Personal Information

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Studio

Name of studio	Architectural Engineering
Design tutor	Mauro Parravicini
Research tutor	Gilbert Koskamp

Argumentations of choice of the studio

The Architectural Engineering studio seemed to be the most practical and relevant studio to me. It addresses very relevant topics and (design) challenges and I felt that I could learn the most in this studio, especially in the field of engineering and detailing. This is an aspect of which I know I would like to improve in. Since I didn't get the change to follow a proper internship at my bachelor's degree at the Amsterdam University of Applied Science, I feel like I sometimes lack knowledge of the work field.

Title

Low-tech timber design for affordable housing in the urban area.

Graduation Project

Keywords

Timber design, Low-tech, Affordability, Sustainable Development, medium -rise housing, urban area

Problem Statement

The Netherlands is currently dealing with a housing shortage and will do so for the coming years. ABF Research supports decision-making in the fields of Demography & Housing, Spatial Planning & Economy and Healthcare & Facilities with statistics, forecasts and software. They published a rapport on the prospects for population, households and the housing market for the Netherlands in the period 2021-2035 (Groenemeijer et al., 2021)(Appendix 1). From their report it becomes clear that in the period from 2021 to 2035 a substantial addition to the housing stock of approximately 1 million homes is required. It is also striking that the majority of the future households consist of single people (70%). The greatest demand for both owner-occupied and rental homes is in the low-cost sector, where there is approximately a 1:3 ratio of new rental properties to owner-occupied homes per year. The existing housing stock consists of

64% single-family homes and 36% multi-family homes. The construction task up to 2035 consists of 51% single-family homes and 49% multi-family homes. Part of the explanation for the significant increase in multi-family homes is the relatively high concentration of housing demand in urban areas (Groenemeijer et al., 2021). Therefore, a coalition of 34 organizations in the field of housing, construction and care and welfare has drawn up an action plan in collaboration with municipalities and provinces to tackle this enormous demand for housing (NOS, 2021). The housing coalition wants to build faster, cheaper and more factory. This means that the scarce land in the Dutch urban areas must be used efficiently. However, according to Verheul (2017), the existing housing supply in and around the major cities has become inadequate for many groups. This applies in particular to starters and transferees. The average amount spent on housing as a percentage of income varies from 30 to 37 percent. Other groups also find their home more difficult. The majority of seniors in urban areas prefer to live in low-urban areas. That also applies to families. Efforts to keep families in the city by creating family-friendly neighborhoods close to the center are still very limited (Verheul, 2017).

Another major issue is the impending catastrophe of climate change. According to the United Nations Environment Program (2020), the construction sector is responsible for 38% of total CO_2 emissions. Therefore a lot can and needs to be done in this sector to align with the Sustainable Development Goals (United Nations, 2015) and to make it a zero-emission, efficient and resilient sector. This entails adopting concepts around circular economy to reduce the demand for materials and the embodied carbon in buildings. Besides, this means adopting nature-based solutions that enhance building resilience. Finally, it means embedding principles of health into the development of new buildings and renovation of existing homes to protect its inhabitants (United Nations Environment Program, 2020).

Objective

The aim of this graduation project is to contribute towards solving the housing shortage by improving the quality and quantity of affordable housing and towards achieving the Sustainable Development Goals of the UN by efficient use of low-carbon materials. All in all, this means that development must take place in a sustainable manner, in which the pillars of 'People', 'Planet' and 'Profit' must be in balance. People should have a comfortable, affordable and healthy living environment. The planet requires a reduction of CO_2 emissions and efficient use of resources. The profit is important to make the project realistic and attractive to developers. To be able to realize certain goals for 'People' and 'Planet' the definition of 'Profit' might have to be defined differently. My fascination within this lies in the possibilities for low-tech solutions to realize affordable housing and to make efficient use of materials. For this I will focus on medium-rise buildings to densify the urban area, while keeping a human scale for buildings. In addition, the focus will be on the use of timber design because of the material properties that are positive for all three pillars of sustainable development and for the possibilities for prefab and modular construction.

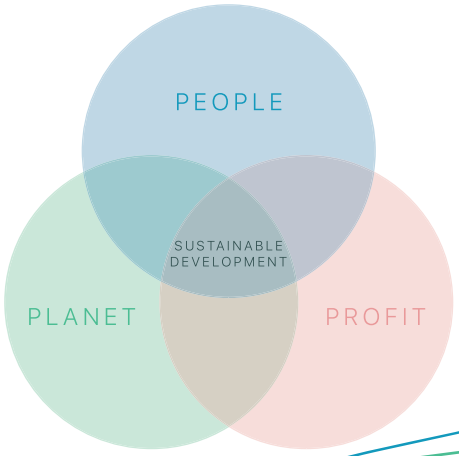
Overall design question

How can the Merwedeterrein in Arnhem be developed in a sustainable way that contributes to the creation of a comfortable, healthy living environment for the users, to the reduction of CO2 emissions from the building sector and that is affordable for the users, while profitable for the contractors?

