



# RESILIENT MODULES

*Adaptable housing and modular timber construction*

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*Master's Thesis 2023*

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Supervisor: Anna Braide*

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*Resilient Modules  
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## ABSTRACT

Architecture and the building industry play major roles in our pursuit of a more sustainable future. With the built environment generating 39% of the annual global CO<sub>2</sub> emissions, the impact on ecological sustainability is unquestioned. But architecture also has a direct impact on social sustainability, with how design can promote health, well-being and equality.

New alternatives to established methods and strategies need to be evaluated in search for a way forward. This thesis investigates the combination of two fields, commonly labeled and suggested as practical responses to the call for sustainability within architecture and the built environment;

- *Adaptable housing strategies*, in terms of socially sustainable layouts capable of responding to changing needs and demands. What we design today is typically focusing on highly specific contemporary programs and preferences. But with this strategy in a world of continuous change, we are leaving out future users. Adaptable housing strategies can respond to changes in needs for an individual household, as it grows and shrinks over time, but also accommodate needs of different types of households and be resilient to our inevitable social, cultural and demographic developments over time.

- *Prefabricated timber modules*, as an environmentally sustainable construction method, in terms of a renewable material combined with energy-efficient prefabrication in a controlled environment off-site. Fewer hours spent on building site and better control of processes leading to less material waste and reduced energy consumption.

The thesis investigates and highlights dynamics, possibilities and limitations in a merge of these two fields. Increasing knowledge on potential alternatives for sustainable residential architecture. The aim is a design proposal of adaptable apartments, built with a system of a prefabricated, volumetric timber modules, and combined into a multi-storey residential building.

Keywords:

sustainable housing, adaptability, modularity, prefabrication, wood

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# **1**

## INTRODUCTION

## 1.1 | BACKGROUND

The United Nations' 17 Sustainable Development Goals (SDGs) define the challenges that need to be addressed in achieving a more sustainable future. Architecture and the built environment plays a big part of the challenges in terms of ecological sustainability, as a major consumer of natural resources and energy, and producer of waste. But it also fosters social sustainability, with how architectural design can promote health, well-being and equality. In line with the SDGs for a more sustainable future, the conservative building industry must evaluate, assess and be open to alternative solutions to its deeply rooted systems and methods.

What is being built today generally lacks correspondence to the modern diversity of household constellations and living preferences. We still almost exclusively design housing with the idea of a homogenous nuclear family in mind, excluding other types of households in the process. Also, the scope rarely extends beyond the first inhabitant(s) of a dwelling, or the snapshot of a specific household situation and dynamics at the time of moving in.

However, no matter how advanced and meticulous forecasts of the future are, in the end they are merely qualified guesses. With this unpredictability of future residential needs, along with a possibly further increased diversity of needs, Manum (2006), Leupen (2006), Schneider & Till (2007) and Braide (2023) among others suggest flexible and adaptable dwelling space as a way to meet the challenges for a sustainable housing stock. Design strategies that allow the dwelling to be resilient and capable of meeting different needs and demands, as well as respond and adapt to changes to them over time.

By this, adaptability is also connected to ecological sustainability. Extensive research and effort is made throughout the building industry to develop environmentally friendly materials and enhance the processes that produce them. The longevity and lifespan of a building is of great importance, as every demolition and rebuild means more energy and resources spent. A dwelling that is not adaptable, but instead very specific and limited in its usability, is therefore at risk of eventually being abandoned and replaced due to lack of use or demand. If this happens before the materialistic and constructional lifespan, it is extremely counteractive to everything else that was done to prolong the lifespan and lower the environmental footprint.

In their most recent (June, 2022) report, Boverket (Swedish National Board of Housing, Building and Planning) estimate that 63,400 new residential units must be constructed every year, in order to cover the total Swedish housing need until 2030. They are specifically pointing at sufficient production of economically affordable dwellings as one of the biggest challenges going forward.

Much like innovation is essential to reach the sustainable development goals, it also has to play a part in reaching new heights of productivity. One part of the solution could be prefabrication in general, and volumetric timber modules in particular. Prefabricated in a controlled environment inside a factory off-site, with standardized, rational methods and significantly reduced time on the building site. Leading to less waste of material, reduced energy consumption and building costs. Productivity, affordability and sustainability combined.

The purpose of this thesis is to bring these two concepts together; adaptability in architecture with modularity in construction. Investigating and highlighting dynamics, possibilities and limitations of a merge. The research questions are:

*1) How can design strategies for adaptable housing be applied using prefabricated modular timber construction methods?*

*2) How can design strategies for adaptable housing be used to accommodate needs and demands of modern domestic groups?*

## 1.2 | PURPOSE & AIM

The thesis unites the two fields of adaptability and modularity, each holding qualities that can contribute to sustainable solutions for the built environment. Exploring qualities of design strategies for adaptability in a contemporary context, as well as applying them within the framework of modular construction.

