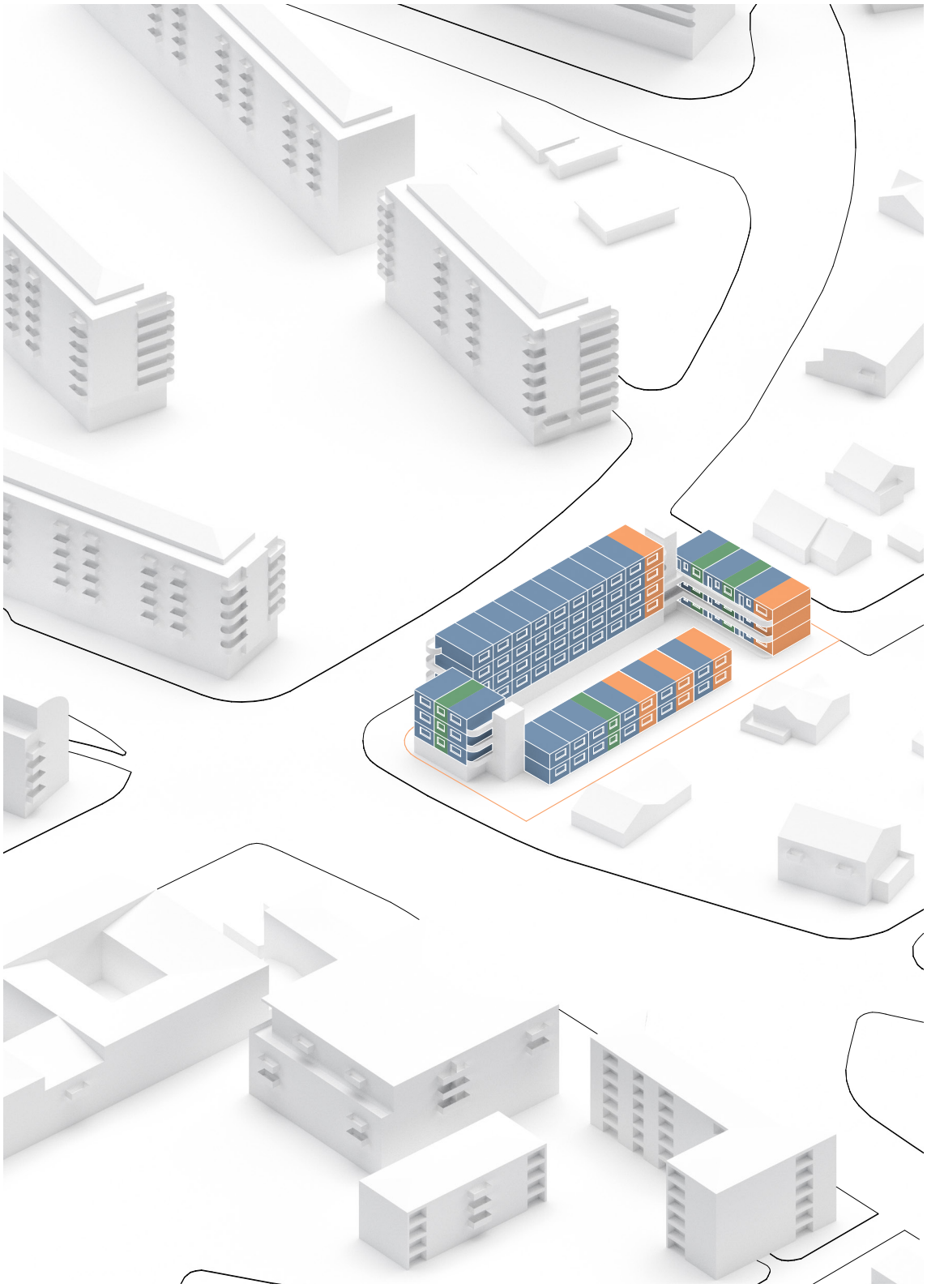
MODULAR HOUSING FOR YOUNG ADULTS

AFFORDABILITY, QUALITY & SITE INTEGRATION



SASKIA GEDIN
Master Thesis 2023, Chalmers University of Technology
Department of Architecture and Civil Engineering
Supervisor: Jan Larsson | Examiner: Kaj Granath

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ABSTRACT

This thesis aims to investigate how residences can be designed as modular structures in cross-laminated timber to create affordable and qualitative housing for young adults that can be easily integrated into different sites to target the housing shortage among young adults in Sweden.

The method consists of a combination of theoretical research and research by design to explore the aspects of modularity, affordable housing, residential qualities, and site integration. The research also investigates the potential of using cross-laminated timber as a construction material, given its sustainable profile and production process, suitable for modular design. Theoretical research is conducted by examining methods for affordable housing, an analysis tool for evaluating residential qualities, and approaches to site integration that respect cultural values. The findings are then used to form design strategies that set the basis for a design proposal of a modular apartment series.

A design application is thereafter carried out to test the potential of the modular apartment series, where the design proposal is applied to a specific site and context. The chosen site has a high cultural value, making it an interesting subject for evaluating site integration. The chosen context of the design application is student housing, providing a more precise context suitable for the chosen site. The design application evaluates the applicability of the design proposal and its relevance to the research questions and the aim of the thesis.

Overall, the thesis presents an in-depth investigation into the potential of modular housing in cross-laminated timber to provide affordable and high-quality residences for young adults in Sweden. The importance of considering site integration and cultural values in the design process is highlighted, along with the practical considerations of using cross-laminated timber as a construction material. The most prominent strategy is found to be to internally optimise similarities in the design to urge affordability and quality while externally allowing for a high degree of customisation to facilitate site integration. The findings can potentially be useful for architects, urban planners, and policy-makers involved in addressing the housing shortage among young adults in Sweden.

Keywords: modular housing, residential qualities, cross-laminated timber

STUDENT BACKGROUND

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1 INTRODUCTION

THESIS FRAMEWORK

BACKGROUND

Housing shortage for young adults is a rising problem in Sweden where as many as 24 % between the age of 20 and 27 live at their parents' house due to economic issues, long renting queues, and limited supply of housing (Hyresgästföreningen, 2021). Sweden has a history of using modular housing and prefabrication as a way to solve housing shortage as seen in *Miljonprogrammet*, The Million Homes Program of the '60s and '70s, and more recent projects such as *Snabba hus* specifically targeted to young adults. The main benefit of modular housing is that prefabricated modules make it possible to produce, construct and assemble dwellings fast all while keeping the cost relatively low.

Modular housing can be a suitable solution for young adults because the target group generally lives in smaller residents and modular housing involve dimensional limitations that better suit smaller apartments. Three main aspects need to be considered in a modular housing project that targets the housing shortage for young adults: designing for affordability, designing to attain residential qualities, and designing for site integration. In this thesis, strategies for approaching these aspects will be looked into and used to form a design proposal and design application.

RESEARCH QUESTIONS

– How can residences be designed as modular structures in cross-laminated timber to create affordable and qualitative residences for young adults?

– How can modular residences be designed to facilitate application and integration to different sites?

AIM

The thesis aims to target the housing shortage of young adults in Sweden by exploring the potential of designing modular housing in cross-laminated timber to provide affordable and qualitative residences applicable for serial production. Furthermore, the thesis aims to explore how modular housing can be designed to enable successful site integration for the respectful exploitation of an area.

DELIMITATIONS

The housing shortage in Sweden is widespread among several groups of people in society but the thesis will focus on the subject of young adults as they are at high risk due to their general economical vulnerability as students, unemployed, or newly employed. It is also a group of people whose residential needs of generally smaller residences are suitable for modular structure solutions.

The thesis explores modular housing mainly from a Swedish perspective. Some background and theory references have a wider perspective and are used to gain broader knowledge that is potentially relevant for application to a Swedish context. The design proposal and design application are designed for a Swedish context following Swedish building regulations.

The construction method of the modules is delimited to explore the use of cross-laminated timber as it is a promising local material in a Swedish context with a sustainable profile and production process suitable for modular design.

METHOD

To answer the research questions, the aspects of modularity, affordable housing, residential qualities, and site integration all need to be investigated. The chosen method to do so is a combination of theoretical research and research by design where the findings are applied and tested in practice.

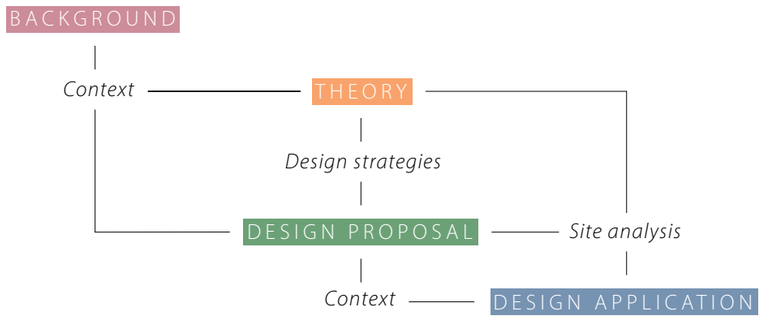
Initially, the background of the topic is examined by looking into the housing shortage of young adults, the historic and current potential of modular housing as an affordable building method, different modular structures, and the properties of the chosen material cross-laminated timber. This provides context to relate the theoretical research and the design proposal to.

Thereafter, research papers, reports, and studies are examined and compiled to make up an analytic framework and to form theoretical design strategies that can potentially answer the research questions. Sources are chosen based on relevance to the topics of modularity, affordable housing, residential qualities, and site integration. As well as the relevance for application in a Swedish context.

The design strategies are used to make up a design proposal for a modular apartment series in cross-laminated timber for young adults. The design proposal constitutes a prototype that potentially is applicable. The implementation of the design strategies is evaluated in terms of what compromises had to be made in practice.

Ultimately, a design application is carried out where the design proposal is applied to a specific site and context. The chosen site was selected because of the area's high cultural value, which makes it an interesting subject for evaluating site integration. A site analysis is done to get an understanding of the area and an assessment of cultural values is done following the findings of the theoretical research. The chosen context of the design application was selected to be student housing, as a specific target within the subject of young adults. It was selected to provide a more precise context that is suitable for the chosen site. The design application evaluates the potential of the design proposal, which is then discussed in relation to the research questions and the aim of the thesis.

FIGURE 1.1 Illustration of the method



THEORY

The main sources chosen to constitute the theoretical base for the thesis and their respective purpose is described below:

- The research paper *Choice and delivery in housebuilding: lessons from Japan for UK housebuilders* (Barlow et al., 2003) to understand the balance of standardisation and customisation in modular design
- The report *Kulturhistoriska värden i plan- och byggprocesser* (Riksantikvarieämbetet, 2020) to gain knowledge of how cultural values can be respected and integrated in new building projects
- The research project *MAB*, *Manual för analys av bostadskvaliteter* (Granath & Nylander, 2023) to make up a theoretical framework and point of reference for evaluating residential qualities
- The pilot study *1000 ungdomsbostäder* (Prolong, 2020) to get a perspective of how municipalities in Sweden are planning for building affordable housing for young adults

READING INSTRUCTIONS

The thesis is divided into eight chapters that follow the process of answering the research questions.

1. Introduction: presentation of the framework of the thesis

2. Background: presentation of the housing situation for young adults in Sweden, modular housing, and cross-laminated timber

3. Theory: presentation and discussion of the relevance of theoretical studies and reports regarding modular design, site integration, residential qualities, and affordable housing for young adults

4. Site analysis: analysis of the context and cultural values of the site of the design application according to the theory of successful site integration from chapter three

5. Design strategies: presentation of design principles and strategies derived from the theory chapter on how the design proposal should be designed to attain the aspects of affordability, quality, and site integration as stated in the research questions

6. Design proposal: presentation of a proposal of a modular apartment series derived from the design strategies and background knowledge

7. Design application: presentation of an application of the design proposal to the specific site analysed in chapter four, to test the applicability of the design concept

8. Discussion and conclusion: evaluation of the design proposal and design application in relation to the aim of the thesis and the research questions

2 BACKGROUND

THE HOUSING SITUATION FOR YOUNG ADULTS

POLITICAL GOALS

The Swedish government's goals for youth politics, which concern children and young adults from age 13 to 25, are stated as follows: All youth shall have good living conditions, the power to shape their own lives, and the ability to impact societal development (Regeringen, n.d.). Boverket (2019) evaluates the goals and how they relate to housing issues in their report *Bostäder och platser för ungdomar*. They state that having good living conditions is strongly reliant on your housing situation and that being able to move out on your own as a young adult is a key aspect in obtaining the power to shape your own life. Yet, young adults are among the most vulnerable groups in society to housing shortage as discussed in the previous section.

Sweden has agreed to the UN Sustainable Development Goals for Agenda 2030 where goal 11 *Sustainable Cities and Communities* concerns the housing situation for all. The target goal 11.1 states: "*By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums*." (United Nations General Assembly, 2015, p. 21). Targeting the housing shortage for young adults would be a step in the right direction for the national political youth goals as well as the UN Sustainable Development Goals.

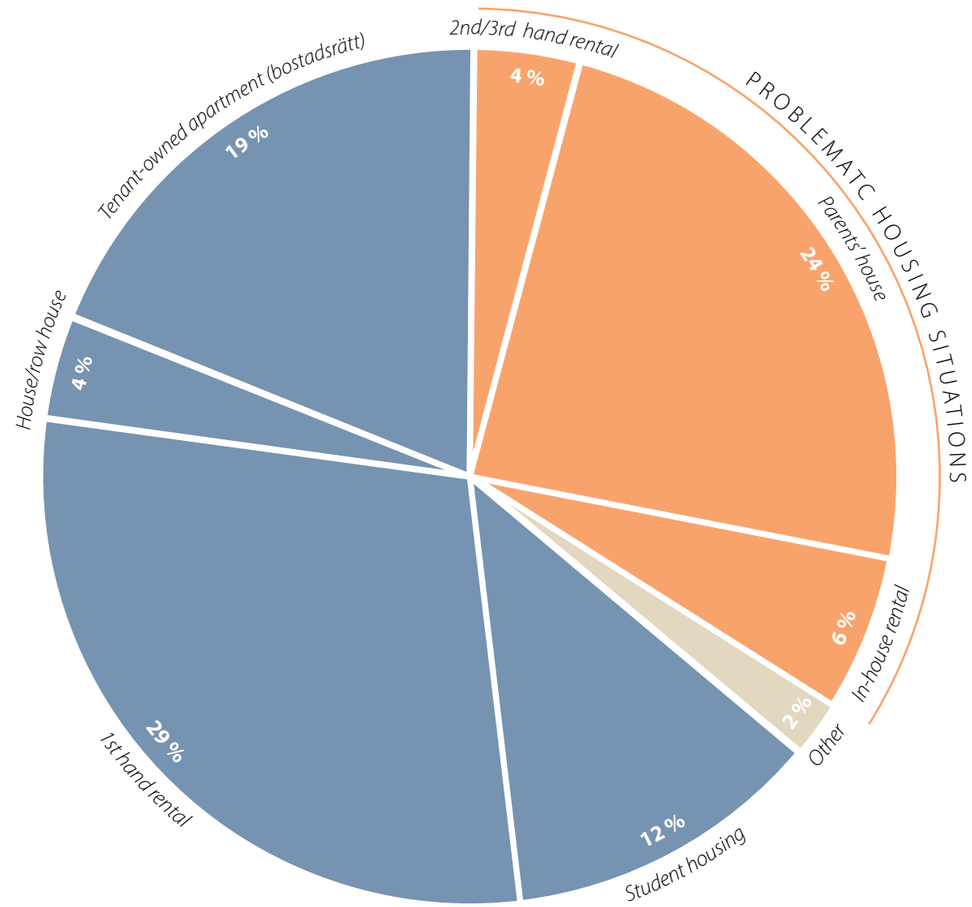
CURRENT HOUSING SITUATION

Since 1997, Hyresgästföreningen has conducted a survey every other year to investigate the current housing situation for young adults, aged 20-27, in Sweden. The latest survey (Hyresgästföreningen, 2021) shows that 34 % are currently in housing situations that can be considered problematic (see Fig 2.1). 24 % live in their parents' house and 85 % of them answered in the survey that they would like to change their current housing situation and move out. 4 % live as second or third hand rental tenants and 6 % as in-house rental tenants (*inneboende* in Swedish). These are housing situations that are often at high risk of having inadequately high rent and short-term rental conditions that make the situations unsustainable.

CHANGING THE HOUSING SITUATION

Compared to other EU countries, Swedish young adults generally move out from their parents' house at a younger age because it is part of the Nordic culture to detach from the parents regardless of marital status (Boverket, 2019). However, since 1997 the percentage of young adults living in their parents' house has increased from 15 % to the current number of 24 % (Hyresgästföreningen, 2021). The majority of the young adults living at their parents' house are students or unemployed. Participants of Hyresgästföreningen's survey express that economic issues, long renting queues, and a limited supply of available housing are some of the reasons why they are not able to change their housing situation. There is thus a high demand for qualitative and affordable housing applicable as student housing, tenant-owned apartments, and first hand rental apartments, which would be the ideal housing situation for young adults.

FIGURE 2.1 The current housing situation for young adults , 2021
Based on data from Hyresgästföreningen, 2021



PREFABRICATION: A HISTORIC PURSUIT OF AFFORDABLE HOUSING

THE PROMISE OF PREFAB

Affordable housing can be defined as housing with acceptable relationships between household income and expenditure on housing costs (Worthington, 2011). This definition also relates to Boverket's definition of housing shortage mentioned earlier in the chapter where inadequate accommodation cost in relation to disposable income, among other things, is stated to pose a high risk. Modularisation and prefabricated building construction have since the early 1900s provided a means to affordable housing.

