there are shared facilities such as laundry room, common rooms and community garden that bring the inhabitants together. This project, as an urban infill project, should be replicable by the social housing associations.

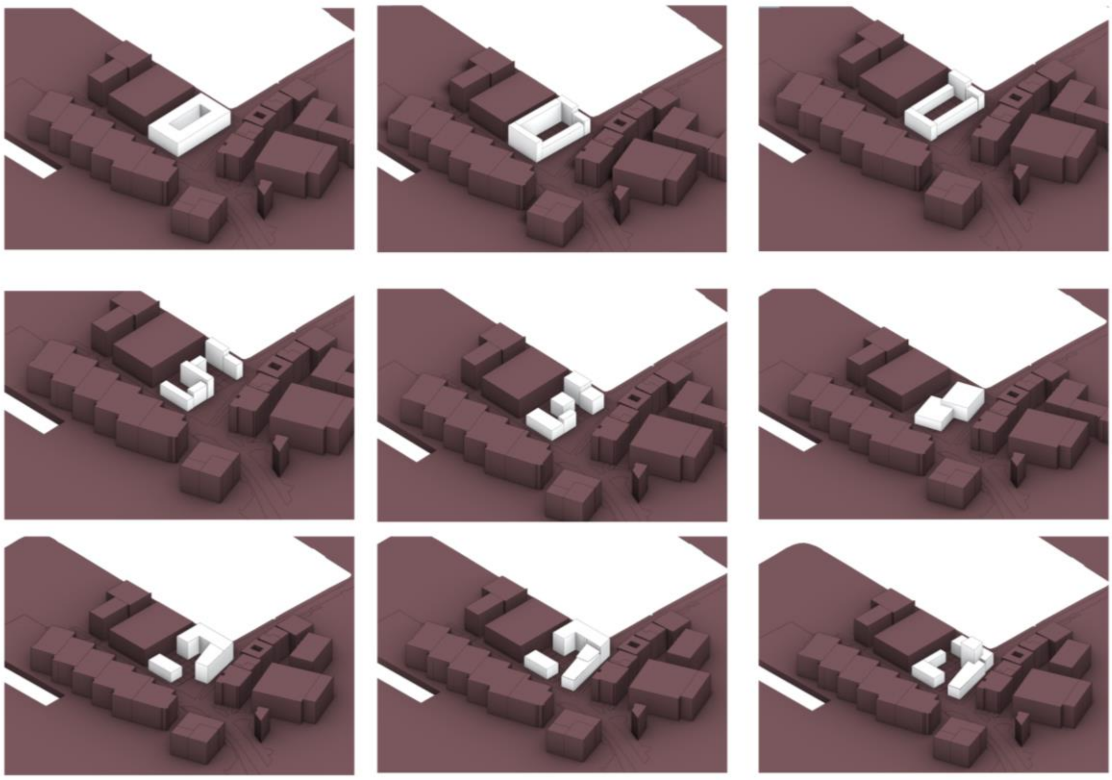


Figure 2 Form study

Along with the research paper I studied many buildings that focus on affordable housing design. These cases also use measures such as lowering construction costs, repetition, shared functions and flexibility to provide long term affordability.

Different forms are studied in the context, according to the atmosphere they create and how much shade is created. The building in the north of the plot is a 600-unit student hotel. The volume had to have a relation with the student hotel and the streets surrounding it. Therefore, the preliminary volume creates a lively plinth for the streets and some opening nodes for the invitation to the block. The volumes should be deep enough to let the light in for the apartments. In case of having modules in size 4 x 7.5 m, a corridor of one meter in the middle and another module on the other side, the depth of blocks would be 16 m.

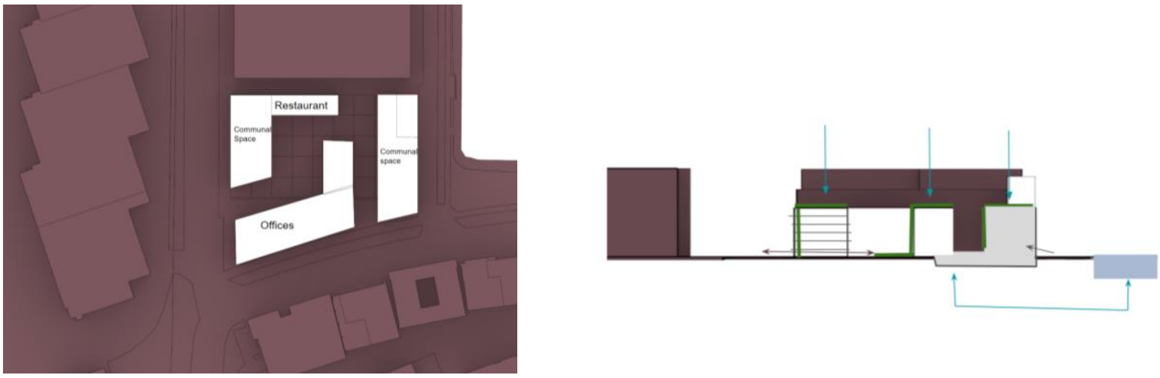


Figure 3 Sketches of the design

The design of the module is essential. The research only discussed the structure and partial skins, but the final product needs other aspects of skin, infill and services. The module will be designed for flexible change of functions, so another module for services should be planned inside the current modules dedicated to the wet activities. The floor finishing should also have layers for pipes cable and acoustics.

Furthermore, the modules will have a set of options for architectural customization. For example, changing the space plan, adding a balcony, turning to duplex, and varying façade designs are some of the options.

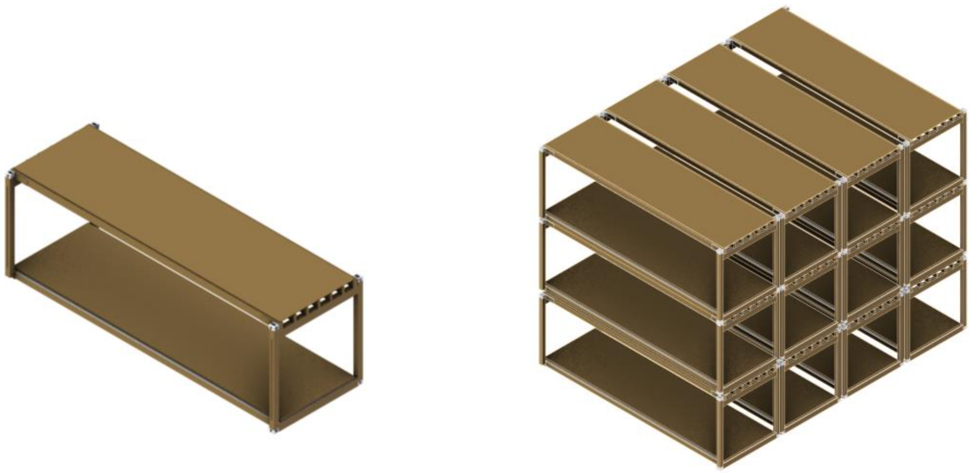


Figure 4 LVL modules

Lastly, the customisations must have a limit. Endless customisation only increases the costs, and this is in contrast with the goal of the project.

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