The aim is a design proposal of adaptable apartments, combined into a multi-storey residential building. Constructed with a prefabricated, standardized system of volumetric modules in wood. Based on aspects of spatial use, construction and aesthetics, the thesis explores dynamics, possibilities and limitations of a merge of the two fields to increase knowledge on sustainable alternatives for residential architecture.

## 1.3 | METHOD

The process consisted of three main methods, which initially was performed in three phases in chronological order from 1-3. Subsequently, iterations of complementary *theoretical research* along with *research by design* was carried out interchangeably for the rest of the work.

### 1) *Theoretical research*

Collection of theoretical background by literature studies. Gaining knowledge of the research field of adaptability and narrowing down which aspects of a broad topic that would be included for the scope of this thesis.

### 2) *Case study & module factory visit*

Visiting Derome's volumetric timber module factory in Väröbacka, Sweden, to learn more about the preconditions and implementation of this construction system. Thereafter, a general analysis of the system was made, guided by results from previous theoretical research. Knowledge from phase 1 and 2 then formed a foundation for the subsequent research by design.

### 3) *Research by design*

Development of the apartments and combining them into a standard floor of a multi-storey residential building.

## 1.4 | DELIMITATIONS

The context of this thesis is Swedish housing situation and industry, with a typology of apartments within a multi-storey residential building.

Among several possible methods of modular prefabrication, the focus is specifically on timber volumes, with Derome's system AdderaPluss as main reference.

Adaptability has a long history in architectural research, with different definitions for similar terminology, and with focus on adaptable concepts both before and after a dwelling is occupied. The scope of this thesis is on *after* inhabitants move in, while closest resembling the theoretical angles of Manum (2006) and Braide (2019, 2023).

## 1.5 | READING INSTRUCTIONS

The thesis is divided into five main chapters; *Introduction*, *Theoretical framework*, *Research by design*, *Design proposal* and *Discussion*.

Chapter 2 (Theoretical framework) defines foundational theory on Adaptability in the context of this thesis. The design strategies in focus are explained and discussed through different angles as preparation for the design work. This chapter also presents the construction method and the reference system of AdderaPluss, both listing constructional dimensions and technical drawings, but also analysis of the system in regards to adaptability.

Chapter 3 (Research by design) highlights main topics and decisions from the design process.

Chapter 4 (Design proposal) presents architectural drawings of the designed apartments and the multi-storey residential building, together with comments on adaptability. The adaptable capabilities unlocked by the design strategies are exemplified and illustrated in detail with a time-space model.

Chapter 5 (Discussion) concludes the thesis by reconnecting to the research questions with reflections on adaptability, modularity, the merge of the two and potential future investigations.

# 2

## THEORETICAL FRAMEWORK

## 2.1 | ADAPTABILITY

### 2.1.1 - What is adaptability?

Adaptability is not a new concept, but has been researched and applied to different extents within housing architecture for nearly a century. The term has been defined and nuanced in several ways by many different researchers depending on context and approach. For this thesis, adaptability is defined as

*Adaptability: a dwelling's capacity of responding to the residents' changing spatial needs and demands over time.*

A definition closest resembling the theoretical approach of Braide (2023) and Manum (2006) in terms of that it encompasses both eventual changes in spatial needs of an individual household, but also that it involves capacity of adapting to preferences of several different types of households. Examples of changing needs of a household could be those triggered by life transitions such as a family having a kid, or a kid moving out, thus changing the size of the household and possibly the spatial needs. An example of different preferences between similarly sized households could encompass the preference of only one space for daily social activities, while another household might favour two separate ones.

A dwelling's capacity of responding to changes in spatial needs and demands are often debated as a key component in sustainability within housing architecture. Manum (2006) argues that in an ever changing society, over time the needs and preferences change with it. We need to look further than only responding to our current needs and programs, and realize that these are not static over time, but in continuous change.

For the scope of this thesis, three main design strategies for adaptable dwellings will be in focus; *generality*, *flexibility* and *elasticity*;

- *Generality* being a spatial arrangement where several rooms of a dwelling are of similar size and shape, allowing interchangeability of activities and functions between them.

- *Flexibility* meaning strategic planning of rooms, allowing for logical partitioning of the space into several smaller spaces or rooms, for example by addition of a flexible light-weight wall, sliding wall or mobile partition.

- *Elasticity* meaning adaptability by modifying size. For example, a strategically positioned room or part of the dwelling that could be divided and separated from the rest, if needed. Potentially also equipped with a separate entrance to be able to serve as an entirely autonomous unit.