A prefabricated (prefab) building is, by definition, where an entire building or its components is manufactured off-site and assembled on-site (Gunawardena & Mendis, 2022). The promise of prefab is intriguing: high-quality mass production, short building times, affordability, and clever yet simple solutions. Prefab has almost become an aspirational ideal for building constructions of different sorts. In the book *Prefab Housing and the Future of Building: Product to Process* (Aitchison, 2018), the author writes about how the promise of prefab has cast a cyclic spell over the building industry where each successive generation comes to rediscover prefab, spend an immense amount of time and energy to find *the* perfect solution, only to encounter the same problems and make the same mistakes as the previous generations. Aitchison goes on to explain how the promise of prefab lures us to believe that the value lies in the prefabrication:

> One could also be forgiven for thinking that prefab itself is not merely a goal but a value, which takes on aspirational and sometimes moral connotations. We think this view to be misguided. Prefabrication does not have intrinsic *value*, nor is it some kind of *quality* to be aspired to. Rather, prefabrication and industrialisation are a means to an end. (p. 64)

When approaching the idea of prefabricated modular projects, Aitchison believes that we need to understand that prefab is a means to an end and a process of great complexity. The intended product is the goal and contains the values we seek. For instance ,the value of affordability, and prefab could be a suitable process to achieve that. Only with that approach can a project be successful, and the promise of prefab be attained.

HENRY FORD SYNDROME

"*Why can't we mass-produce houses – standard, well-designed, at low cost – in the same way Ford mass-produces cars?*" (Herbert, 1984, p. 3). Architecture professor Gilbert Herbert writes about what he calls the Henry Ford Syndrome in his book *The Dream of the Factory-Made House*. He states that the architectural profession is suffering from the syndrome, which entails the encapsulated dream of affordable mechanically produced mass housing. Designers have for a long time been seduced by the idea of an attractive, durable, cheap, housing product capable of being produced by industrial processes, just like cars. In the 1930s, a movement of innovative exploration and experimentation of the potential of industrial production of housing became popular. The greatest architects of the time such as Le Corbusier, Gropius, and Frank Lloyd Wright all explored ideas of industrialised buildings in different ways. Le Corbusier even named one of his prefab projects Maison Citrohan, as a reference to the Citroën cars. But the practical realisations of the grand projects were limited (Herbert, 1984). Yet somehow the dream was kept alive and to this day still is.

THE POTENTIAL OF MODULARITY

THE DRIVERS BEHIND MODULARISATION

There are two main benefits of modular construction compared to traditional methods – speed of construction and reduced labour (Gunawardena & Mendis, 2022). These benefits can then lead to further advantages of cost-effectiveness and significant time savings for the whole process and potentially result in more affordable housing. In the research report *Defining Modules, Modularity and Modularization* (Elgård & Miller, 1998), the authors divide the underlying desire for modular projects into three main drivers:

FIGURE 2.2 The drivers behind modularisation
Adapted from Elgård & Miller, 1998

DRIVERS	REDUCE COMPLEXITY	UTILIZE SIMILARITIES	CREATE VARIETY
	to increase overview and better handling	*to gain rationalization benefits*	*to provide the customer a well-fitted product*
STRATEGIES	• Break down independent units • Work in parallel • Plan well	• Avoid work – not inventing the wheel again • Reduce risks by using well-known solutions • Reduce internal variety	• Provide useful external variety • Allow for combination of modules

The challenge of all modular products lies in balancing standardisation and customisation. Reducing complexity and utilizing similarities means a higher level of standardisation while creating variety requires some level of customisation. Achieving the outmost potential of modularity comes down to attaining the possibility to develop a broad variety of products, in this case residential buildings, through combinations of a limited number of modules. (Elgård & Miller, 1998)

SERIAL PRODUCTION

One of the greatest potentials of modular housing is the possibility of serial production. Limited design variations and standardised construction elements enable the same modules to be serially produced and applicable for several projects. Housing researcher Anna Granath Hansson (2017) writes in the research paper *Boosting affordable housing supply: Could type approval of serially produced housing be a piece in the puzzle?* that the main potential benefits of serial housing construction are quicker building permission processes, and cost-efficient housing production. Granath Hansson continues to explain that the goal of serial housing production is to first develop and rationalise construction techniques and processes and then by using these advances reduce housing production costs to achieve housing affordability goals.

Serial production and industrial prefabrication techniques have been developed since the early 1900s and have been utilised to solve the housing shortage previously in Sweden in the Million Homes Program as discussed further in the following pages of the thesis. As the housing shortage constitutes a rising problem in many cities of Sweden today, the potential of modularisation and serial production should once again be explored as a way of solving the crisis.

CATEGORISATION OF MODULAR STRUCTURES

THREE CATEGORIES

There are many different names found in literature for categorising modular structures and the different types entail different use of application. The structures are generally divided in the same manner as skeletal frame, flat panel, and volumetric unit structure.

1. SKELETAL FRAME STRUCTURE

Skeletal frame structure is typically used for office buildings and mixed-use buildings because they offer a high degree of flexibility in the configuration of plan layout (Albus, 2017). The structure is made up of load-bearing posts and beams, which makes large facade openings possible along all sides of the building. The span capacity is determined by the dimensions of the beams and the structure can therefore be used for long-span structures (Engström et al., 2015).

2. FLAT PANEL STRUCTURE

Flat panel structure is typically used for residential buildings because the load-bearing walls limit the flexibility of the plan layout (Engström et al., 2015). However, a flexible configuration of light inner walls and large openings in the facade are possible within the structure. The structure is made up of flat wall and slab elements that are assembled on-site. The span capacity is determined by the thickness of the slab.

3. VOLUMETRIC UNIT STRUCTURE

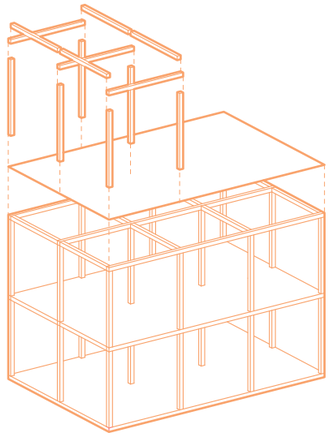
Volumetric unit structure is typically used for smaller apartment units, and kitchen and bathroom units because of the transportation regulations that limit the width to maximum of 4,15 meters (Engström et al., 2015). The limited dimensions also reduce the plan flexibility of the unit as well as control the ability for larger spans. However, the prefabrication of a whole load-bearing unit optimises the ability of off-site construction, which can enable significant time savings and cost-effectiveness of construction (Albus, 2017).

CHOOSING THE APPROPRIATE STRUCTURE

Deciding which system is most appropriately used for a project depends on what type of construction is intended for the structure and what the function of the building is. Cross-laminated timber and prefabricated concrete constructions are appropriately used for panel structures and unit structures because of the nature of prefabricated production as large slabs. Timber or steel post and beam construction is in accordance with its form more appropriately used for skeletal frame structure. However, it is possible to build up flat panels or volumetric units off-site using post and beam construction as well. The choice also comes down to the span capacity and plan flexibility desired for a project determined by its function. As described earlier, each structure is more fitting for certain building functions. The level of off-site construction can also determine which structure is more appropriate for a project because it can be significant for cost and time savings.

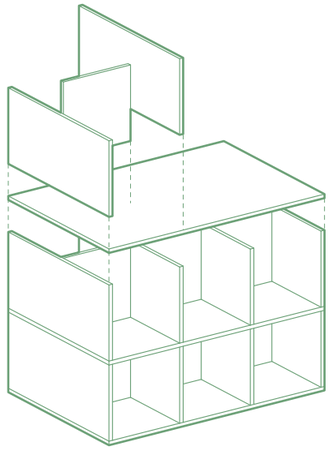
All considered, volumetric unit structure would be most appropriate for the design proposal of the thesis because of the building function (residential), young adults as the target group (smaller apartments), the intended use of cross-laminated timber as construction method, and affordability as a major objective.

FIGURE 2.3 The three categories of modular structures
Adapted from Albus, 2017



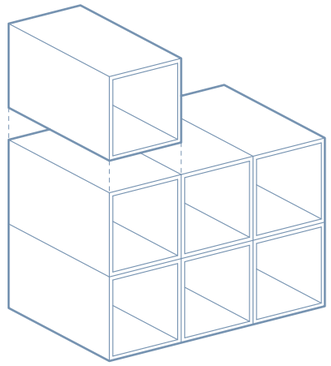
SKELETAL FRAME STRUCTURE

Off-site construction
Span capacity
Plan flexibility



FLAT PANEL STRUCTURE

Off-site construction
Span capacity
Plan flexibility



VOLUMETRIC UNIT STRUCTURE

Off-site construction
Span capacity
Plan flexibility

DESIGN FOR TRANSPORTATION, LIFTING, AND HANDLING

CRITICAL DIMENSIONS

The transportation regulations have a big impact on the design of modular housing, especially for whole volumetric units because the width restriction is strictly limiting the dimensions of the units and the possible plan layout within. According to Trafikverket (2011), housing modules cannot exceed 4,15 m in width when transported and the height of the transportation should not exceed 4,5 meters (see Fig. 2.4). Exceptions to the width limitation can be made in dialogue with Trafikverket if there is adequate reason and only concerns a few units of a more extensive delivery to the same address.

The width limit of 4,15 m is a critical restriction to the freedom of the design of a project. When designing a modular apartment series based on volumetric unit structure the plan layout must be made in such a way that it is configurated with the dimension limitations in mind. The dimensions of the unit must be a deciding factor for the plan layout early in the process so that it is designed wisely in accordance with the restriction.

LIFTING AND HANDLING

The lifting and handling of modular units impose temporary loads and support conditions that must be considered. The two main methods for lifting modular units are top lifts and bottom lifts (Gunawardena & Mendis, 2022). A top lift is commonly done by connecting adjustable spreaders that lift the unit from the top. A top lift should ideally be carried out by connecting the lifting mechanism to structural columns, which are stiff enough to carry the tensile force applied when the full weight of the units acts upon them. For the case of modular units in cross-laminated timber, as investigated in the thesis, a bottom lift might be more suitable since the structure does not involve structural columns to lift from. Bottom lifts are done by connecting the lifting mechanism to the bottom of the unit, and with a spreader beam on top.

In order to make any modular building viable, the overall geometry, rigidity, and weight of modules need to be fit for lifting, transportation, and assembly criteria. Engineering expertise needs to be involved to ensure safe handling. Furthermore, to favour easy handling the design of the plan layout should ease installation on site, and accessibility to connections even after installation. (Gunawardena & Mendis, 2022)

FIGURE 2.4 Transportation of modular volumetric units
Dimensions based on Trafikverket, 2011

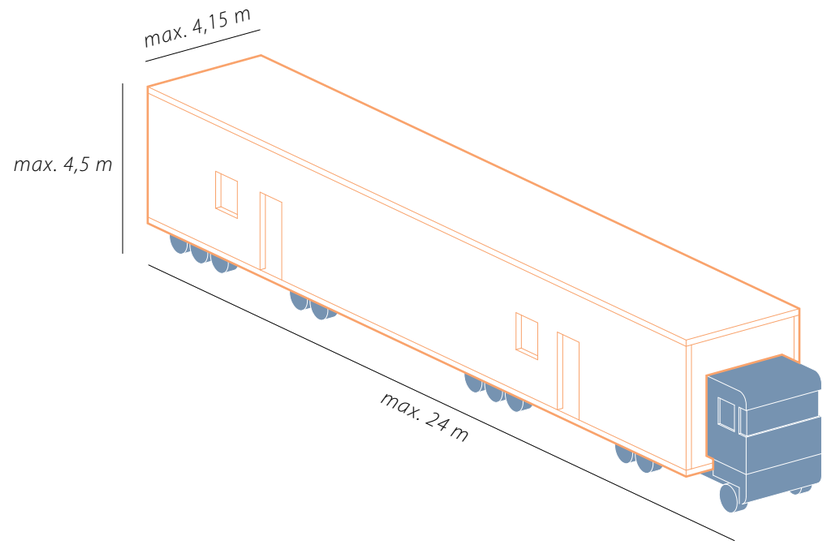
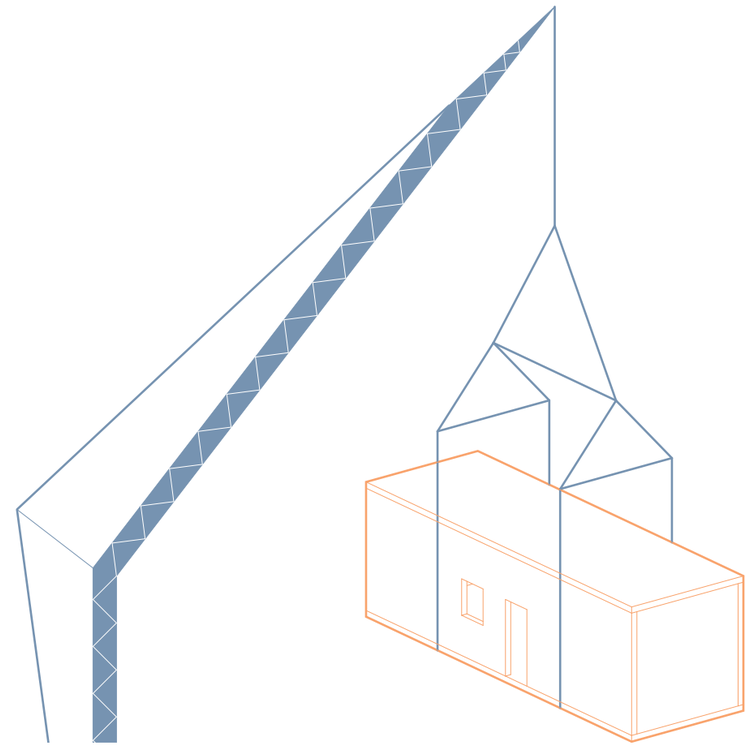


FIGURE 2.5 Bottom lift of modular volumetric units



EXAMPLES OF MODULAR HOUSING IN SWEDEN

THE MILLION HOMES PROGRAM

Industrialised housing construction and prefabrication had been developed since the 1920s in Sweden with influences from other European countries (Aitchison, 2018). Post-World War II, the housing shortage was of great concern all over Europe and several initiatives for affordable housing were invested in. In Sweden, the nationwide initiative for solving the housing shortage caused by rapid urbanisation, growing prosperity, and demand for larger space and higher standard was called *Miljonprogrammet*, The Million Homes Program (Vidén, 1999). The initiative entailed that one million residences were to be built within ten years. The residential buildings were commonly constructed of prefabricated concrete elements that could be serially produced and repeatedly used for multiple projects.

The residences were of good quality with good standard kitchens and bathrooms, and a rational floor plan (Vidén, 1999). However, the site integration and overall exterior expression were criticised for creating modern slums that neglected human values (Wirtén, 2010). For much of the general population of Sweden, The Million Homes Program has given industrialised housing a bad reputation.

One of the issues in the design process of The Million Program Homes houses was that workload was shifted from the architect to the contractor, resulting in lost control over production decisions, which caused certain architectural values to be disregarded in the design (Aitchison, 2018). Nevertheless, The Million Homes Program was successful in the sense of providing affordable, qualitative housing but perhaps failed to acquire other aspects of personalisation and character that people desire for their neighbourhood and home.

BOKLOK

BoKlok is a joint venture modular housing company in Sweden founded by IKEA and Skanska in the 1990s. The company's vision is "*to create new sustainable homes for the many*" (BoKlok, n.d.), and the main objectives are affordability, sustainability, and quality. BoKlok has developed several series of modular housing concepts all constructed as volumetric units in timber that are combined to form different sized apartments. The first modules were designed by architect Gun Ahlström, IKEA interior designer Madeleine Nobs, and Skanska project manager Inger Olsson (Aitchison, 2018). The modules are produced off-site and the exterior expression of the facade and balconies are to some extent customised for each project. Architect firm SandellSandberg has been involved to develop the architectural expression of the houses and a catalouge of different materials and colours has been produced to enable different combinations to be used depending on the site (SandellSandberg, n.d.).

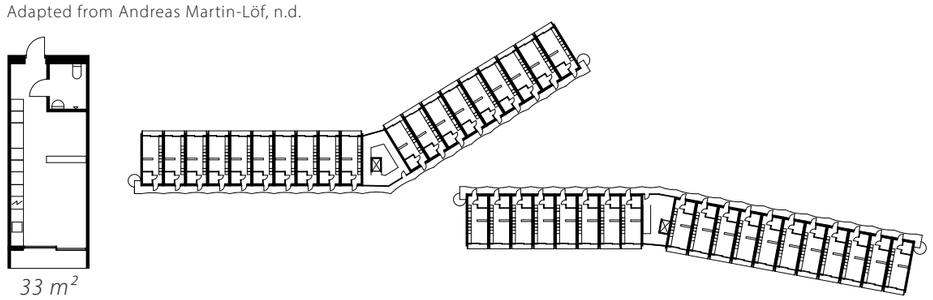
To achieve a predictable, rapid, and cost-effective building process that enables affordable housing, BoKlok limits the site choice to those that have simple circumstances so that city planning and design complications are kept to a minimum (Aitchison, 2018). This allows the overall planning of a project to be done within a day and the whole development process to be realised in less than half the typical time for residential buildings in Sweden. Figure 2.6 shows the modules and apartments of one of BoKlok's modular series.

FIGURE 2.6 BoKlok modular apartment series
Adapted from BoKlok, n.d.

SNABBA HUS

Snabba hus is a modular housing concept in Sweden developed by Jagvillhabostad in collaboration with Svenska bostäder in 2017. The concept is to create mobile modular housing units for young adults that can be built on temporary building permits as a means to provide affordable housing with a rapid planning and building process that will target the housing shortage for young adults (jagvillhabostad, n.d.). The idea is that once the building permits expire, the modules can easily be moved and reassembled on another site. Four projects have been realised located in Västberga, Råcksta, Knivsta, and Norra Ängby, all designed by architect firm Andreas Martin-Löf. The apartments are built off-site as complete volumetric units constructed of prefabricated concrete elements (Andreas Martin-Löf, n.d.). The modules are roughly the same for all projects but the configuration on site and the facade expressions differ. Figure 2.7 shows the typical modular apartment unit and the site configuration of Snabba hus Råcksta.