GRADUATION PLAN

DESIGN QUESTION

How can the Merwedeterrein in Arnhem be developed in a sustainable way that contributes to the creation of a comfortable, healthy living environment for the users, to the reduction of CO_2 emissions from the building sector and that is affordable for the users, while profitable for the contractors?



PEOPLE

- Comfortable, healthy living environment
- Affordability (users)
- Customization
- Adaptation

PLANET

- CO2 emissions
- Nature inclusive
- Sustainable use of resources
- Embodied carbon/energy

PROFIT

- Affordability (developers)
- Prefabrication
- Low-tech

THEMATIC/TECHNICAL RESEARCH

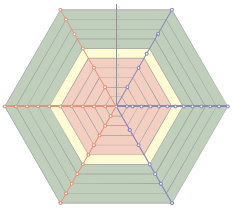
How can low-tech possibilities for timber design increase the affordability of medium-rise housing?

Theoretical framework:
- State of the art timber design

Subquestion 1:
How can the affordability of housing be measured?

Literature on:
- Definition affordability for the users
- Definition affordability for the developers
- What aspects determine the affordability of housing?

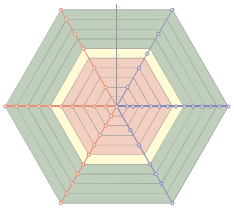
Results:
Parameters affordability



Subquestion 2:
How can the degree of low-tech in housing design be measured?

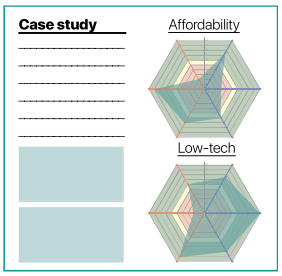
Literature on:
- Definitions low-tech inside the field of architecture.
- Definitions low-tech outside the field of architecture.
- What aspects determine the degree of low-tech in housing?

Results:
Parameters degree of low-tech



Subquestion 3:
What is the degree of affordability and low-tech in existing approaches for timber design?

Case studies: testing on parameters affordability and degree of low-tech. Case studies will include on or more of the following aspects:
- Modular design
- High-rise
- Flexible living
- Housing
- Medium-rise
- Public function



Results: overview of the following:
- The design aspects that determine affordability and degree of low-tech.
- Approaches of low-tech timber design that increase affordability.
- Which aspects of affordability cannot be achieved by low-tech.

DESIGN RESEARCH

How can the Merwedeterrein in Arnhem be developed in a sustainable way that contributes to the creation of a comfortable, healthy living environment for the users, to the reduction of CO_2 emissions from the building sector and that is affordable for the users, while profitable for the contractors?

Site analysis Merwedeterrein, Arnhem:
- Nature (water, green, biodiversity)
- Acoustics
- Sightlines
- Facilities
- Safety
- Logistics
- Demographics/target groups
- Goals municipality Arnhem

Additional research on healthy living environment and nature inclusiveness.

FOLLOW-UP DESIGN

Thematic Research Question

In order to find out how timber design can best be implemented to create affordable housing, while using low-tech approaches, the thematic research question will focus on these aspects.

Research question:

How can low-tech possibilities for timber design increase the affordability of medium-rise housing?

Subquestions:

1. How can the affordability of housing be measured?
2. How can the degree of low-tech in housing design be measured?
3. What is the degree of affordability and low-tech in existing approaches for timber design?

Hypothesis:

By optimizing the efficiency and simplicity of material use, fabrication methods, building design and construction time for a medium-rise timber building, quality affordable housing can be ensured for users and developers.

Antithesis:

Even through optimization, quality affordable housing cannot be ensured for users and developers. Concessions have to be made on either the quality or the affordability of the medium-rise timber building. Low-tech approaches might not be the best option in order to achieve a certain level of housing quality or affordability.