These three strategies along with the additional aspects of *spatial configuration* and *connections*, how positioning of rooms in relation to each other affects their use and adaptability, will be the foundational theory discussed in this chapter.

#### *Adaptability and household diversity*

Manum (2006) and Braide (2023) mention two different kinds of households; uniform and pluralistic. *Uniform* being traditional households such as young couples, singles, nuclear family or older couples. These are uniform in the sense that they are socially very close households, where only one space for daytime social activity is enough in general. *Pluralistic* households include contemporary constellations such as generational living, collective living, rearranged families and households with specific cultural needs that are better suited for more than one space for daily social activity.

Braide (2023) points out what is being designed and built today primarily corresponds to the needs of uniform households. Adaptable design strategies could help meeting the needs of also the pluralistic households.

#### *Adaptability and form of tenure*

The two main forms of tenure in Sweden today are rental (hyresrätt) and condominium (bostadsrätt). Naturally, in a rented apartment the inhabitants have less freedom in performing the adaptable strategies, compared to a condominium. The strategy of *generality* however, is a concept that works regardless, since it does not involve any structural changes.

However, with a landlord interested in sustainability of his rental dwelling stock, at least the *flexibility* concept could work well in this form also, if not better. Aspects of communication is an issue brought up later in this chapter, as a barrier for implementation of flexible strategies. In many cases the inhabitants do not realise the possibilities of their dwelling layout, this information is easily lost over a couple switches of condominium ownership. A landlord could be this communicator, as well as coordinator for good implementation and storage of standard flexible walls and partitions to use.

## 2.1 | ADAPTABILITY

### Generality

#### 2.1.2 - Design strategy: Generality

Generality is a concept of using same or similarly sized and shaped rooms, thus making their functions easily interchangeable. In comparison to the more specific room labelings commonly seen in contemporary architecture, the space then becomes highly adaptable and allows the household to take on bigger control of the spatial organisation. Manum (2006) defined generality as

*Generality: the capacity of a fixed situation to serve a variety of demands or wishes.*

Schneider & Till (2007) are presenting essentially the same concept but phrasing it "functionally neutral rooms" or "rooms without a specific use". Another label often used in research is "multipurpose room".

Naturally, functions with very specific integration of technology such as kitchen and bathroom can not be part of this interchangeability but has to be more or less locked in its position. But rooms with functions such as sleeping, socializing and eating can easily be exchanged according to changes in needs and preferences over time. As an example, some might spend most time at home during daytime and prefer the living room in position for plenty of daylight, others might prefer it positioned for the evening sun. In a bigger apartment, some households might prefer a dining room separated from the kitchen, some prefer a secondary living room, others will choose to turn that space into an extra bedroom instead.

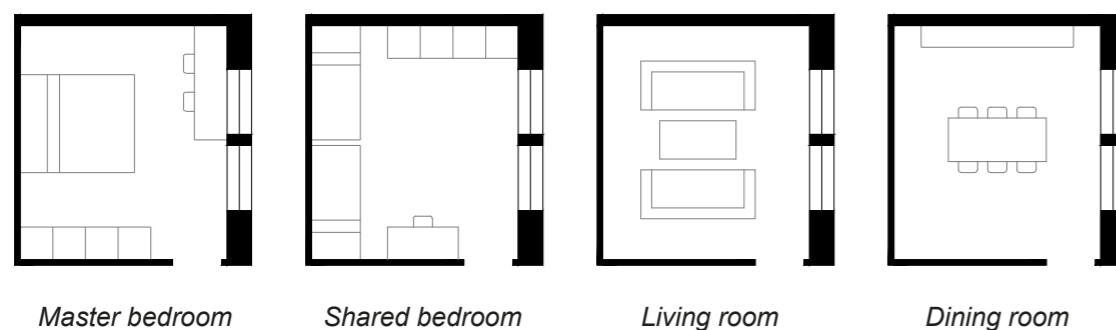


Fig 1) Generality concept

#### Generality and room dimensions

Several different measurements have been mentioned by researchers, in terms of what is large enough for a room to serve as general, multipurpose, universal or functionally neutral.

- Manum (2006) summarizes some research on generality and points to that floor areas of 12-15 m<sup>2</sup> have been recommended in different contexts.

- Leupen (2006) states dimensions of approximately 4 x 4 m and 16 m<sup>2</sup> as being able to host any basic activity.

- Nylander (2007) mentions spaces of 4 x 4 as a historical reference often seen in Swedish vernacular cottages (parstugor). He also points at dimensions of 3.5 - 3.7 m as commonly used in various building standards.