FIGURE 2.7 Snabba hus Råcksta modular apartments
Adapted from Andreas Martin-Löf, n.d.



THE POTENTIAL OF CROSS LAMINATED TIMBER

AN INNOVATIVE REFINEMENT OF TIMBER

Cross-laminated timber (CLT) was developed for commercial use in the 1990s in Switzerland and Austria. It is a refinement of timber where rigidly bonded planks in crosswise layers make up a composite of great strength and stiffness (Svenskt Trä, 2017). The product aimed to modernise traditional timber construction by creating a readily available building material that has the potential to compete with concrete construction-wise.

Even though Sweden has a long history of building with timber, it was not until 1994 that a regulatory change made it possible to erect timber-constructed housing greater than two storeys (Aitchison, 2018). The change made it possible for CLT to enter the Swedish market and as of today, there are three large CLT manufacturers in Sweden: Martinsons, Stora Enso, and Södra. Two of them established their CLT production in 2019, which shows the trend of increasing demand in recent years.

PROPERTIES

The development of CLT expanded the potential use of timber for efficiently constructing prefabricated multi-storey buildings. CLT has great potential to be used for modular buildings because the panels are completely industrially made and cut to the right form off-site. The manufacturing process and the material properties of CLT enable great architectural freedom for both shaping the panels and creating openings (Albus, 2017). Further on, studies have shown that the visual and tactile experience of wooden material has the property to induce physiological relaxation in humans (Ikei et al., 2017). Using CLT as not only a load-bearing structure but also as the finished interior or exterior cladding therefore has the potential to have a positive effect on our well-being.

The CLT manual, *KL-trähandbok*, written by the Swedish organisation Svenskt Trä (2017) provides the following list of material properties:

- High load-bearing capacity in proportion to its dead load
- Small production tolerances and good shape stability
- Good load-bearing capacity when exposed to fire
- Good thermal insulation capacity
- Low dead load, which entails lower transportation and assembly costs
- Good capacity to tolerate chemically aggressive environments
- Flexible production that enables different shapes as well as curved surfaces

SUSTAINABILITY

The construction industry makes up approximately 10 % of global energy-related CO2 emissions and changes need to be made in order to move towards zero-emission, efficient and resilient buildings (United Nations Environment Programme, 2020). One way to approach the environmental hazard of the building industry is to evaluate the choice of material in construction. CLT has the potential of being a sustainable alternative to steel and concrete due to its abundant supply, if forestry is managed correctly, and its property of storing carbon (Kwok et al., 2020). Further on, the modular aspect of CLT makes it possible to minimise waste in production as well as to disassemble and reuse the panels for new structures (Svenskt trä, 2017). The material can also be converted into energy through combustion.

CROSS LAMINATED TIMBER PREFABRICATION

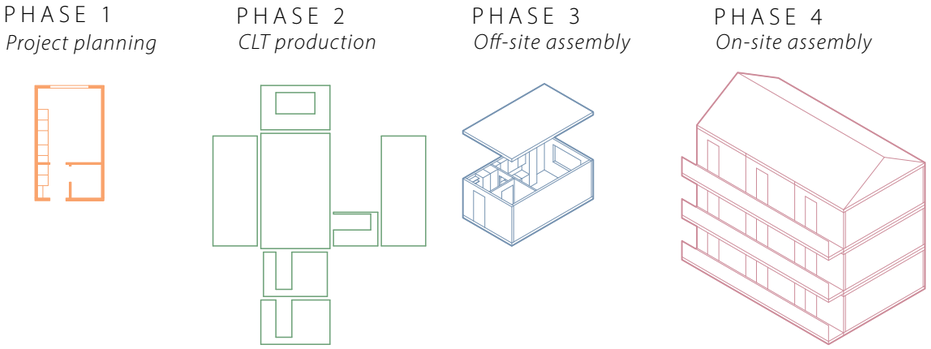
PROCESS

The process of prefabricating CLT panels consists of many steps. Generally, generic panels are not produced and stored waiting to be processed, instead the panels are produced directly for the specific dimensions ordered. This way, material waste can be reduced. The CLT production process is thoroughly described in *KL-trähandbok* (Svenskt trä, 2017). In the first step of the process, wooden planks from a sawmill are extended by dovetail joints, planed, and then glued together side by side to form a panel layer. It is important that the moisture level of all planks is between 8-11 % and that the difference in level between adjacent planks is not greater than 5%. A uniform moisture level will give the final panel greater strength properties and reduce the risk of splits and cracks. Thereafter, all layers of planks are glued together under pressure and arranged so that every layer is laid out in a perpendicular direction to the layer before. Once the panel has hardened, it can be processed and cut into exact shapes and sizes using a CNC machine. The CNC router makes it possible to create all cuts for installations, joints, doors, and windows completely off-site. Before the panels are packaged and sent out, they are visually inspected and polished to the desired finish.

VOLUMETRIC UNIT FABRICATION

As described earlier, CLT is an appropriate construction material for building whole volumetric modular units because of the material properties and the prefabrication process. Nock (n.d.), a Swedish company that specialises in the fabrication of modular residential units constructed in CLT, describes their process to consist of four phases as illustrated in Fig 2.8.

FIGURE 2.8 The process of a volumetric unit house
Based on Nock, n.d.



DIMENSIONS

The Swedish manufacturers Martinsons, Södra, and Stora Enso produce CLT panels with dimensions of maximum 3 - 3,5 x 16 meters (Martinsons, 2022; Södra, 2022; Stora Enso, n.d.). The panels are mainly produced from spruce wood, are made up of 3 - 7 layers of bonded planks, and the panels generally range from 60 millimeters to 280 millimeters in thickness. CLT can be used for exterior walls, interior walls, slabs, and roofs and the different areas of application determine the appropriate number of layers and thickness of the panel.

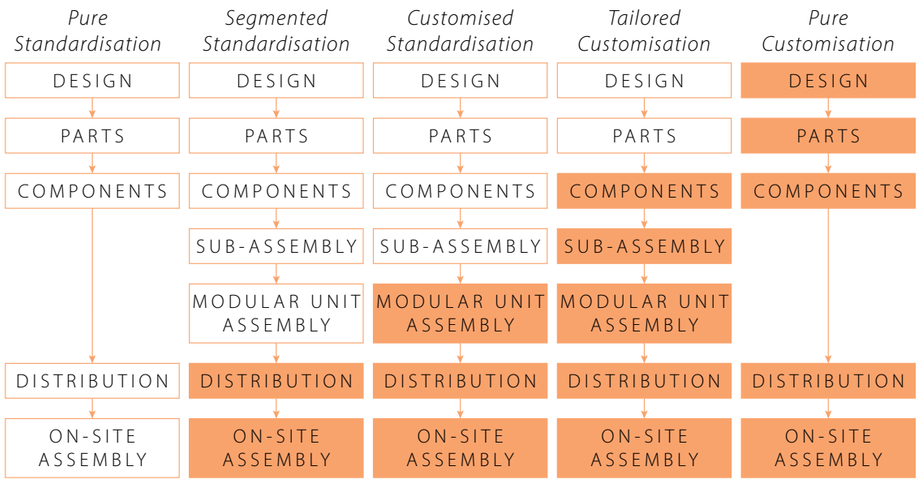
3 THEORY

BALANCING STANDARDISATION AND CUSTOMISATION IN MODULAR DESIGN

STRATEGIES FOR STANDARDISATION/CUSTOMISATION

The balance between standardisation and customisation is one of the key challenges in modular design. While a high degree of standardisation entails the outmost cost and time effectiveness in production, it reduces the ability for customisation by the customer as well as for flexible design variations that are crucial for site integration and for creating a distinctive design. In the research paper *Choice and delivery in housebuilding: lessons from Japan for UK housebuilders* (Barlow et al., 2003), the authors analyse the level of standardisation versus customisation in modular housing systems in Japan, a country where modular housing is widespread. The analysis aims to map out different strategies for approaching the issue of standardisation versus customisation. In the research paper, the level of standardisation and customisation is divided into five different strategies that differ depending on where in the supply chain the possibility for customisation is offered. The strategies are pure standardisation, segmented standardisation, customised standardisation, tailored customisation, and pure customisation. Figure 3.1 shows the model for the strategies where the white areas in the supply chain represent standardisation and the coloured areas in the supply chain represent customisation.

FIGURE 3.1 Strategies for standardisation/customisation in the housebuilding industry
Adapted from Barlow et al., 2003



FINDING THE APPROPRIATE BALANCE

Considering the context of the thesis; affordability, quality, and site integration, the matter of standardisation/customisation must be discussed in regard to each of those aspects. As discussed in chapter **2 Background,** affordability is best achieved with a high level of standardisation. Regarding quality, standardised qualitative solutions ensure quality for all and reduce the need to invent multiple solutions for similar problems. Thus, a common qualitative design, parts, components, sub-assembly, and modular unit assembly can all beneficially be standardised. Regarding site integration, standardisation is a limiting factor. A higher level of customisation is needed to allow for flexibility to adapt to local conditions and for variations in expression and volumetric configuration. Adding up, the design proposal and design application of the thesis would be suited to utilise the strategy of segmented standardisation.

SITE INTEGRATION: DESIGN WITH RESPECT TO CULTURAL VALUES

INTEGRATING CULTURAL VALUES

Riksantikvarieämbetet (2020), a Swedish governmental authority, has in collaboration with Boverket, ArkDes, and Statens konstråd published a report on how cultural values can be integrated into newly built projects. In the report, the current framework for integrating cultural values is presented, the potential ability to integrate cultural values is discussed, and examples of how cultural values can be integrated are brought up.

It is stated in the report that the preservation and integration of cultural values is of great importance for several reasons. For example, it stimulates social sustainability by contributing to positive and inclusive identities, and engages people in democratic processes regarding our cultural heritage. It also enables future generations to take part in and interpret history and cultural heritage as well as to maintain and create attractive surroundings and neighbourhoods. The potential to succeed to integrate cultural values in newly built projects is stated to depend on the presence of antiquarian expertise in the planning process and the specified interest in protecting cultural values presented in the detailed development plan and area regulations.

SUCCESSFUL INTEGRATION

The report highlights that the most crucial factor for successfully integrating cultural values in a new building project is that the cultural values are at all identified. Detailed development plans do not provide sufficient information for integrating cultural values, hence additional supporting information is needed early in the process. Such additional information can constitute of guidelines for national interest, the municipality's program for preservation, the municipality's architectural policy, or antiquarian analysis executed by expertise.

The housing exploitation of Kvarnholmen in Stockholm is brought up as an example of a project where cultural values were identified and evaluated at an early stage of the planning. An extensive antiquarian analysis was made and set the basis for the exploitation of the area. Thus, early on cultural values of the functionalistic architecture by KF's architecture office were identified and were considered in further planning. Even though the exploitation implied the addition of multiple buildings as well as the demolition of a few existing buildings, the underlying analysis of cultural values allowed for it to be done respectfully to the historical and cultural values of the site. For instance, a characteristic silo had to be demolished but was renewed through a building that replaces its shape and is a reminder of what was once there.

CONDITIONS FOR THE THESIS DESIGN APPLICATION

Regarding the design proposal of the thesis, the housing modules must be designed in such a way that a successful site integration is possible through customisation to local conditions in terms of building dimensions and overall expression. But most importantly, the site of the design application must be analysed in such a way that cultural values are identified, considered, and respected early in the process. An antiquarian description is available for the chosen site of the application as well as a detailed development plan and a description of national interest that affects the surrounding area of Upper Johanneberg. It is of great importance for a successful site integration that those documents set the basis for the design application of the thesis.

MEASURING RESIDENTIAL QUALITIES

CRITERIA FOR QUALITATIVE RESIDENCES

Sweden has a unique history of social housing policy that has resulted in an extensive implementation of standards and regulations to ensure basic housing quality for all residences (Andersson et al., 2018). A research platform at Chalmers, CBA (Centrum för boendets arkitektur) has an ongoing project called *MAB*, *Manual för analys av bostadskvaliteter* (Granath & Nylander, 2023) where evaluation criteria for qualitative residences are developed as a mean for analysis. The criteria are based on historical research on residential qualities as well as more recent findings. The residential qualities of MAB are divided into three aspects: functionality of the home, spaciousness of the home, and atmosphere of the home. The aspects each contain several criteria that are either attained or not for a specific residence. The number of attained criteria determines the quality grade of the residence in each aspect as bronze, silver, or gold. The results then give a total grade for all aspects summed up. For this thesis, the evaluation criteria of MAB are used as a design guidance for the design proposal as well as a tool to analyse the quality of the outcome. The different aspects and their respective criteria are briefly described below and illustrated in Fig. 3.2. In-depth descriptions of each aspect as stated in MAB (Granath & Nylander, 2023) are summarised and translated from Swedish to English in the following pages.

1. FUNCTIONALITY OF THE HOME

The aspect of functionality of the home evaluates the utility and efficiency of the residence. The criteria within this aspect are efficient area use, technical rationality, furnishable area, and potential to remain a resident.

2. SPACIOUSNESS OF THE HOME

The aspect of spaciousness of the home evaluates the spatial experience of the residence. The criteria within this aspect are axiality, movement and circular loop, room shape, and flexibility.

3. ATMOSPHERE OF THE HOME

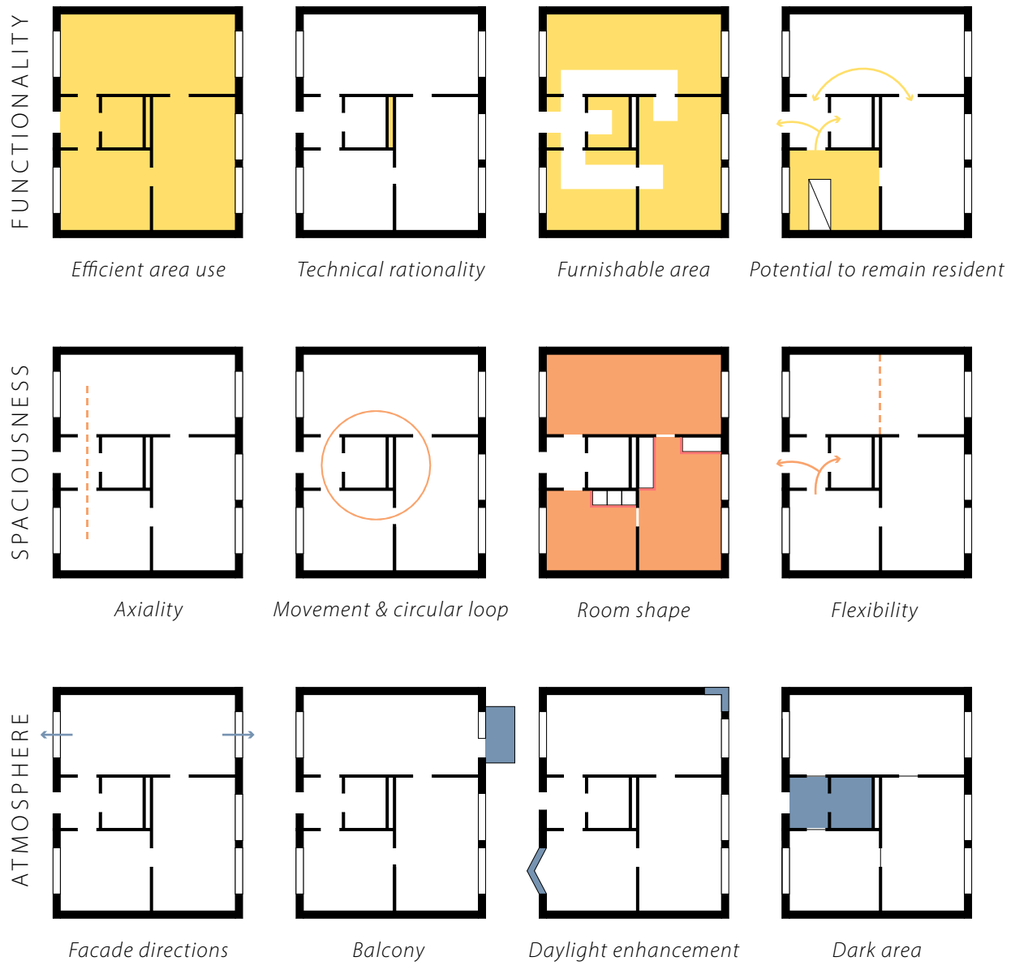
The aspect of atmosphere of the home evaluates the residence's daylight exposure as well as the connection between inside and outside. The criteria within this aspect are multiple facade directions, access to a balcony, explicitly designed daylight enhancement, and dark area.

REFLECTION OF MAB

MAB is currently in a state of development and has not yet officially been published. The version used in the thesis is a preliminary version. The criteria in MAB are in some cases limiting the ability for one-room apartments to be considered qualitative, however, this has been adjusted by adding exception criteria for apartments smaller than two rooms.

MAB is an interesting tool for this thesis because the target group, young adults, often live in smaller apartments where quality is compromised by size constraints. Using the quality criteria to evaluate the design proposal will also test where the threshold of floor area lies for the possibility to design qualitative small apartments according to MAB.

FIGURE 3.2 Categories and criteria for qualitative residences
Adapted from Granath & Nylander, 2023



FUNCTIONALITY OF THE HOME

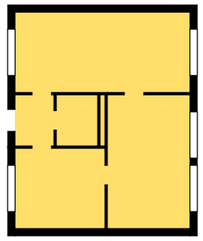
(Granath & Nylander, 2023)

EFFICIENT AREA USE

Aim: To efficiently use the area of the residence. Efficiently used area entails that the residents are not paying for unusable space.