Key terms

- Low-tech:
  "Low-tech seeks to re-balance the relationship between buildings and technology. It is about leanness, fewer components, a preference for natural, low-embodied carbon materials, reduced reliance on technology and mechanical servicing, robustness and flexibility – in essence, simplicity. (…) Low-tech approaches must combine intuitive design (…) with the accurate and empirical processes of iterative design, digital modelling and measurement." (Fowles, 2021)
- (Housing) Affordability (users):
  "The average amount spent on housing as a percentage of the income of a household" (Verheul, 2017). *"A commodity can become 'unaffordable' for households f (a) the households' income falls, (b) the price of the commodity rises or (c) cheap supplies of the commodity cease to be available"* (Hallett, 2021)
- (Housing) Affordability (developers):
  The ability of property developers to finance the construction of (new) affordable housing for (low-income) households. Governments can introduce different types of support and measures to help property developers finance the provision of new affordable housing. (OECD, 2021)
- Prefabrication:
  "All systemized off-site manufacturing of components and elements." (Knaack et al., 2012)

- Modularity:
  "Modular building not only refers to the practice of building to a standard dimensional module, but also to the prefabrication of a volumetric building unit. Modules are three-dimensional independent units or partially completed sections. (…) Modules are standardized components of an overall system. The components can be further broken down into separate elements." (Knaack et al., 2012)
- Flexibility:
  "The ability of a building to respond to changing situations in its use, operation, or location. This is architecture that adapts rather than stagnates; responds to change rather than rejects it; is motive rather than static. It is a design form that is by its essence cross-disciplinary and multi-functional and consequently, is frequently innovative and expressive of contemporary design issues" (Kronenburg, 2005)

Theoretical framework

With the aim of contributing towards solving the housing shortage and towards achieving the Sustainable Development Goals of the United Nations, while maintaining a balance in the sustainable development pillars 'People', 'Planet' and 'Profit', the use of timber construction is a very relevant option to investigate.

<u>People:</u>

According to the report of the Ministry of Internal Affairs and Kingdom Relations from November 2020, the 'petrification' of the city creates a need for greenery to counteract psychological effects such as claustrophobia, depression and unease. By building with biobased materials that remain visible, their tactile, natural character can contribute to the mental health of people and thus to productivity and performance. Biobased materials can also create a strong connection with nature, which can help to recover from physical and psychological stress. Although more and more research is being done into the consequences of the use of biobased materials on people's health, it is a relatively new research field that requires a strong interdisciplinary approach (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020).

Kaufmann et al. (2018) have investigated the influence of timber construction on the interior air quality of buildings. They concluded that timber construction is not dangerous for the interior air pollution when the construction and the components are chosen carefully. A distinction has to be made between emissions from wood as a natural product and those from additives in processed wood products. Further scientific research into the positive effect of wood on interior climates and their users are currently ongoing (Kaufmann et al., 2018).

<u>Planet:</u>

Timber construction can offer a good solution to the increasing demand for renewable and bio-based construction methods (Kaufmann et al., 2018). Sustainable forestry can ensure a long-term, ecological supply of this natural material. Only maintenance of woodlands and the use of timber will preserve our forests as cultivated ecosystems, as sources of raw materials and as stores of carbon and energy (Kaufmann et al., 2018). The amount of CO2 in the atmosphere can be reduced in two ways: either by reducing CO2 emissions or by storing extracted carbon from the atmosphere. Wood is able to contribute to both of these reduction methods (Kaufmann et al., 2018). Furthermore, a cascading use of wood and wood products makes it possible to extend the period for

which atmospheric carbon is stored multiple times. Wood products can be reused, recycled into materials and be used as an energy producer (Kaufmann et al., 2018). However, multiple factors have to be taken into account here: in order to contribute to achieving climate goals, the used wood has to come from sustainable forestry. Therefore, the advantages of the carbon storage must be weighed up against an economic use of timber in the buildings construction and fittings.

Profit:
When talking about the 'profit' aspect of the use of timber construction, it is interesting to look at the low-tech options of current timber products and techniques. Timber products have the inherent property of being a natural, low-embodied carbon material. Therefore, the simplicity of the timber products will have to be looked at, which could have a major impact on the affordability of the construction, both for users and developers.

Kaufmann et al. (2018) give an overview of the currently most commonly used timber products and its properties. Timber products can be divided into solid wood products and wood-based materials. The latter are made by bonding wood in a wet or dry process, often with the help of adhesives. This allows certain properties of the wood to be enhanced, depending on the function of the product.

Common solid wood products and wood-based materials (Kaufmann et al., 2018)

- Solid wood, sawn softwood / sawn hardwood
- Finger-jointed solid timber / solid construction timber
- Double and triple laminate beams
- Glued laminated timber
- Lightweight timber beams / supports
- Cross laminated timber
- Three-ply laminate sheeting
- Single-ply sheeting
- Veneered plywood
- Beech veneer plywood
- Laminated veneer lumber (LVL)
- Medium-density fiberboard (MDF)
- Porous wood fiberboard
- Cement-bonded particle board, chipboard
- Chipboard, particle board
- OSB board
- Long span lumber (LSL)
- Lightweight wood wool construction board (WW)

Each product or material has its own aspects relevant to its use. Therefore, it is important to consider and compare the appropriate materials or products with each other, depending on the desired function.