- Schneider & Till (2007) mentions 3.6 m wide by 4.0 m deep for their definition of a neutral space, which would mean 14.4 m<sup>2</sup>.

- Yunitsyna (2014) establish different brackets based on amount of defined functions the room can host. The functions referred to are cooking, getting together, dining, sleeping and working. She mentions 3.1 m as the minimal width and 15.4 - 16.4 m<sup>2</sup> as the minimal area for a universal room. She labels a room partially universal (definition: can accommodate 3 of the living activities) if the area is between 11.2 - 15.4 m<sup>2</sup>.

- Ledent (2017) takes on a wide historical approach, noticing the recurrence of the 4 x 4 m room in various contexts. He argues that this size is able to accommodate any kind of living needs as well as changes to them. Specifically pointing to it passing the test of time through several ages and cultures as a strong argument.

What crystallizes from above suggestions of measurements, is the propensity of a square, or close to square shape among spaces that are considered general/universal/neutral/multipurpose. Braide (2019) also mentions this and Nylander (2007) suggests a general room should be more or less square shaped, referencing studies from Bostadsstyrelsen (1988) on versatility of square versus rectangular shaped rooms of same total area.

## 2.1 | ADAPTABILITY

### Generality

When it comes to suitable dimensions of a general room, there are more than one factor in play. There is the obvious versatility of different possible furnishings on one hand, but then there are also regulations on accessibility to take into account.

If excluding kitchen and bathroom from the discussion on generality due to their relative technical complexity, the basic activities regulated in the Swedish building regulations (BBR) are social activity (daglig samvaro), sleep & rest (sömn & vila) and dining (måltider). There are different regulations for available space for these activities depending on dwelling total area (<35 m<sup>2</sup>, 35-55 m<sup>2</sup>, or 55+ m<sup>2</sup>) and amount of people in the household (1, 2-3, or 4+). For the sake of adaptability over time, a relevant general room in this context therefore has to be of enough space to accommodate the highest levels of these two categories (55+ m<sup>2</sup> area dwelling and 4+ people in the household). Figures 2-4 show the minimum dimensional requirements for these levels;

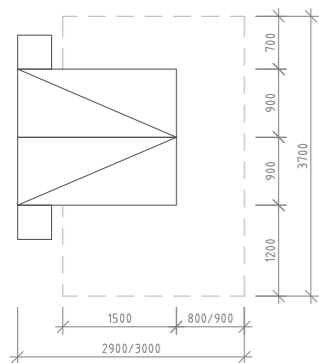


Fig 2) Sleep & rest - dimensions for master bedroom

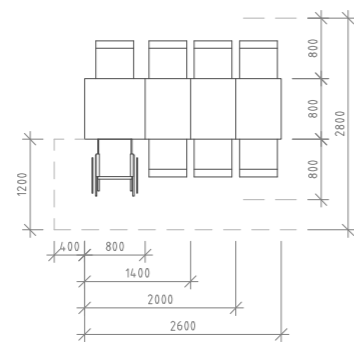


Fig 3) Dining - seating dimensions for amount of people in household plus 2 guests

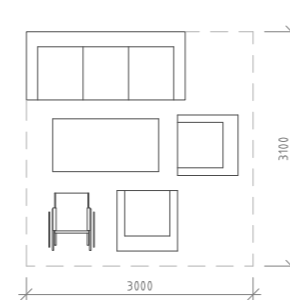
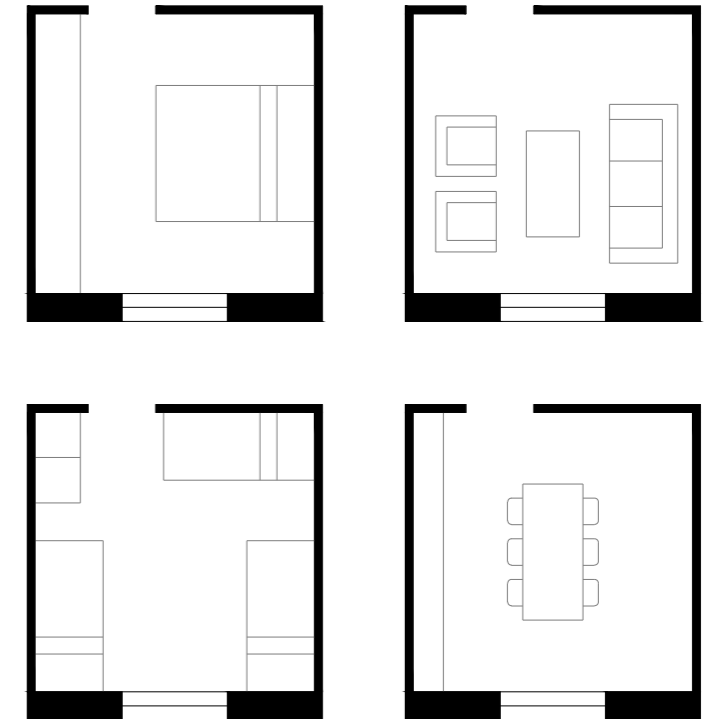