Definition: A residence is considered to have efficient area use if the area is a maximum 95 % of the average area of that resident type produced in the last three years.

Criteria: The area of the residence is less than 95 % of the average area of that resident type produced in the last three years.



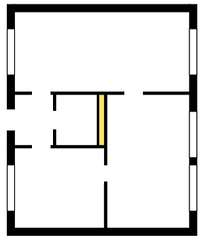
Efficient area use

TECHNICAL RATIONALITY

Aim: To increase the rationality and cost-effectiveness of a building by coordinating shafts for the kitchen and bathroom and ease technical maintenance.

Definition: Technical rationality is attained for residences with one coordinated shaft for both the kitchen and bathroom that is accessible for maintenance from the stairwell. For residences with a separate guest toilet, an additional shaft is acceptable.

Criteria: All shafts are reached from the stairwell or coordinated.



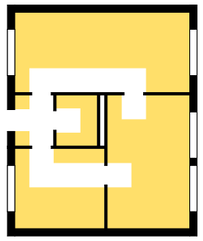
Technical rationality

FURNISHABLE AREA

Aim: To achieve a high degree of usable area that is not disturbed by communication space or door openings.

Definition: Furnishable area is an area greater than 0,45 x 0,45 m^2 undisturbed by communication space and door openings. Storage rooms without windows are not included. Communication space is a 0,8 m wide continuous passage between room openings. Door openings take up 1 m^2 on either side.

Criteria: The furnishable area should make up a minimum of 50 % of the total area of the residence.



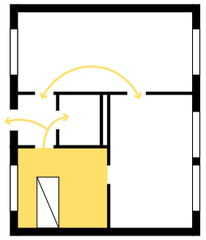
Furnishable area

POTENTIAL TO REMAIN RESIDENT

Aim: To be able to remain a resident regardless of growing old or needing medical care in the home.

Definition: The potential to remain resident is dependent on the bedroom capacity, room closeness, and functional autonomy. One bedroom must be capable of medical care surrounding a single bed. The bedroom must be within 6 m of storage, a bathroom, and the entrance. The residence must obtain a plan layout that allows for functional autonomy so that another person can be undisturbed by the medical care.

Criteria: The residence is functional regarding bedroom capacity for medical care, room closeness, and functional autonomy. For residences with less than two rooms, the criterion for functional autonomy is disregarded.



Potential to remain resident

SPACIOUSNESS OF THE HOME

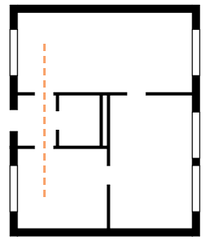
(Granath & Nylander, 2023)

AXIALITY

Aim: To enhance the experience of space and light of a residence by being able to move along an axis through several rooms.

Definition: Axiality is when one can move through several rooms in a residence along an axis and experience a sequence of spaces. Bathrooms, storage rooms, and closets are not included.

Criteria: There are a minimum of two axialities through at least three defined spaces in the residence. For residences with less than two rooms, one axiality is sufficient.



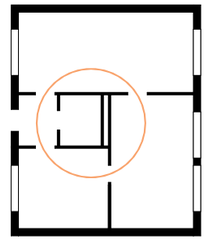
Axiality

MOVEMENT AND CIRCULAR LOOP

Aim: To enhance the experience of the space by being able to move in different ways and reach rooms from multiple directions.

Definition: Circular loop is when there is a possibility to move in a circle around fixed furniture, structural elements or between different rooms.

Criteria: There is a minimum of one circular loop in the residence. For residences with less than two rooms, a room of 20 m^2 or greater is sufficient to be considered to attain good movement.



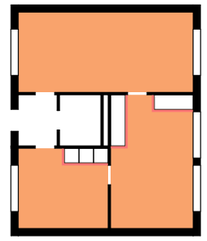
Movement & circular loop

ROOM SHAPE

Aim: To enhance the experience of a clearly defined room, which is rational and aesthetically pleasing.

Definition: A room is well-shaped if it can be defined using only one rectangle. The analysis only includes bedrooms, kitchen, dining area, and living room.

Criteria: The shape of the bedrooms, kitchen, dining area, and living room can be defined using only one rectangle.



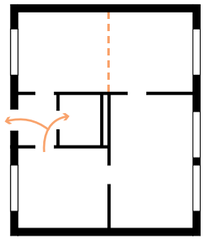
Room shape

FLEXIBILITY

Aim: To allow for flexible use of the rooms, capacity to house several households, and ability to change plan layout over time.

Definition: There are 5 possible aspects of flexibility: 1. General rooms, meaning that the dimensions of a room allow for different use. 2. Parallelism, meaning that different functions and communication between different rooms can be ongoing without disturbing one another. 3. Variable number of rooms, meaning that one room can be divided into two with sufficient dimensions and daylight exposure. 4. Connections between rooms, meaning that a room has several openings or doorways to other rooms. 5. Autonomous room, meaning that a room is close to the entrance and has a neutral communication to a bathroom.

Criteria: A minimum of three of the five definitions are attained in the residence. For residences with less than two rooms, a room with dimensions 3 x 3,1 m constitutes a flexible residence.



Flexibility

ATMOSPHERE OF THE HOME

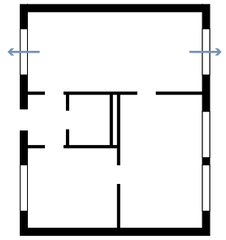
(Granath & Nylander, 2023)

FACADE DIRECTIONS

Aim: To allow direct daylight to enter the residence throughout a greater portion of the day. Daylight from multiple directions also gives a variety of different types of light.

Definition: Separate facade directions are defined as being angled a minimum of 45° differently. Angled bay windows and windows toward a glazed balcony are not included.

Criteria: The residence has windows in a minimum of two different facade directions.



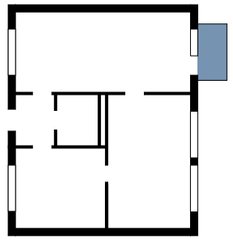
Facade directions

BALCONY

Aim: To give a connection to the outside and provide a private outdoor space.

Definition: A balcony, or terrace, is a private outdoor space that is accessible directly from a room in the residence. An access balcony can be considered a private outdoor space if it is furnishable, and the width is at least 2,2 m.

Criteria: There is a balcony or terrace directly accessible from the residence.



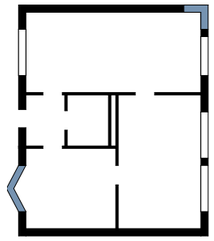
Balcony

DAYLIGHT ENHANCEMENT

Aim: To enhance the exposure of daylight in the resident and allow for a more varied diffusion of light.

Definition: Daylight enhancement entails architectural elements that increase the amount and the quality of light entering the residence. Such architectural elements are bay windows, French balconies, windows over corners, and chamfered window niches.

Criteria: The residence contains at least one architectural element for daylight enhancement.



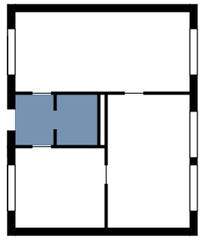
Daylight enhancement

DARK AREA

Aim: To minimise the area without exposure to daylight and visual contact with the outside.

Definition: Rooms or parts of rooms without visual contact with a window are dark areas. The analysis is done with doors closed between bedrooms, kitchen, and living room, and towards hallways and entrances. All rooms are included in the analysis and all areas greater than 0,45 x 0,45 m are summed up. Fixed wardrobes are not included as an area.

Criteria: The dark area constitutes a maximum of 15 % of the total area of the residence.



Dark area

DESIGNING AFFORDABLE HOUSING FOR YOUNG ADULTS

STRATEGIES FOR AFFORDABLE HOUSING DESIGN

Hyresgästföreningen has together with Malmö City and different actors in the building industry initiated a project called *1000 ungdomsbostäder*. The initiative aims to urge innovation in the building industry and develop strategies for affordable housing design that will set the basis for building 1000 new residences for young adults in the Malmö region. A pilot study of the initiative (Prolong, 2020) presents the background of the project and the outcome of workshops on strategies for affordable housing design. The goal of affordable housing is stated in the pilot study to be that a 35 m^2 sized apartment should correspond to a monthly rental cost for the tenant of 5538 SEK/month. The background to the proposed goal is that the rental cost is less than 30 % of a minimum wage single household's disposable income. The strategies presented in the pilot study are divided into three main areas: product, process, and productivity.

PRODUCT

The development of the residence should be based on the preferences of the target group of young adults so that the product satisfies the needs of the future tenants. Investigating preferred aspects of a residence enables identification of what areas can be compromised for cost savings and what areas should not. An example is the potential of designing residences where some functions are shared between multiple tenants as a means to optimise the area use. A study by Hyresgästföreningen (2020) shows that the laundry room is the space that most young adults, 84 %, are ok to share with others whereas the living room, kitchen, and bathroom are spaces that almost 50 % would not be ok with sharing. In one of the workshops presented in the pilot study, the potential of implementing access balconies and outdoor stairwells instead of corridors and indoor stairwells is also brought up as a way to reduce the rental cost while not compromising the quality of the residents' private space. These are all aspects that will be considered in the development of the design proposal of the thesis.

PROCESS

A well-functioning cooperation between different actors is crucial for the development of an efficient production process. This can be achieved by involving the right actor at the right time and to the right extent to reduce unnecessary work and time spent in the process. For example, in one of the workshops presented in the pilot study, it is brought up that the electricity, plumbing, and ventilation installers are often brought in too late in the process, which entails much rework to be done. As this aspect is very comprehensive, it will not be investigated further as a strategy in the development of the design proposal. However, it relates to technical rationality, which will be evaluated as a quality using MAB.

PRODUCTIVITY

Increasing productivity is done by identifying moments in the process that can be done more efficiently. Examples of aspects that counteracts productivity according to the pilot study are a culture of "doing it the way we have always done", developing a new strategy for each project, and a lack of innovative solutions. The potential of prefabricated elements is brought up as a means to increase productivity, which strengthens the argument of modular housing for the design proposal. However, the aspect of flexibility is also brought up as an issue connected to prefabrication because an affordable housing project must be designed in such a way that the site area used is optimised.

4 SITE ANALYSIS

SITE CONTEXT

LOCATION

The site for the design application belongs to the Krokslätt district but is located on the border to Johanneberg at the corner where Eklandagatan and Gribraltargatan meet. It is an attractive location for student housing because of the proximity to Chalmers University of Technology, various facilities of Gothenburg's University, as well as the city centre. The location of the site is interesting and implies certain design challenges of site integration because it is right at the partition between a more urban built environment and small-scale garden houses. Furthermore, the surrounding area is protected by national interest and Gothenburg's preservation program. Hence, what is built on the site must be designed with great respect to the location.

DETAILED DEVELOPMENT PLAN

The site is currently unbuilt. In 2014 a detailed development (Stadsbyggnadskontoret, 2014) plan for an office building on the site was produced but the process of actualising the plan has not been taken any further. In the detailed development plan, it is stated that residential buildings have been ruled out because of the noise level at the site. The documented noise level was 63-66 dBA, which exceeds the recommended value for residential buildings, 60 dBA. However, since then a new regulation (SFS 2017:359) has been implemented, which allows the noise level to be 65 dBA for residences that are 35 square meters or less. In the case of student housing, most of the residences would be designed small regardless. Thus, considering student housing to be planned on the site is a plausible idea. The detailed development plan suggests a building height of two to four stories. Residential stories are generally lower than office stories, therefore five stories could potentially be plausible as well.

PREVIOUS BUILDINGS

The site consists of two lots, which were both built on in the 1960s. Lot 102:2 (eastern part) was occupied by a small-scale residential house. Lot 102:9 (western part) was occupied by an Esso petrol station (see Fig. 4.1). Both buildings were later expanded and remodeled, and eventually demolished. (Stadsbyggnadskontoret, 2012)

FIGURE 4.1 Archived drawing of Esso petrol station
Stadsbyggnadskontoret, 2012

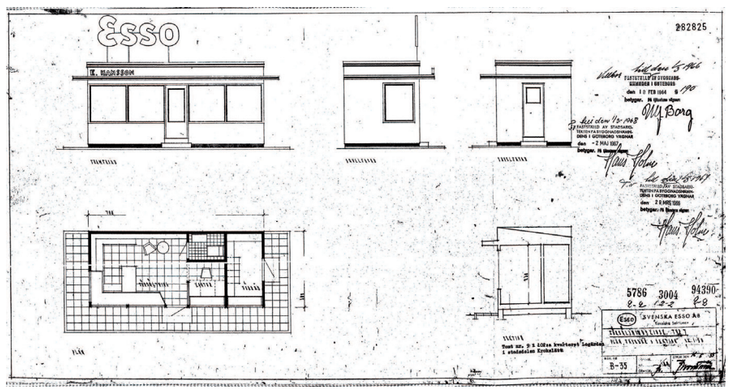


FIGURE 4.2 Site context

SURROUNDING BUILDINGS

LAMELLAS

Building height:
The surrounding lamellas range from 5-8 storeys and have flat roofs.

Building placement:
The buildings are generally aligned with the street direction and placed within a short distance from the street and space for greenery on the opposite side.

Building function:
The buildings are generally residential housing and the ones located along Gibraltargatan have commercial ground floors that give a sense of urbanity to the area.

SMALL-SCALE HOUSES

Building height:
The surrounding small-scale houses range from 2-3 storeys and generally have gable roofs.

Building placement:
The houses are generally placed within 4-6 meters distance from the street and are surrounded by private gardens.

Building function:
The houses are generally residential family homes.

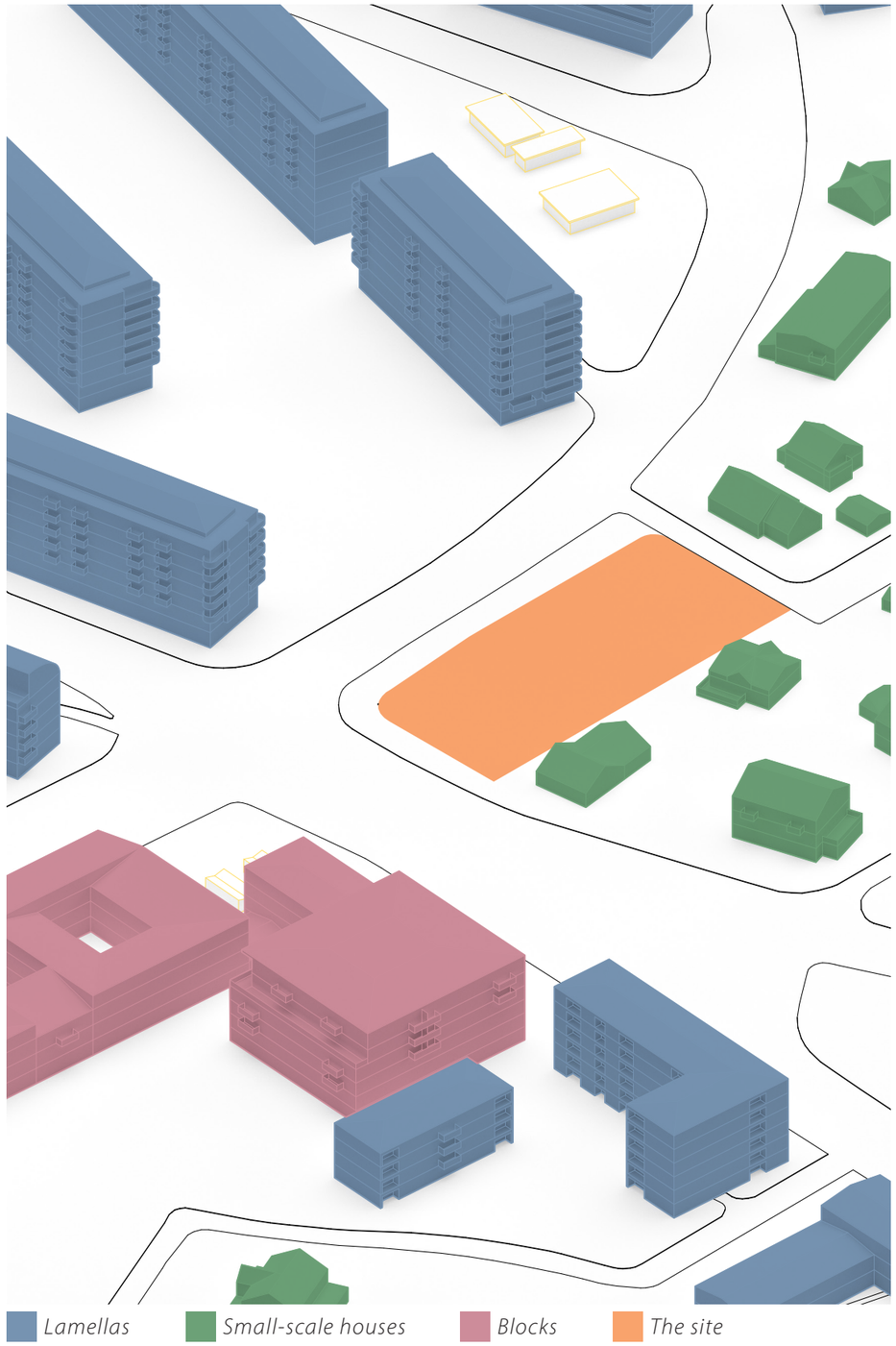
BLOCKS

Building height:
The surrounding block buildings range from 4-5 storeys and have flat roofs.

Building placement:
The buildings are aligned with the street direction and placed within a distance from the street allowing for communication and parking.

Building function:
The buildings are residential student housing and facilities of Gothenburg's University.

FIGURE 4.3 Surrounding buildings



ASSESSMENT OF CULTURAL VALUES

NATIONAL INTEREST

The distinction of areas of national interest is a way of ensuring the preservation of Sweden's cultural values and heritage in nature and in the built environment. It aims to be a framework for further development of a certain area where the national interest can be seen as providing potential rather than being a barrier so that long-term sustainable solutions can be established (Riksantikvarieämbetet, 2016).