Methodologies

How can low-tech possibilities for timber design increase the affordability of medium-rise housing?

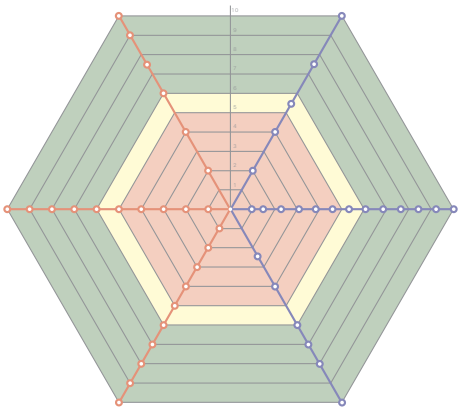
Theoretical framework: (Huß et al., 2019)

- State of the art timber design (Zwerger, 2012) (Kaufmann et al., 2018)

Subquestion 1:
How can the affordability of housing be measured?

Literature:
(Hallett, 2021) (Dömer et al., 2015) (Phillips, 2020) (Hofmeister, 2018) (Werk: Bauen + Wohnen)

Results:
Parameters affordability

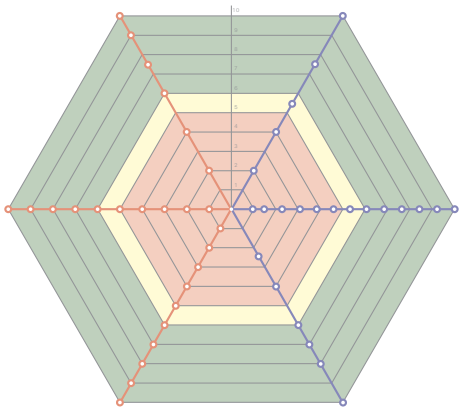


Subquestion 2:
How can the degree of low-tech in housing design be measured?

Literature:

- (Fowles, 2021)
- ... more references/literature needed for definitions

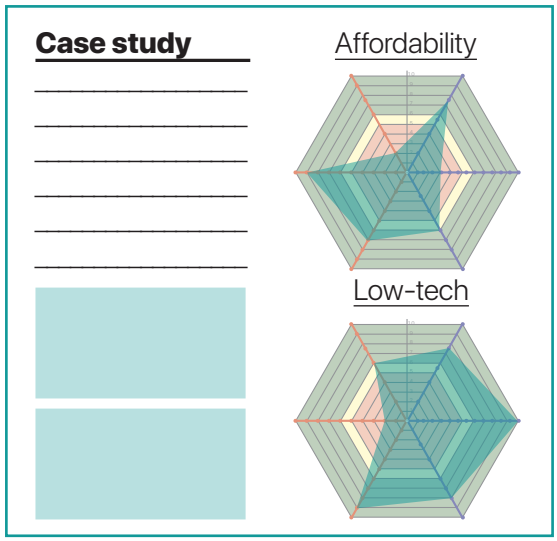
Results:
Parameters degree of low-tech



Subquestion 3:
What is the degree of affordability and low-tech in existing approaches for timber design?

Case studies: (iterative process)

- Hotel Jakarta, SeARCH
- Brock Commons, Acton Ostry Architecture
- Mjøstårnet, Voll Arkitekter
- AIZ Campus Kottenforst, Waechter + Waechter Architekten
- BSH20A 'Stories', Olaf Gipser Architects
- Einfach bauen, Technische Universität München



Optional:

- T3 Bayside, 3xn
- HoHo, RLP Rudiger Lainer
- Forte tower, Andrew Nieland/Lendlease Australia
- Suurstoffi 22, Burkard Meyer