Fig 4) Social activity - Dimensions for seating group

A general room capable of hosting all these activities would therefore need free space of 3.7 x 3.0 m at a bare minimum. With need for storage in a master bedroom and fair levels of maneuverability around a living room seating arrangement, dimensions of around 3.7 x 3.7 m is a more feasible minimum for a general room. This also references back to earlier research pointing towards a square shape. These measurements are tested in four illustrations in figure 5.

Fig 5) Different furnishings of a 3.7 x 3.7 meter room. Examples of master bedroom, living room, shared bedroom with up to 3 beds, and a dining room.



Door and window placements are important. With the door 0.7 meters away from a corner, it allows for efficient storage or desk space along one of the walls. As seen in the shared bedroom, there is still enough room for placing a bed along the wall with the door.

### Barriers for implementation

Generality is a desirable design strategy in that it does not involve any structural changes for the inhabitants, as adaptability is already built into the design. However, the possibly only barrier lies in the exact above discussion of room dimensions; generality demands space. Today the trend is rather the opposite, to squeeze out every surplus square meter with highly specific rooms and bestowing them minimal dimensional requirements for those uses. A dwelling based on general rooms is then automatically at a certain disadvantage. There is no way around that economy is tied into every square meter. In that sense, general rooms can be considered inefficient in its use of available space compared to contemporary practice.

Also, a goal of generality is being adaptable to the needs of several different households with possibly different amount of people. This coupled with the fact that kitchen and bathroom optimally need to stay more or less the same due to technical complexity, also leads to space inefficiency in some cases where the total dwelling area has gone down but the size and area occupied by kitchen and bathrooms stay the same. However this is more a consequence for adaptability as a whole, regardless of strategy.

## 2.1 | ADAPTABILITY

### Flexibility

#### 2.1.3 - Design strategy: Flexibility

A flexible plan is where adaptability is achieved by structural changes such as addition or removal of light weight walls, sliding doors or movable partitions. For example, the ability to divide a big living room into a medium living room plus a small bedroom. Another example of flexibility is the change between an open floor plan and one with separated rooms. In particular, as often seen in contemporary dwellings, one big room for cooking, eating and socializing or divided by a wall into one kitchen and one living room.

*Flexibility: ability to change number of rooms, by adding or removing movable walls or partitions.*

Along with a large enough original space capable of being divided into two functional partitions, also strategic placement and design of windows strongly affect the potential for flexibility. Braide (2023) defines two main principles; flexible walls either being positioned perpendicular to the facade wall between two windows, or flexible walls attached to a window post.

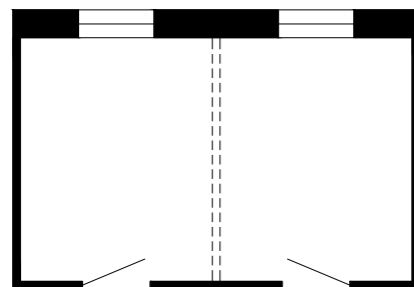


Fig 6) Flexible wall between two windows

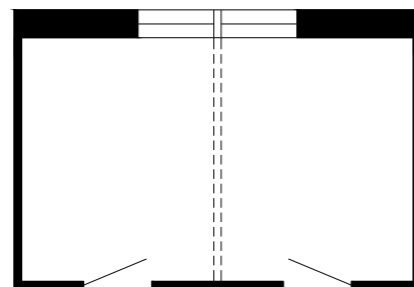


Fig 7) Flexible wall attached to window post

Experimenthuset i Järnbrott (figure 8) from 1952 was designed with flexibility in mind, making use of light weight internal walls and strategic positioning of windows and other fixed elements to allow for several different room configurations. An especially delicate solution is showcased by the window placement in the kitchen, dictating the possibility of two different kitchen types depending on between which two windows the kitchen island is positioned. Either a more closed kitchen with the table inside the loose boundary created by the kitchen island, or outside the kitchen island resulting in a closer connection between eating and socializing.