Gothenburg's city centre is identified as an area of national interest (Riksantikvarieämbetet, 2022). In the motivational description, Upper Johanneberg is mentioned as a point of certain interest: "*Folkhemmets ("the people's home") functionalistic urban planning in Upper Johanneberg with directionally oriented lamellas in inclining rocky terrain.*" (p. 15, translated by the author). The functionalistic ideals, the shape and orientation of the buildings, and the building's relation to the terrain can be identified to be the main characteristics that make up the cultural values of national interest for Upper Johanneberg.

GOTHENBURG'S PRESERVATION PROGRAM

Kulturhistorisk Värdefull Bebyggelse (Culturally-Historically Valuable Buildings) is Gothenburg's program for the preservation of the built environment. The program aims to compile a basis for preservation from several programs of cultural interests to make up an overall assessment useful for further planning and development of Gothenburg (Lönnroth, 1999). The motivation for the cultural and historical preservation of Upper Johanneberg is stated as follows:

> "Upper Johanneberg is Gothenburg's most distinctive functionalistic area and the first area of the city to be built entirely following functionalistic architectural ideals. The environment as a whole is well preserved with a strict functionalistic urban plan and light plastered residential buildings surrounded by generous areas of greenery." (p. 132, translated by the author)

The functionalistic ideals, the urban planning, and the cohesive facade cladding of the buildings can be identified as cultural values to preserve.

ANTIQUARIAN DESCRIPTION

The antiquarian description for the chosen site was produced by Stadsbyggnadskontoret (2012) as an investigation for further development to complement the detailed development plan. The functionalistic character of Upper Johanneberg as well as the transition from the urban scale housing of Johanneberg to the small-scale housing of Krokslätt are highlighted in the antiquarian description as important aspects to consider when planning for a new building on the site. More specifically, scale, distance, surface cladding, and window placement are identified in the description as qualities to respect. Recommended approaches of how to do so are presented:

- Scale down the building towards the small-scale housing of Krokslätt
- Respect the current circumstances of building placements in relation to the site and its surrounding
- Get inspiration for surface claddings from already existing materials in the area rather than introducing something new
- Window placements should be modest and characterised by regularity

CHARACTERISTICS OF UPPER JOHANNEBERG

SHAPES

Protruding

Orthogonal

Rounded

The buildings' main shapes are oblong rectangular blocks that are only disrupted by some protruding rectangular portions and suspended balconies. Rigid orthogonal shapes are contrasted by rounded corner balconies.

MATERIALS

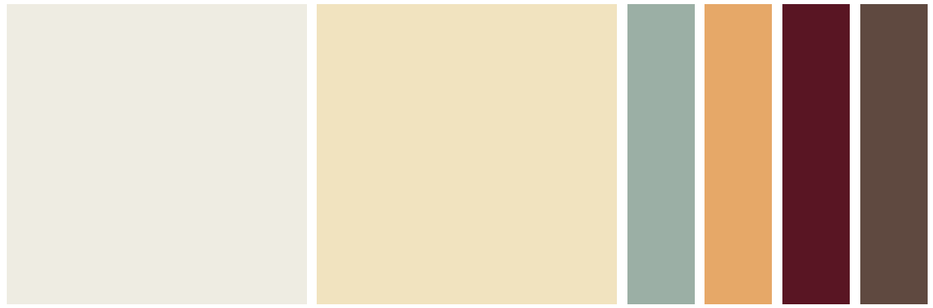
Plaster

Corrugated steel

Steel frame

Most of the facades are plastered smoothly. The balconies are covered in corrugated steel sheets with a top railing and the windowsills and window frames are made of steel.

COLOURS



Main colours *Accent colours*

The buildings generally have pale beige or pale yellow as the main colour for the body and accent colours for the roof, balconies, windowsills, and window frames.

5 DESIGN STRATEGIES

THREE PRINCIPLES

STRATEGIES FOR THE DESIGN PROPOSAL

Derived from the knowledge gathered in the background and theory chapter, three principles for design have been articulated. The three principles aim to target the aspects of affordability, quality, or site integration as design strategies to base the design proposal on.

1. OPTIMISE THE USE OF SIMILARITIES

– To utilise the potential of prefabricated design and serial production by reducing the number of variations, creating a more cost- and time-effective planning and building process.

• Design modules that can be utilised for several apartment types
• Intentionally incorporate similar design elements such as recurring door and window dimensions

2. RATIONALISE INTERNAL LAYOUT

– To develop one thorough concept for the layout of a qualitative residence, which can to some degree be constant for all apartment types, reducing the need to invent multiple solutions.

• Make use of the dimensional restrictions of modular design to find appropriate chains and sequences of functions
• Find functional, spatial, and atmospheric qualitative design solutions defined in MAB that are recurring for multiple apartment types

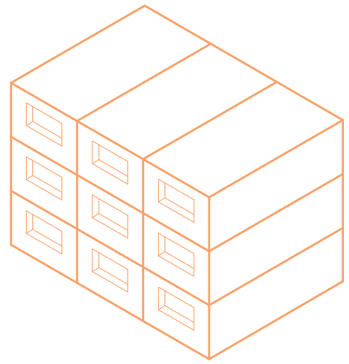
3. PROVIDE VARIETY AND FLEXIBILITY EXTERNALLY

– To enable certain aspects of customisation for adequate site integration and site adaptation where the design can respect the local built environment and cultural values

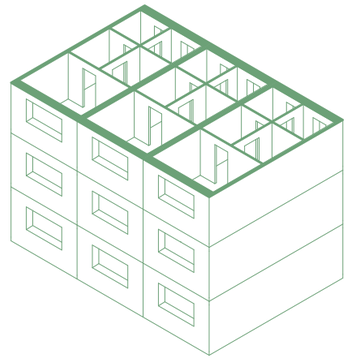
• Implement customised access balconies and stairwells as entrance situations to enable flexible site integration
• Design a standard neutral base and let the external cladding, and roof be completely customisable

FIGURE 5.1 Design strategies diagram

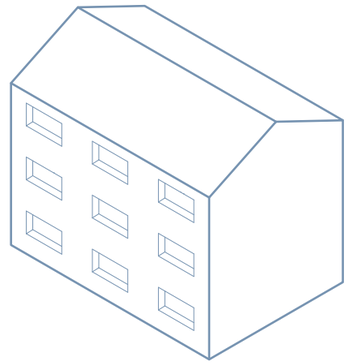
1. Optimise the use of similarities



2. Rationalise internal layout



3. Provide variety and flexibility externally

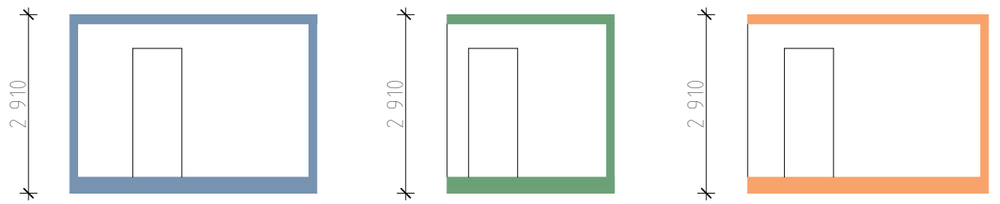


6 DESIGN PROPOSAL
MODULAR APARTMENT SERIES

THE MODULES

PLAN

SECTION



MODULE A, B, AND C

The modular apartment series is made up of three modules, A, B, and C, that can through different combinations form three different apartment types that correspond to three common household types of young adults: one person single household, two persons couple household, and 2 persons collective household. Module A is the base module for all apartment types and contains all fundamental functions such as the entrance, storage, kitchen, and bathroom. Gathering all essential functions in one module reduces internal variations and rationalises the apartment layout to make up a cohesive concept with consistent qualities in all apartments.

PREFABRICATION, TRANSPORTATION, AND ASSEMBLY

CLT VOLUMETRIC UNITS

The modules are designed as volumetric units constructed in cross-laminated timber that are prefabricated off-site. The walls and slabs are produced and processed through CNC machining to the right size and with openings for doors and windows. Each module constitutes a self-supporting structure that is built up as an individual unit.

ACCORDANCE WITH TRANSPORTATION REGULATIONS

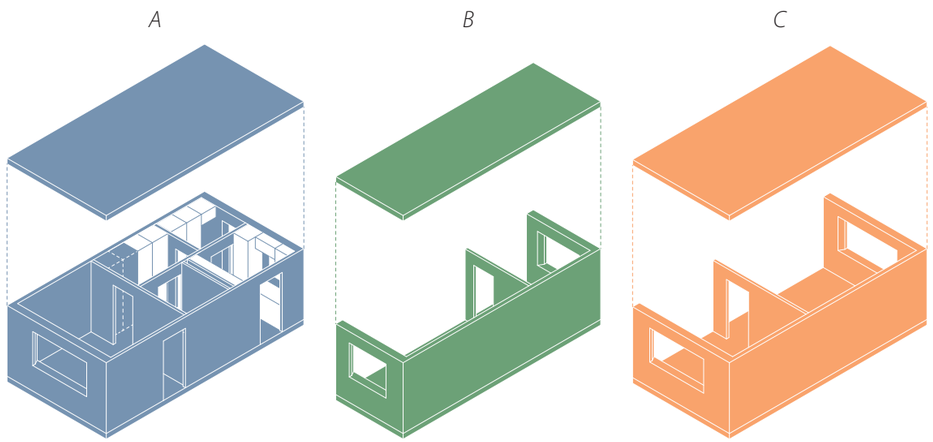
The modules are designed in accordance with transportation regulations to ease transportation to the site. Thus the width of the units is kept under 4,15 m.

HYBRID OFF- AND ON-SITE ASSEMBLY

The modules are produced and assembled to complete units off-site in factory to advocate an efficient process that is non-weather dependent. The units are insulated outwardly and the interior cladding is fixed. Overall, the units are completed in a standardised manner, however, some aspects such as colours of fixed interior elements or windows frames can be customised for each project.

On-site, a site-specific foundation is built and the modules are lifted onto place, secured, and all installations are completed. Project customised access balconies are attached to each floor and customised stairwells are built as well. Lastly, once all units are in place, a customised facade and roof are added.

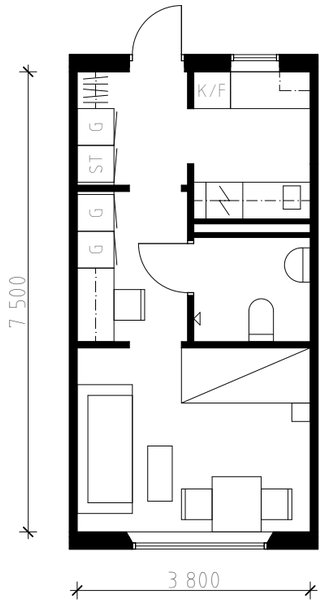
AXONOMETRY

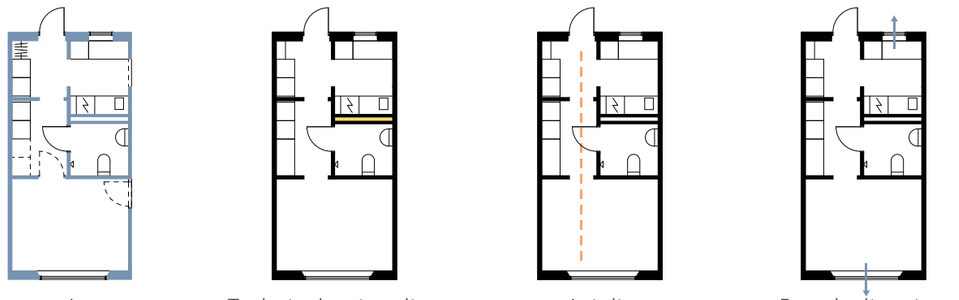


APARTMENT 1

1 ROOM AND KITCHEN – 28,5 m²

1 person single household





A *Technical rationality* *Axiality* *Facade directions*

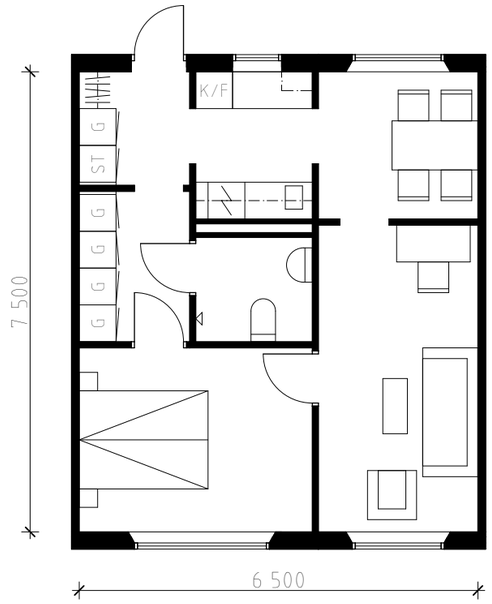
QUALITY EVALUATION

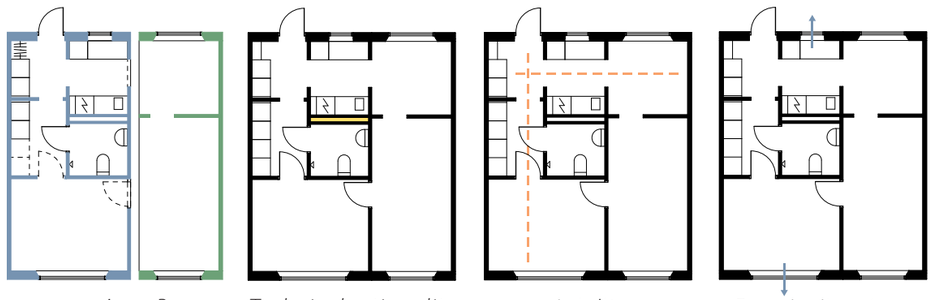
The residence attains the highest grade, gold, in the MAB quality analysis in all three categories of functionality of the home, spaciousness of the home, and atmosphere of the home resulting in an overall grade gold. Three aspects within the categories were not attained: furnishable area, movement and circular loop, and balcony. The criteria for furnishable area, and movement and circular room are difficult to meet for smaller residences and were thus not prioritised in the design. Balcony was not included in the design because it is a distinctive element of a building that could affect the potential for site integration. For the full MAB analysis, see **Appendix 1**.

APARTMENT 2

2 ROOMS AND KITCHEN – 48,8 m²

2 persons couple household





A + B *Technical rationality* *Axiality* *Facade directions*

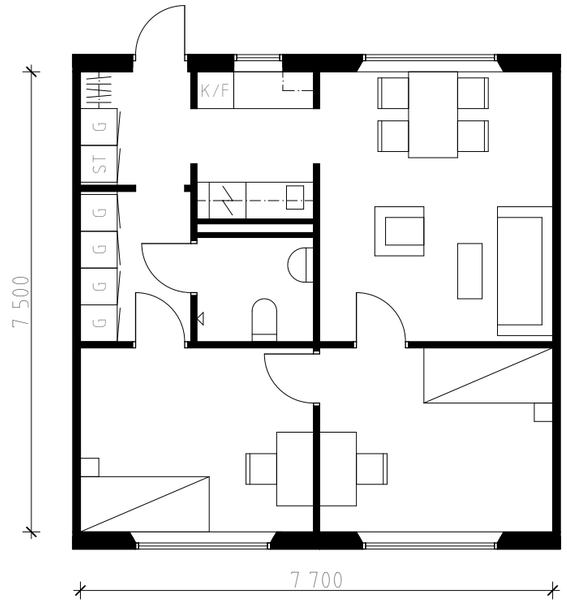
QUALITY EVALUATION

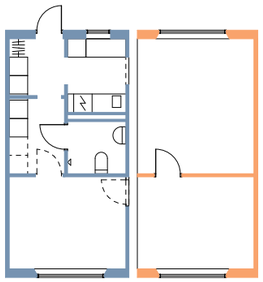
The residence attains the highest grade, gold, in the MAB quality analysis in all three categories of functionality of the home, spaciousness of the home, and atmosphere of the home resulting in an overall grade gold. Two aspects within the categories were not attained: flexibility, and balcony. The criteria for flexibility generally require bigger rooms, and more rooms, aspects restricted by the nature of the modular design and the apartment type. Balcony was not included in the design because it is a distinctive element of a building that could affect the potential for site integration. For the full MAB analysis, see **Appendix 1**.

APARTMENT 3

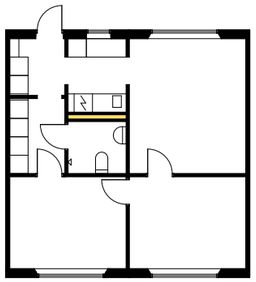
3 ROOMS AND KITCHEN – 57,8 m²

2 persons collective household

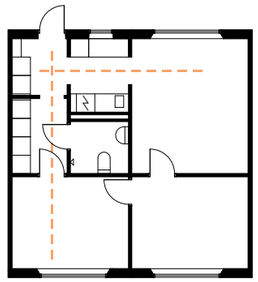




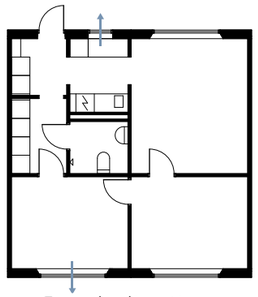
A + C



Technical rationality



Axiality



Facade directions

QUALITY EVALUATION

The residence attains the highest grade, gold, in the MAB quality analysis in all three categories of functionality of the home, spaciousness of the home, and atmosphere of the home resulting in an overall grade gold. Two aspects within the categories were not attained: flexibility, and balcony. The criteria for flexibility generally require bigger rooms, and more rooms, aspects restricted by the nature of the modular design and the apartment type. Balcony was not included in the design because it is a distinctive element of a building that could affect the potential for site integration. For the full MAB analysis, see **Appendix 1**.