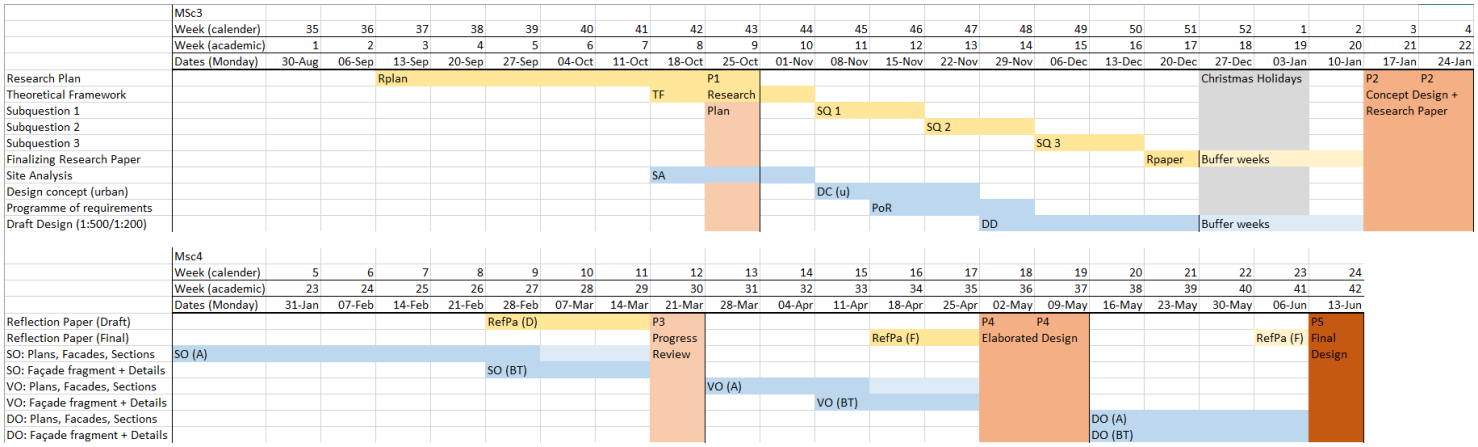
Case studies:

- Hotel Jakarta, SeARCH, Amsterdam (high-rise, timber, prefab, hotel)
- Brock Commons, Acton Ostry Architecture, Vancouver (high-rise, timber, prefab, housing)
- Mjøstårnet, Voll Arkitekter, Brumunddal (high-rise, timber, housing, public functions)
- AIZ Campus Kottenforst, Waechter + Waechter Architekten, Bonn (low-rise, timber, school, flexibility, modularity)
- BSH20A 'Stories', Olaf Gipser Architects, Amsterdam (mid- to high-rise timber, housing, commercial, open building)
- Einfach bauen, Technische Universität München, Bad Aibling (low-tech/simplicity, housing, low-rise)

Optional:

- T3 Bayside, 3xn, Toronto
- HoHo, RLP Rudiger Lainer, Vienna
- Forte tower, Andrew Nieland / Lendlease Australia, Melbourne
- Suurstoffi 22, Burkard Meyer, Risch Rotkreuz

Planning



Relevance

The thematic research is generic in nature and does not yet focus on a specific location. The results of this research gives an overview of the design aspects that determine affordability and the degree of low-tech. Besides, it gives an overview of existing approaches of low-tech timber design that increase affordability and which aspects of affordability cannot be achieved by low-tech. In the graduation project, these research results will be applied to the specific location of the Merwedeterrein in Arnhem, where they will be combined with the results of the location analysis and the research on creating a healthy living environment and on nature inclusiveness. This way a design can be made that is specific to this location and that will answer the main design question of this graduation project.

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Appendix 1: ABF Research: prospects for population, households and the housing market for the Netherlands in the period 2021-2035 (Groenemeijer et al., 2021)

	Single parent families	Couples	Families	Singles	Total
Amount	33.960	127.350	93.390	594.300	849.000
Percentage	4%	15%	11%	70%	100%

The expected increase of households in number and types, NL, 2021 – 2034

	Added (new construction, transformation and housing division)	Withdrawn (demolition, zoning change and housing merging)	Total
Amount	1.160.000	168.000	+ 990.000
Percentage	+ 14.5%	- 2,1%	+ 12.4%

The expected change in housing stock, NL, 2021 – 2034

Desired program new construction, NL, 2021 – 2034

	Owner-occupied homes	Rental homes	Total
Amount	52.000 p. year	31.000 p. year	83.000 p. yr
Percentage	63%	37%	100%

Desired development owner-occupied homes by price segment, NL, 2021 – 2034

	Cheap owner-occupied homes (< € 330.000)	Medium-priced owner-occupied homes (€ 330.000 - € 480.000)	Expensive owner-occupied homes (> € 480.000)	Total
Amount	28.000 p. year	15.000 p. year	9.000 p. year	52.000 p. yr
Percentage	53.8%	28.8%	17.3%	100%

Desired development rental homes by price segment, NL, 2021 – 2034

	Regulated rental homes	Mid-rental homes	Expensive rental homes	Total
Amount	23.700 p. year	5.400 p. year	1.900 p. year	31.000 p. yr
Percentage	76.5%	17.4%	6.1%	100%