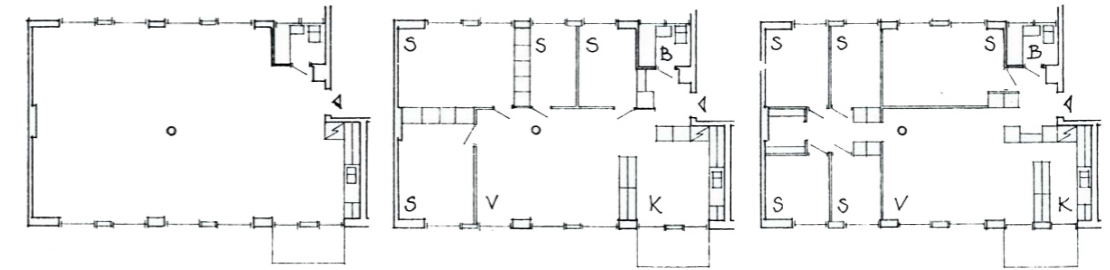


Fig 8) Flexibility on display in three different room arrangements of the same apartment. Experimenthuset i Järnbrott. Tage & Anders William-Olsson (1952)

#### Barriers for implementation

Flexibility differs from generality in that it involves structural change, and the feasibility is therefore highly dependant on the construction, implementation, relocation and performance of the flexible elements.

Another aspect mentioned by Braide (2019), is a reouccuring lack of communication in housing projects with flexible layouts, in terms of informing the residents of both the strategy overall, that it can be done and how to actually employ it practically.

For a flexible layout, a plan for ventilation and air ducts should preferably be part of the design and planning stage, which is of course very rarely the case in what's already built today. Every possibly new room created by the addition of walls, need to be connected to the ventilation system, or these rooms are at risk of questionable air quality and thermal comfort.

## 2.1 | ADAPTABILITY

### Elasticity

#### 2.1.4 - Design strategy: Elasticity

An elastic layout in the context of this thesis means increasing or decreasing the size of the dwelling in accordance to needs. It involves strategic positioning of room(s) to allow for them to either be fully integrated with the rest of the dwelling, a more private and secluded section of the dwelling, or an entirely independent unit with a separate entrance.

*Elasticity: the capacity of responding to changing demands by modifying size of the dwelling.*

Illustrated in figure 9, due to its position in relation to the stairwell and the rest of the apartment, the green colored part can either be a logical part in a row of bedrooms, or serve as an independent unit with its own separate entrance from the stairwell. A middle step could be having a door with access into the rest of the dwelling, but still with a separate entrance from the stairwell.

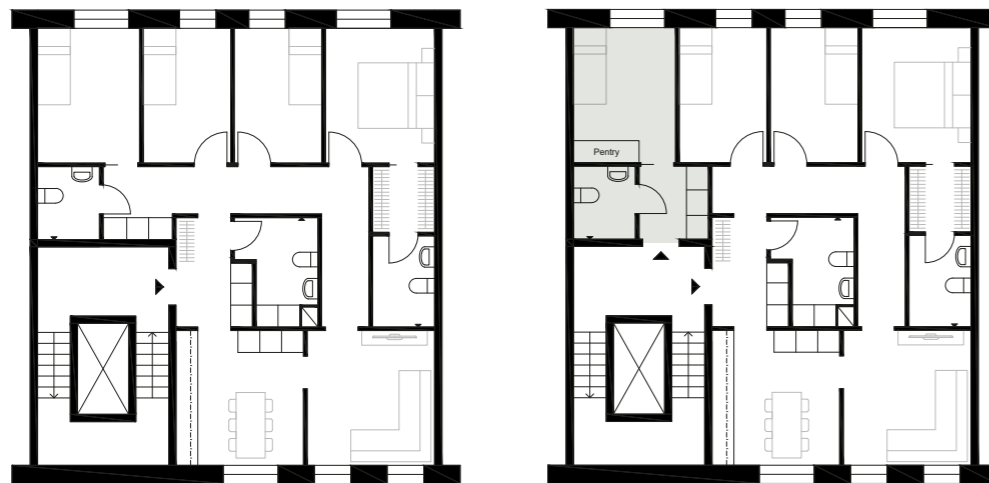


Fig 9) Elasticity concept. Own sketch from former work.

Elasticity can also involve enlarging the dwelling by taking room(s) from the neighbour apartment, or reducing it by giving room(s) to the neighbor. This type of elasticity is often part of the planning stage when combining apartments into a full building floor, but as pointed out by Braide (2019) could be logistically challenging when the apartment is already occupied. This thesis focus on adaptability *after* occupants move in.

Tarpio and Huuhka's (2022) study on residents' views on adaptable housing point to several aspects of elasticity being highly desirable among the participants. Particularly mentioning two entrances being experienced beneficial in several ways. Examples of scenarios an elastic layout with two possible entrances could support includes;

- Dividing the dwelling for intergenerational living. This could either be a space for an elderly family member, with or without need for care, or a more secluded teenager area. An effective way of altering the level of privacy, by choosing between having either the separate entrance door or the connection to the rest of the apartment open or closed, or having both open.