0 5m

1:100

IMPLEMENTATION OF THE DESIGN STRATEGIES

1. OPTIMISE THE USE OF SIMILARITIES

• Design modules that can be utilised for several apartment types

The apartments have been designed so that Module A is a common base module for all, containing all fundamental functions such as the entrance, storage, kitchen, and bathroom. A consequence of that is that the kitchen counter space deviates from the Swedish recommended standard for different households. Apartment 1 has more counter space than what is recommended while Apartment 2 and 3 have the required counter space but configured in a different manner than what is recommended. Nonetheless, it is a deliberate design choice where the advantages of keeping the same layout for all apartments as well as the spatial qualities that the chosen kitchen configuration entails were concluded to justify the deviation from the recommendations.

• Intentionally incorporate similar design elements such as recurring door and window dimensions

There are only three variations of window dimensions and two variations of door dimensions, one for the exterior doors and one for the interior doors. It has not been limiting for the design but rather rationalised the spatial and atmospheric qualities.

2. RATIONALISE INTERNAL LAYOUT

• Make use of the dimensional restrictions of modular design to find appropriate chains and sequences of functions

The dimensional restriction of the transportation regulations (maximum 4,15 m in width) has been a dominating aspect of the plan layout possibilities. Finding a suitable chain of functions for the width of the module has been a determining factor for the whole plan layout. 600 mm storage, 1200 mm communication, and 1900 mm bathroom were found to be a chain of functions that works as a sequence and fits within the dimensional restrictions.

• Find functional, spatial, and atmospheric qualitative design solutions defined in MAB that are recurring for multiple apartment types

The apartments were planned with the MAB quality criteria in mind aiming for grade gold for all apartments. For example, the criteria of technical rationality placed the kitchen in coordination with the bathroom installations, for axiality and circular movement to be attained there had to be two paths of communication.

3. PROVIDE VARIETY AND FLEXIBILITY EXTERNALLY

• Implement customised access balconies and stairwells as entrance situations to enable flexible site integration

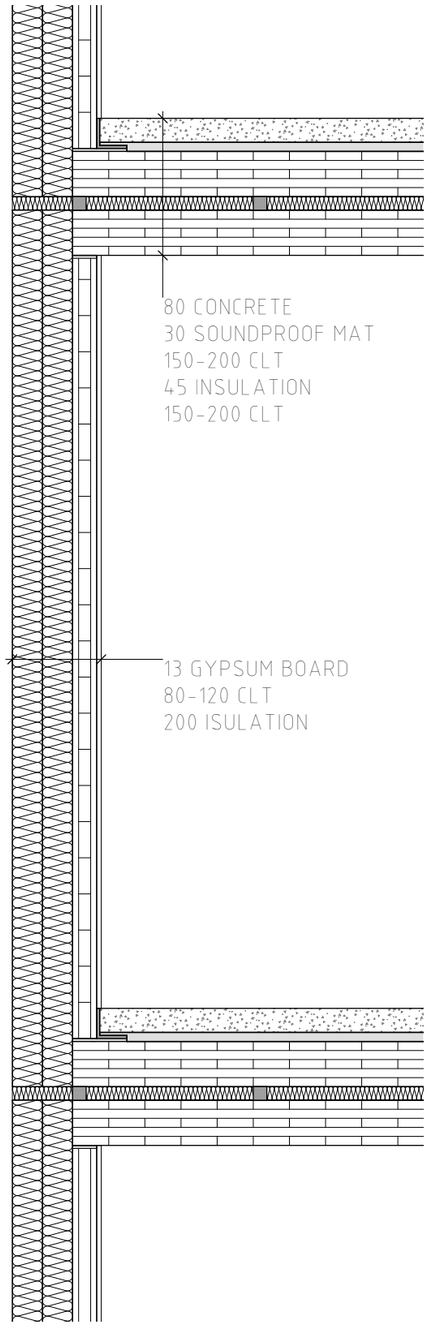
The entrance situations have not been touched upon in the modular apartment series other than being designed for access balconies. The design is completely customisable.

• Design a standard neutral base and let the external cladding, and roof be completely customisable

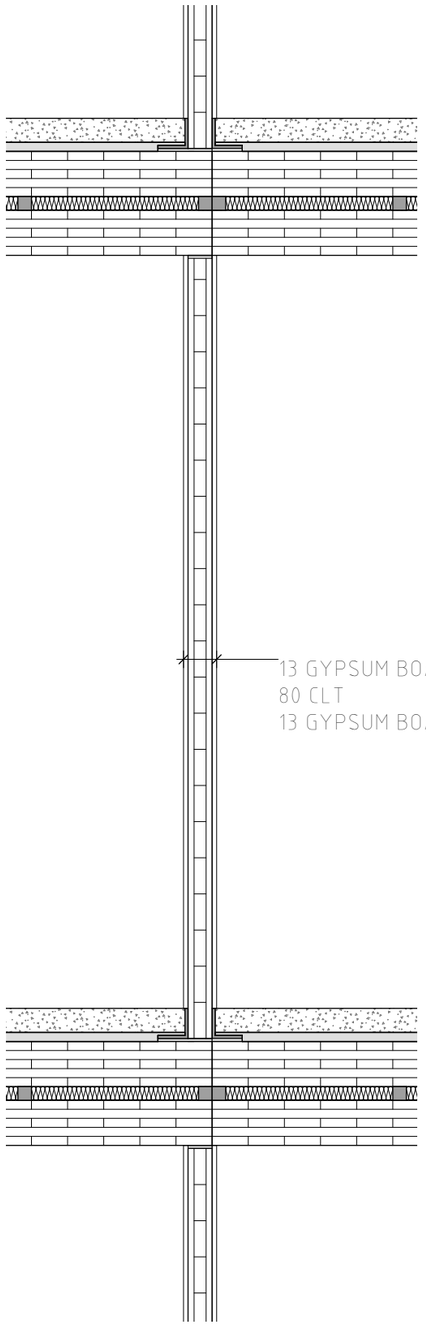
The modules make up a standard neutral base, which leaves the exterior to be completely customisable on-site.

PRINCIPLE DETAILS FOR ASSEMBLY

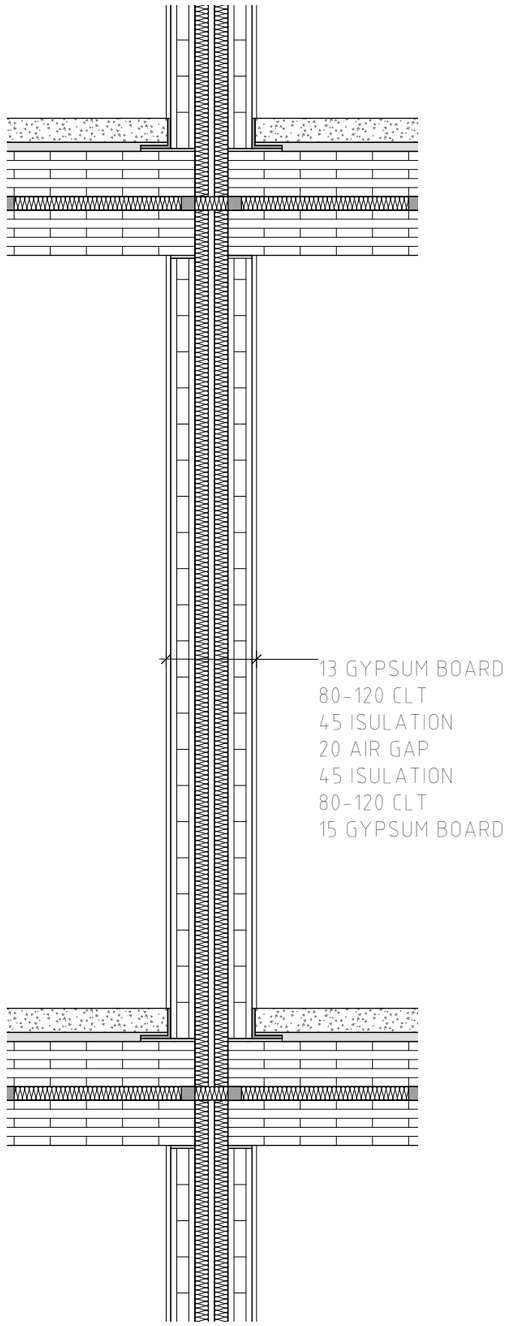
DETAIL A
Vertical section



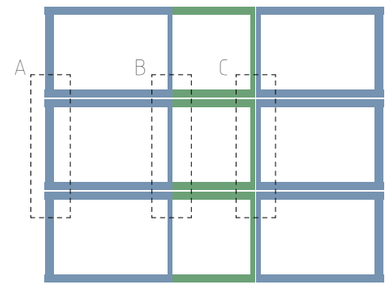
DETAIL B
Vertical section



DETAIL C
Vertical section



Detail markers



7 DESIGN APPLICATION
ESSO STUDENT HOUSING

A CONTEMPORARY ADDITION

ESSO STUDENT HOUSING

Esso student housing is a proposal for the lot Krokslätt 102:2 and 102:9 that is adjacent to Upper Johanneberg. The name "Esso" is a reference to what was once built there: an Esso petrol station. The proposal offers 63 student apartments of three different types, a generous bicycle parking garage for the residents, and commercial facilities on the ground floor to urge activity in the area. Esso student housing is intended to be a merging gradient between the urbanity of Upper Johanneberg and the small-scale houses of Krokslätt by adapting the scale and fractioning the volumes. The building height ranges from two to five storeys.

THE APARTMENTS

The three different apartment types in the building correspond to three common household types of young adults and students in general: one person single household, two persons couple household, and two persons collective household. The apartments are shown in depth in the previous chapter **6 Design Proposal**. The apartments are organised along access balconies that connect to two stairwells. This allows for daylight to enter each apartment from two directions and also implies that each apartment has a quiet side in relation to the street noise. The apartments are organised in such a way that the same apartment types are stacked vertically, which rationalises the vertical shafts and technical installations. Central technical rooms for installations and ventilation are placed underground in a basement where storage units for each household are also located.

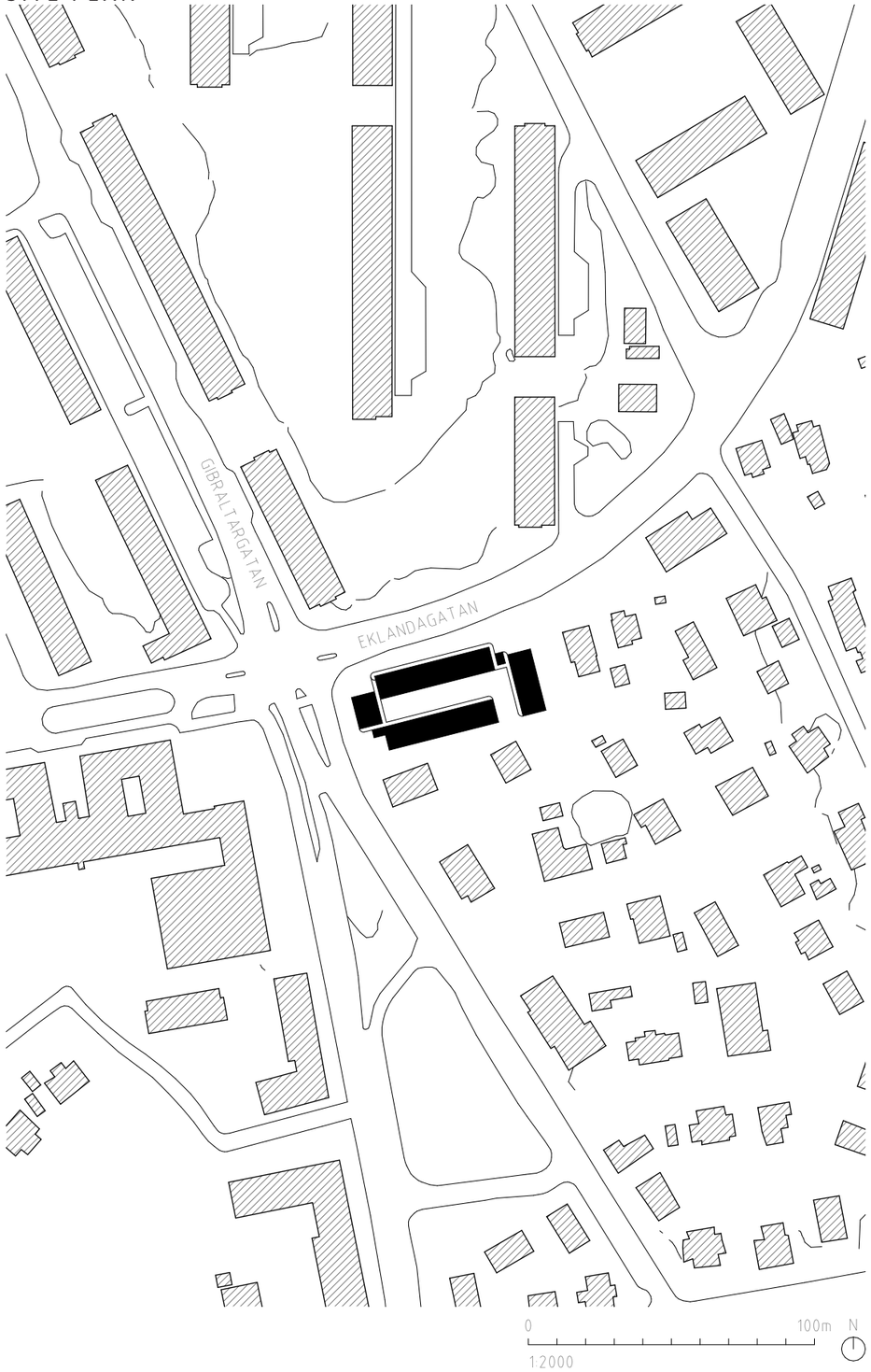
SITE INTEGRATION

The design of the proposal has highly been responsive to the assessment of cultural values from chapter **4 Site analysis**. Functionalistic ideals, identified as valuable in the National Interest and in Gothenburg's preservation programme have been carefully implemented by incorporating certain common characteristics of the area such as shapes and cladding as well as considering the functionalistic urban planning of orientation and relation to the street and the terrain.

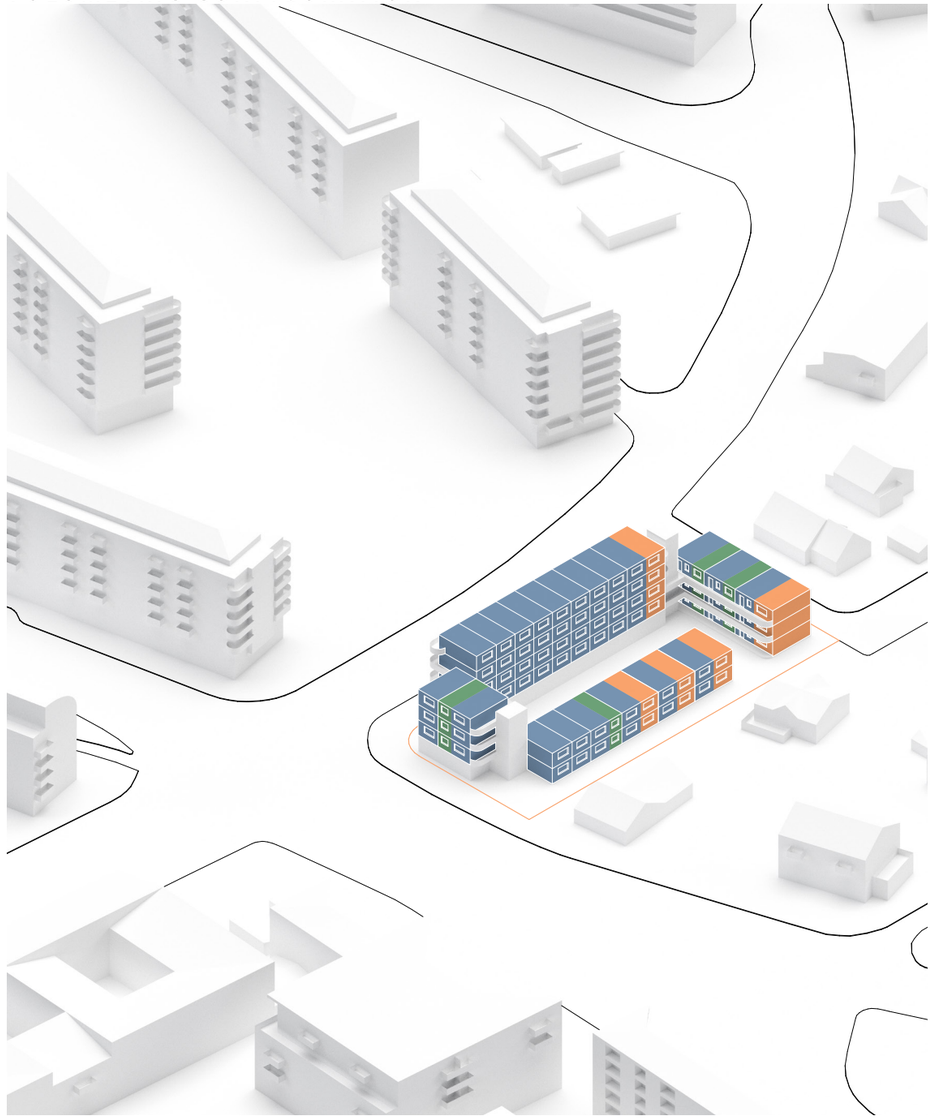
The assessment from the antiquarian description had more specific recommendations that have also been respected in the proposal. The scale of the building steps down towards the smaller houses of Krokslätt and the volume has been divided into four fractions to further loosen up the scale and adapt the building height to suit the situation of each side of the lot. Colours and surface cladding have been extracted from what can already be found in the area but in some cases with a new interpretation, which makes the building a contemporary addition rather than a strict imitation of 1930s functionalism.

SITE PLAN AND VOLUMETRIC CONFIGURATION

SITE PLAN



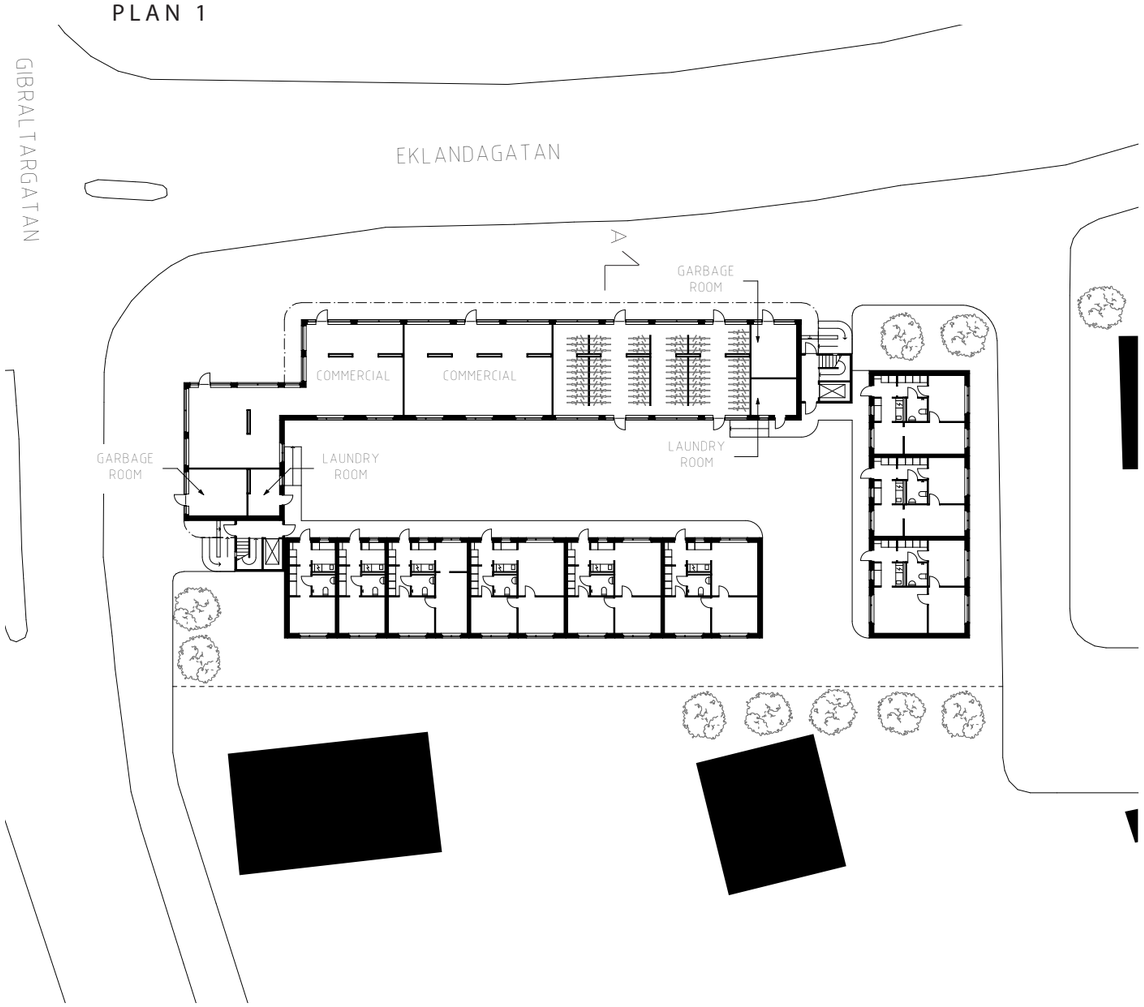
VOLUMETRIC CONFIGURATION



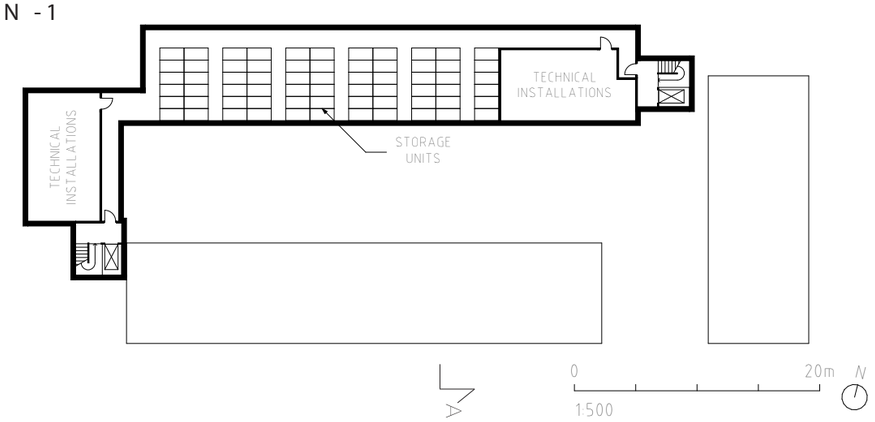
APARTMENTS			BOA		BIA		BTA	
1:	39	62 %	1:	1 112 m²	Laundry room:	21 m²	Plan 1:	987 m²
2:	11	17 %	2:	537 m²	Garbage room:	35 m²	Plan 2:	972 m²
3:	13	21 %	3:	751 m²	Bicycle room:	122 m²	Plan 3:	644 m²
Total:	63		Total:	2 400 m²	Total:	178 m²	Plan 4:	460 m²
							Plan 5:	354 m²
			LOA				Total:	3 417 m²
			Total:	207 m²			*(+ dark BTA:*	*3 892 m²)*
							BOA+LOA+BIA/BTA:	0,82

FLOOR PLANS

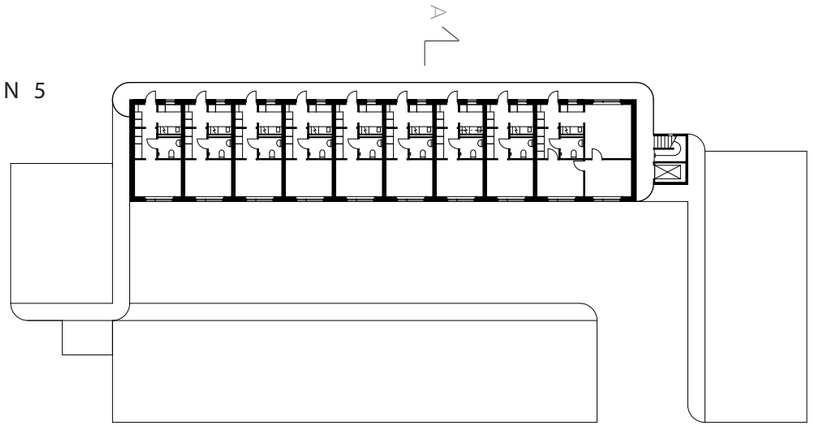
PLAN 1



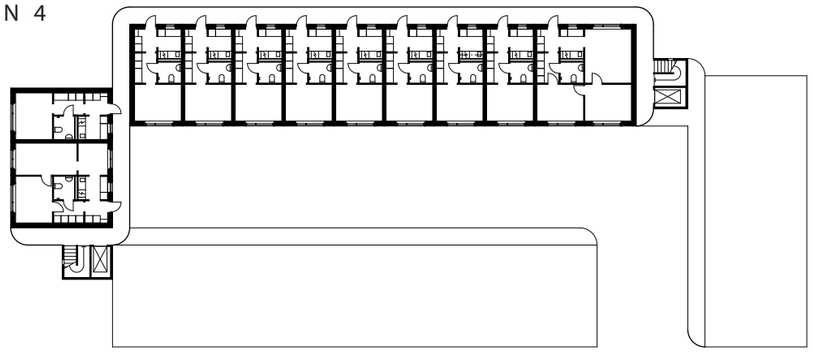
PLAN -1



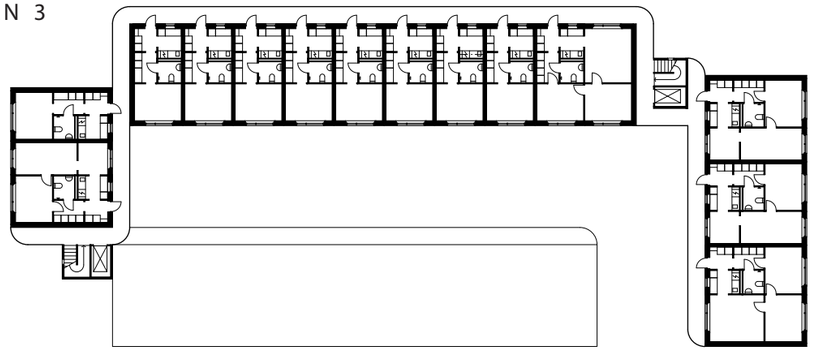
PLAN 5



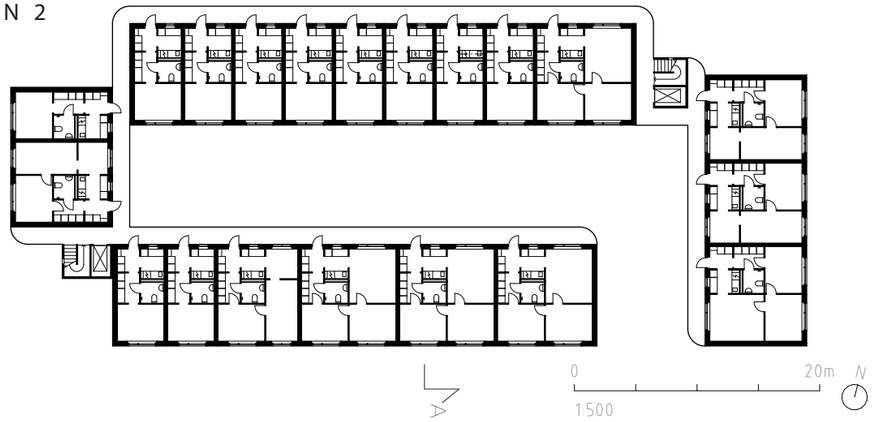
PLAN 4



PLAN 3

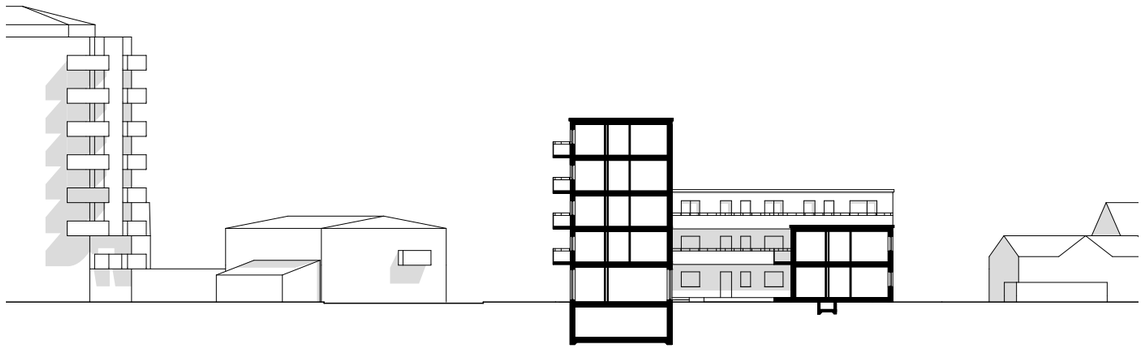


PLAN 2

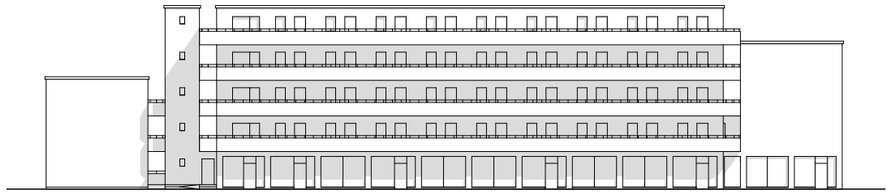


SECTIONS AND ELEVATIONS

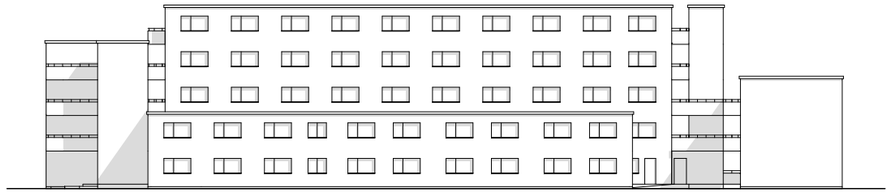
SECTION A-A



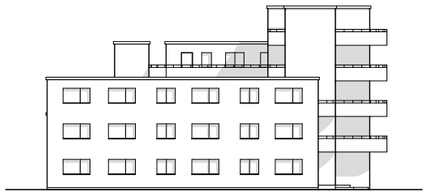
ELEVATION NORTH



ELEVATION SOUTH



ELEVATION EAST



ELEVATION WEST

THE EXTERIOR

EXTERIOR EXPRESSION

Esso student housing has a functionalistic inspired exterior expression that is strongly related to the expression of Upper Johanneberg. The facades are smoothly plastered in a light yellow colour and the access balcony railings are made of corrugated steel sheets with a top rail. All volumes have flat sedum roofing with an elevated border covered in red metal sheets to define the building's bounds towards the sky.

Orange accents are used to elevate the distinctiveness of the building to give it character and to highlight both vertical and horisontal elements that frame the volumes. The ground floor is glazed along Eklandagatan and Gibralatargatan to create an active street with commercial facilities at the corner.

THE INTERIOR

INTERIOR EXPRESSION

The interior of the apartments constitutes of clearly defined rooms and spaces with high residential qualities. Certain walls and the skirting boards are painted according to the colour representation of the modules as a reference to the modular design and to give the interior character.

The exposed flooring is made up of a layer of casted concrete to form a durable surface suitable for the wear of student housing. The concrete flooring also adds a certain sheen and reflection to elevate the space. The ceiling is made up of the exposed CLT of the construction, which provides transparency to the construction of the building as well as adding that warm soothing character of wood in the residents. Fixed furniture such as wardrobes and kitchen cupboards are constructed in exposed plywood to give the interior expression a sense of continuity.

8 DISCUSSION AND CONCLUSION

DISCUSSION AND CONCLUSIONS

AFFORDABILITY

Modular housing was set out as a hypothesis to be a means for designing affordable housing and it was found to be a prominent strategy for affordability if there is an *effective* use of prefabrication and modules, meaning a design with a reduced number of variations that facilitates serial production. This implicates certain limitations to plan layouts if several types of apartments are designed using the same modules. In the design proposal, the number of modules was aimed to be reduced for this reason, resulting in a total of three modules to make up three apartment types. A successful solution was found to be the placement of all essential functions (entrance, storage, kitchen, bathroom, bedroom) into one common module since this reduces the number of variations significantly as well as rationalises technical installations and the spatial configuration. However, as a consequence the kitchen counter space, being the same for all apartments, deviates from the recommended Swedish standard as the counter space is either greater than the recommendation or configured differently. It is a compromise that was considered to be justified for its advantages of rationalisation. Another solution for reducing the number of variations in the design proposal was the repetitive use of the same window and door dimensions. In total three window types were implemented and two door types. This was not experienced as a limitation for the design but rather as a framework.

A driving factor for the overall cost of a project is the efficiency of site usage as well as the efficiency of the total planned area usage. In the detailed development plan for the site of the design application, it is stated that a maximum of 55 % of the site area can be built on and in the proposal 47 % of the site area is built on, which could be considered as efficient usage. Fire regulations (8 meters between the buildings) and a respectful distance to the adjacent lots (4 meters) restricts the site area to be exploited further. Regarding the total planned area, the ratio between BTA and BOA + LOA + BIA indicates the efficient use of the area in the sense of what percentage is rentable area that generates revenue. The proposal of the design application gives a ratio of 0,82, which is considered to be high (0,8 is often strived for).

Affordable housing is a complex subject and there are countless factors involved related to cost in a building process that are beyond the architect's control. In the thesis, I have only been able to touch upon aspects where the architectural design impacts the cost.

QUALITY

The modular design was found to facilitate the attainment of residential qualities overall as the common module, designed to attain many qualities, was implemented in all apartment types. Because of that, all apartments were able to achieve the gold grade for residential qualities according to MAB and are almost qualitative equivalent regardless of apartment type. Using the MAB criteria as a guide for the design process provided a very useful framework where it became evident which criteria were more easily implemented and worked well in combination and which ones are more difficult to attain and might have to be compromised in the design proposal. Overall, the criteria were a great asset in the design process and the proposal resulted in high-quality residences. However, the criteria did highly dictate the size of the apartments as many criteria were based on area requirements. This resulted in the smallest apartment of 1 room and kitchen being 28,5 m^2, which might be considered to be on the bigger end if applied as student housing. However, it is the responsibility of an architect to design residences that are qualitative and since affordability has been approached in other ways than reducing the apartment size, the priority of quality can be justified.

It is a useful tool to be able to quantify residential qualities but ultimately the qualities can only be evaluated through actual experience. In the case of a design proposal, where experiencing the space is not possible, the criteria provide great guidance. Furthermore, residential qualities are subjective to the resident but in the case of designing apartments where the objective is serial production and application to several instances, general "objective" qualities ensure a certain standard for all.