- Home-based work, with a separate entrance for clients and customers. The 2020 Covid pandemic put new light on this feature, with many people realising the benefits of working from home if and when possible. Even after restrictions were lifted, many chose to adopt home-based work to different degrees, even as a pandemic-free life ensued. Thus creating a raised demand for possible home office space in general.

- Coping with economic difficulties by renting out one part of the dwelling.

#### *Barriers for implementation*

Turning an elastic space into an entirely new apartment involves a legal process of housing division, as well as the space becoming subject to fire regulations and requirements of a separate fire escape route. All in all a somewhat complicated undertaking and not something that can easily be switched back and forth. In the case of renting out the elastic space as a more secluded part of the rest of the dwelling however, then that is a much more feasible option and still a great quality of an elastic layout.

## 2.1 | ADAPTABILITY

### Spatial configuration and connections

#### 2.1.5 - Spatial configuration and connections

The spatial configuration of a dwelling relates to the context of the individual rooms, how they are positioned in relation to each other. The usage and adaptability of a room is not only dependant on its individual properties, but also surrounding rooms and their properties.

As illustrated in figure 10, the function of a room (A) that can only be reached from one other space (B), is highly affected by which type of space (B) is. (A) can in this case work well as a bedroom, which only access is through a living room (B). But (A) does not work well as a living room, in case (B) is a bedroom, which presumably is preferred to be a private space without any movement coming through. In contrast, room (C), having more than one point of access, is not functionally restricted by the character of room (B). In terms of maximum adaptability of a dwelling, each room should therefore have more than one point of access, or access from a neutral communication.

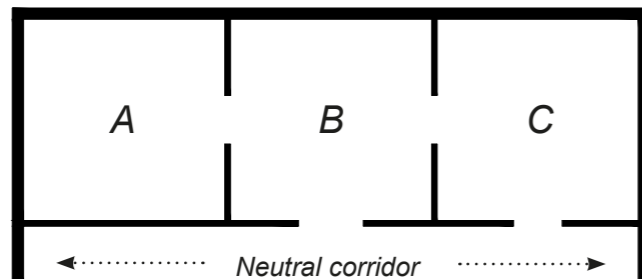


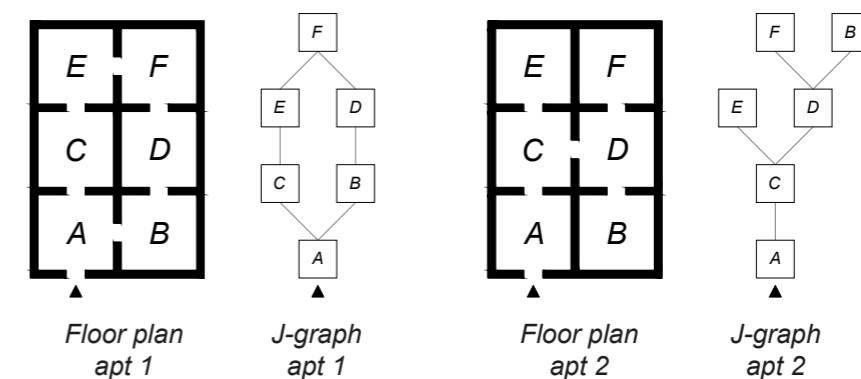
Fig 10) Spatial configuration

Hillier (1996) points out how spatial configuration and how you can move between rooms affect the functionality of each individual room as well as the functionality of the entire dwelling. Leupen (2006) states that layouts, where the spatial configuration allows access to every room from either a central point or via several routes, is more capable of "being adapted to suit different living patterns" compared to those with rooms holding only one point of access.

Another important social aspect unlocked by this arrangement is the possibility of *parallel use* within the dwelling. Two rooms which both have neutral access points, without having to pass through the other, can host parallel activities without interfering with one another. A great social quality in every day life which improves the possibility of privacy within the dwelling.