SITE INTEGRATION

A prerequisite for the applicability of a modular apartment series intended for serial production is that it can be applied and integrated into various sites. The quality and affordability of the apartments are of course aspects of great significance to the individual residents but the overall architectural expression and integration in the built environment is of great significance for the whole public and something that the architects need to plan consciously and take responsibility for. Modular housing systems are at risk of being monotonous-looking and repetitive due to the benefits of optimising similarities in production. Furthermore, if the modules are fully manufactured off-site, the seams between each module will be evident and visible, which is not necessarily a problem but it needs to be addressed in some way. In the case of Snabba Hus (Andreas Martin-Löf, n.d.), presented in chapter **2 Background**, the whole concept of the modular housing is that the modules are temporarily placed on a site and then intended to be moved to another site once the building permit ends. With that prerequisite in mind, the site integration is not of great significance for the project, and exposing the seams between the modules even highlights the concept further. However, the prerequisite for the design proposal of this thesis is that the design applications are more permanent, thus site integration is of greater importance and needs to be addressed differently.

Identifying cultural values and valuable characteristics of a specific site early in the planning process was found to be a successful way of integrating a project into a specific site. Oftentimes, this involves characteristics visible externally such as historic references, shapes, colours, and materials. These are aspects that will always be site-specific and cannot be generalised in one common design. Thus, external customisation has to be part of the modular design for successful site integration to be possible.

Whether or not a project's site integration is successful or not is highly subjective. However, I think a key factor is whether or not it is evident that site integration has been consciously addressed in a project. In the case of the design application of this thesis, it is evident that the project has been designed in relation to site characteristics and functionalistics ideals so in that sense it has been a successful approach. The design application only tests application to one specific site and in order to evaluate the potential of the modular series properly, several applications would have to be made. The chosen site has been interesting in terms of its high cultural values as a historically prominent functionalistic area but it is also important to consider that functionalistic ideals were also the origin to the rise of industrial housing. Thus, the rational characteristics of the site of course do interact with the nature of modular housing well.

OVERALL

Overall, modular housing for young adults can be concluded to have the potential to be designed in such a way that it urges affordability to a certain degree while simultaneously attaining a high level of residential qualities, and being able to be applied and integrated into a specific site. Thus it can be an applicable solution for targeting the housing shortage of young adults in Sweden and to change the current situation.

The most important factor for the success of the design is the optimisation of similarities, which benefits the affordability of the modular production as well as the residential qualities since they are then constant and recurring. Successful site integration is difficult to plan for through a general method but it has been found to be highly dependent on the availability of antiquarian investigations and proper site analysis that empathises the assessment of cultural values and the character of an area. However, the design proposal and the nature of industrial production in general, make modular design more applicable to sites of certain characteristics where rationality and order are more prominent. Nonetheless, to facilitate adaptation and increase the potential of successful site integration, the adequate approach found is to allow the external expression of a building to be customisable to a high degree opting for a strategy of segmented standardisation.

This thesis illustrates an approach of how modular housing can be a means to improve the housing situation for young adults and simultaneously make up beautiful site integrated additions to our built environment that respect cultural values. The findings can potentially be useful for architects, urban planners, and policy-makers involved in addressing the housing shortage among young adults in Sweden.

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FIGURES

All figures are made by the author unless otherwise stated.

Figure 2.1 The current housing situation for young adults , 2021
Based on data from:
Hyresgästföreningen. (2021). *Unga vuxnas boende, Sverige 2021*. https://www.hyresgastforeningen.se/globalassets/bostadsfakta/rapporter/unga-vuxna/unga-vuxna-2021/unga_vuxna_hela_sverige_2021.pdf

Figure 2.2 The drivers behind modularisation
Adapted from:
Elgård, P., & Miller, T. D. (1998). *Defining Modules, Modularity and Modularization*. IKS.

Figure 2.3 The three categories of modular structures
Adapted from:
Albus, J. (2017). *Prefabrication and Automated Processes in Residential Construction*. DOM publishers.

Figure 2.4 Transportation of modular volumetric units
Dimensions based on:
Trafikverket. (2011). *Dispenstransporter – en handbok*. https://trafikverket.ineko.se/Files/sv-SE/11368/RelatedFiles/2011_057_dispenstrasnporter_en_handbok.pdf

Figure 2.6 BoKlok modular apartment series
Adapted from:
BoKlok. (n.d.). Hållbara hem för de många människorna. https://www.boklok.se/

Figure 2.7 Snabba hus Råcksta modular apartments
Adapted from:
Andreas Martin-Löf. (n.d.) *Råcksta Affordable Housing 2019. https://martinlof.se/projects/racksta/*

Figure 2.8 The process of a volumetric unit house
Based on:
Nock. (n.d.) *Vår process*. https://www.nock.nu/var-process/

Figure 3.1 Strategies for standardisation/customisation in the housebuilding industry
Adapted from:
Barlow, J., Childerhouse, J., Gann, D., Hong-Minh, S., Naim, M., & Ozaki, R. (2003). Choice and delivery in housebuilding: lessons from Japan for UK housebuilders. *Building Research & Information, 31*(2), 134-145. https://doi.org/10.1080/09613210302003

Figure 3.2 Categories and criteria for qualitative residences
Adapted from:
Granath, K., & Nylander, O. (2023) *MAB Manual för analys av bostadskvaliteter* (preliminary version). Centrum för boendets arkitektur, Chalmers.

Figure 4.1 Archived drawing of Esso petrol station
Stadsbyggnadskontoret. (2012). *Eklandagatan 80 Krokslätt 102:2 samt 102:9. Antikvarisk beskrivning och bedömning*. Göteborgs stad. http://www5.goteborg.se/prod/fastighetskontoret/etjanst/planobygg.nsf/vyFiler/Kroksl%C3%A4tt%20-%20Verksamheter%20vid%20Eklandagatan%20-%20Gibraltargatan-Plan%20-%20inf%C3%B6r%20antagande-Antikvarisk%20bed%C3%B6mning/$File/NyAntikvariskBedomning.pdf?OpenElement

APPENDIX 1
MAB ANALYSIS

APARTMENT 1

1 ROOM AND KITCHEN – 28,5 m²				
Total grade	*Quality aspect*	*Aspect grade*	*Quality criteria*	*Yes/No*
Gold	Functionality	Gold	1. Efficient area use	*Yes*
			2. Technical rationality	*Yes*
			3. Furnishable area	*No*
			4. Potential to remain resident	*Yes*
	Spaciousness	Gold	1. Axiality	*Yes*
			2. Movement and circular loop	*No*
			3. Room shape	*Yes*
			4. Flexibility	*Yes*
	Atmosphere	Gold	1. Facade directions	*Yes*
			2. Balcony	*No*
			3. Daylight enhancement	*Yes*
			4. Dark area	*Yes*

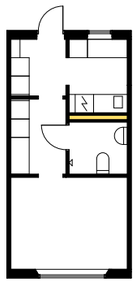
Functionality of the home:

1. Efficient area use: Yes – *The area of the residence, 28,5 m² is less than 95 % (87 %) of the average area of that resident type produced in the last three years (32,5 m²).*

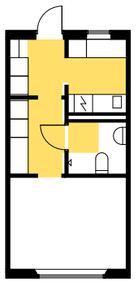
2. Technical rationality: Yes – *All shafts are coordinated.*

3. Furnishable area: No – *The furnishable area is less than 50 % (48 %) of the total area.*

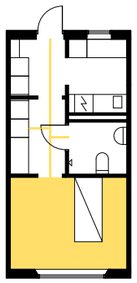
4. Potential to remain resident: Yes – *The residence has a bedroom (3 x 3,8 m) with capacity for medical care, and less than 6 m between bedroom, storage, bathroom, and entrance. The criteria for functional autonomy is disregarded because there are less than two rooms.*



Technical rationality



Furnishable area



Potential to remain resident

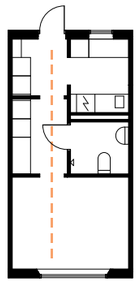
Spaciousness of the home:

1. Axiality: Yes – *There is one axiality (sufficient for residence less than two rooms) through three defined spaces in the residence.*

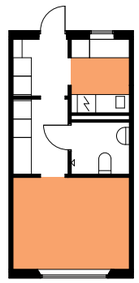
2. Movement and circular loop: No – *There is no circular loop and no room greater than 20 m².*

3. Room shape: Yes
The shape of the main rooms, and the kitchen can be defined using only one rectangle.

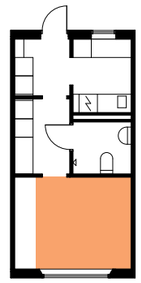
4. Flexibility: Yes – *There is a room that fit 3 x 3,1 m, which is suffiencient as flexibility for a residence that is less than two rooms.*



Axiality



Room shape



Flexibility

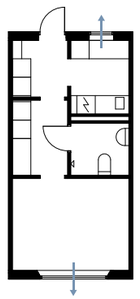
Atmosphere of the home:

1. Facade directions: Yes – There are windows in two different facade directions.

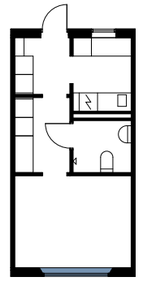
2. Balcony: No – *There is no balcony, or access balcony wider than 2,2 m.*

3. Daylight enhancement: Yes – *There are chamfered window niches.*

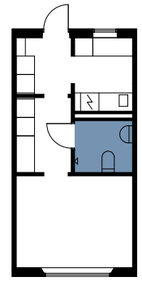
4. Dark area: Yes – *The dark area is less than 15 % (11 %) of the total area.*



Facade directions



Daylight enhancement



Dark area

APARTMENT 2

2 ROOMS AND KITCHEN – 48,8 m²				
Total grade	*Quality aspect*	*Aspect grade*	*Quality criteria*	*Yes/No*
Gold	Functionality	Gold	1. Efficient area use	*Yes*
			2. Technical rationality	*Yes*
			3. Furnishable area	*Yes*
			4. Potential to remain resident	*Yes*
	Spaciousness	Gold	1. Axiality	*Yes*
			2. Movement and circular loop	*Yes*
			3. Room shape	*Yes*
			4. Flexibility	*No*
	Atmosphere	Gold	1. Facade directions	*Yes*
			2. Balcony	*No*
			3. Daylight enhancement	*Yes*
			4. Dark area	*Yes*

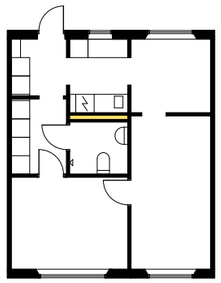
Functionality of the home:

1. Efficient area use: Yes – *The area of the residence, 48,8 m² is less than 95 % (93 %) of the average area of that resident type produced in the last three years (52,4 m²).*

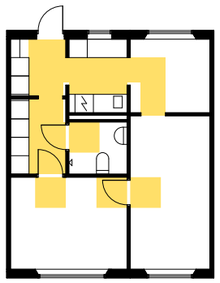
2. Technical rationality: Yes – *All shafts are coordinated.*

3. Furnishable area: Yes – *The furnishable area is more than 50% (57 %) of the total area.*

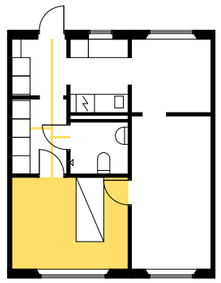
4. Potential to remain resident: Yes – *The residence has a bedroom (3 x 3,8 m) with capacity for medical care, functional autonomy, and less than 6 m between bedroom, storage, bathroom, and entrance.*



Technical rationality



Furnishable area



Potential to remain resident

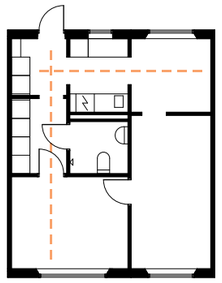
Spaciousness of the home:

1. Axiality: Yes – *There are two axialites through three defined spaces in the residence.*

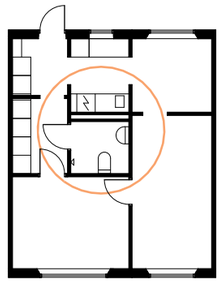
2. Movement and circular loop: Yes – *There is one circular loop.*

3. Room shape: Yes
The shape of the bedroom, kitchen, dining area, and the living room can be defined using only one rectangle.

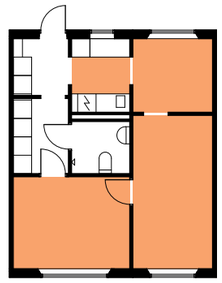
4. Flexibility: No – Three of the five definitions are not obtained in the residence.



Axiality



Circular loop



Room shape

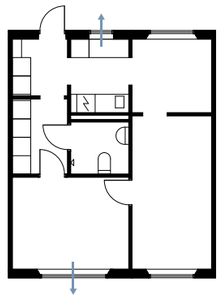
Atmosphere of the home:

1. Facade directions: Yes – There are windows in two different facade directions.

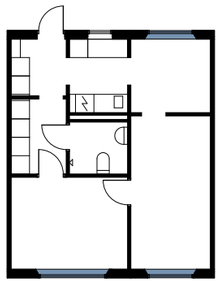
2. Balcony: No – *There is no balcony, or access balcony wider than 2,2 m.*

3. Daylight enhancement: Yes – *There are chamfered window niches.*

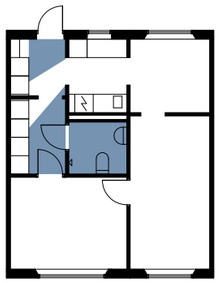
4. Dark area: Yes – *The dark area is less than 15 % (14 %) of the total area.*



Facade directions



Daylight enhancement



Dark area

APARTMENT 3

3 ROOMS AND KITCHEN – 57,8 m²				
Total grade	*Quality aspect*	*Aspect grade*	*Quality criteria*	*Yes/No*
Gold	Functionality	Gold	1. Efficient area use	*Yes*
			2. Technical rationality	*Yes*
			3. Furnishable area	*Yes*
			4. Potential to remain resident	*Yes*
	Spaciousness	Gold	1. Axiality	*Yes*
			2. Movement and circular loop	*Yes*
			3. Room shape	*Yes*
			4. Flexibility	*No*
	Atmosphere	Gold	1. Facade directions	*Yes*
			2. Balcony	*No*
			3. Daylight enhancement	*Yes*
			4. Dark area	*Yes*

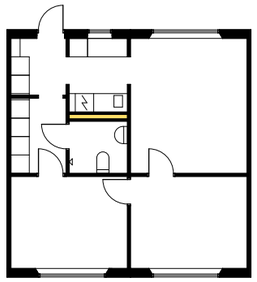
Functionality of the home:

1. Efficient area use: Yes – *The area of the residence, 57,8 m² is less than 95 % (78 %) of the average area of that resident type produced in the last three years (74,3 m²).*

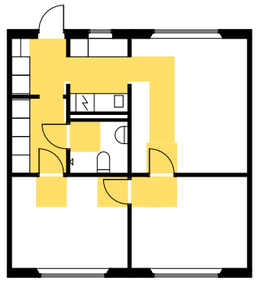
2. Technical rationality: Yes – *All shafts are coordinated.*

3. Furnishable area: Yes – *The furnishable area is more than 50% (57 %) of the total area.*

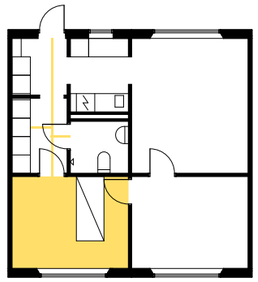
4. Potential to remain resident: Yes – *The residence has a bedroom (3 x 3,8 m) with capacity for medical care, functional autonomy, and less than 6 m between bedroom, storage, bathroom, and entrance.*



Technical rationality



Furnishable area



Potential to remain resident

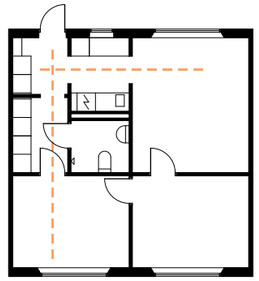
Spaciousness of the home:

1. Axiality: Yes – *There are two axialites through three defined spaces in the residence.*

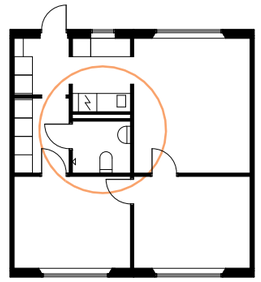
2. Movement and circular loop: Yes – *There is one circular loop.*

3. Room shape: Yes
The shape of the bedroom, kitchen, dining area, and the living room can be defined using only one rectangle.

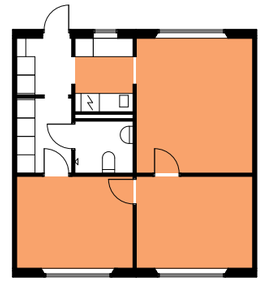
4. Flexibility: No – Three of the five definitions are not obtained in the residence.



Axiality



Circular loop



Room shape

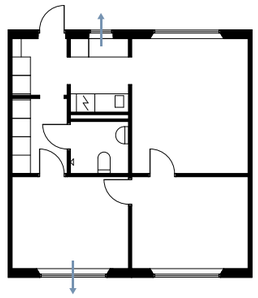
Atmosphere of the home:

1. Facade directions: Yes – There are windows in two different facade directions.

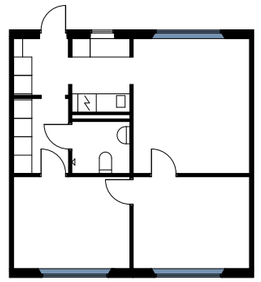
2. Balcony: No – *There is no balcony, or access balcony wider than 2,2 m.*

3. Daylight enhancement: Yes – *There are chamfered window niches.*

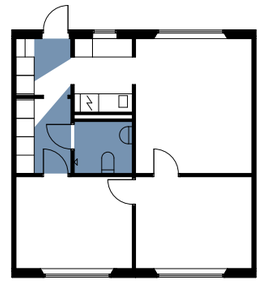
4. Dark area: Yes – *The dark area is less than 15 % (12 %) of the total area.*



Facade directions



Daylight enhancement



Dark area