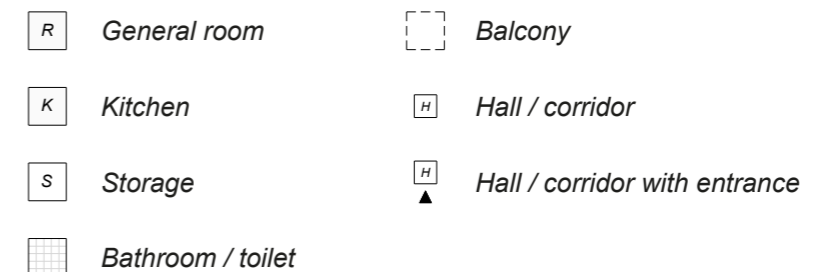
#### Space syntax

A useful tool for conceptualizing and visually support discussion on spatial configuration is *Space syntax*. Originally developed in the early 1970's by Bill Hillier as a set of techniques for analyzing spatial arrangements and human activity patterns, versions of it are nowadays often also used as a complementary tool in research on adaptability within architecture. A graph which Hillier called *the justified graph* or the *j-graph* displays how each space within an apartment relates to one another in terms of connections. This is exemplified below by two floor plans and their corresponding j-graphs to the right of them.



The spatial systems represented in the j-graphs have 4 levels in both examples, which means the deepest level is 4 steps away from the entrance. In the first floor plan, room F is alone on the 4th level, while in the second floor plan both room B and F are on the 4th level. Apartment 1 theoretically meets Leupen's criteria of a layout capable of suiting different living patterns, with each room being accessible from more than one other room. Apartment 2 is more limited in regards to this, with room B and F only accessible from room D, which in turn significantly limits the range of different uses for room D.

For space syntax analyses within this thesis, different types of rooms will be assigned with following symbols, for a quicker overview and readability;



## 2.1 | ADAPTABILITY

### *Design features*

#### **2.1.6 - Design features**

As a summary and general guide for the design work, adaptable design strategies explained in this chapter are boiled down into a list of specific features to be included in the upcoming design proposal.

##### *- Neutral points of access*

A spatial arrangement which strongly affects adaptability and provides the social quality of undisturbed parallel activities within the dwelling.

##### *- Possibility to increase number of rooms*

An important feature in strive for adaptability over time, as response to households growing in number of people.

##### *- More than one living room or space for social activity*

Design for the diversity of contemporary household constellations, beyond the uniform, traditional ones.

##### *- Dedicated bedroom area vs separated bedrooms*

Another case of designing for a diversity of contemporary household constellations. For examples two adults living together that is not a couple.

##### *- Autonomous space*

With a separate entrance from the stairwell, allowing a part of the dwelling to serve as generational living, home office, or space possible to rent out.

##### *- Possibility to choose between open and closed kitchen*

Adaptability as solution to a polarizing design debate.

## 2.2 | MODULARITY

### 2.2.1 - What is modularity?

The term modularity in the context of this thesis refers to modular construction - a system of prefabricated building blocks (modules) that are produced off-site and then delivered to the building site, where they are mounted in position.

The main benefit of modular construction is the raised efficiency and speed of the construction process. By constructing building components off-site in a controlled environment, the time on the building site is significantly reduced. Leading to shorter projects overall, lower costs and reduced disruptions to the surroundings. Another major advantage is the inherent sustainability. Better control in production leads to better resource management, reduced material waste and improved energy efficiency.

Modular construction is a highly relevant method to explore both in terms of sustainability within the building industry, but also in meeting the current high demand of new dwellings, and especially economically affordable ones. In their most recent (June, 2022) report, Boverket (Swedish National Board of Housing, Building and Planning) estimate that 63,400 new residential units must be constructed every year, in order to cover the total Swedish housing need until 2030. Prefabrication and modular construction could be one part of the solution.

#### *Two main types of construction*

There are two main types of modular construction; two-dimensional panelized construction, or three-dimensional volumetric construction. Panelized construction focus on prefabricated walls, roofs and floors that are then transported and assembled into volumes and the final structure at the building site. The volumetric construction involves fabricating complete three-dimensional modules in the factory, including walls, floors, ceilings and finishes. These volumes are then transported and stacked together to form the final structure at the building site.

The volumetric construction method is essentially taking it one step further versus panelized construction regarding efficiency, sustainability and affordability. But on the other hand, a panelized construction with smaller standardized components, allows for more freedom in design and less complicated logistics in transportation.

## 2.2 | MODULARITY

Reference system: AdderaPluss

### 2.2.2 - Reference system: AdderaPluss

The volumetric timber modular system AdderaPluss, developed by Swedish company Derome, serves as the main reference for the construction method used in the design proposal for this thesis.

In a 17,000 m<sup>2</sup> factory in Väröbacka, Sweden, the volumetric modules are built from scratch in what resembles a classical assembly line construction method. Moving between workstations where parts are added in sequence until the entire module is finished, wrapped in packing material and ready to be loaded onto trucks for transportation to the building site.

The modular system has a few different versions, or product lines. Below is the product line *Stavder* illustrated as an example. Consisting of seven standard module designs with widths ranging from 2.55 to 3.95 meters, and same length of 9 meters to be able to stack them in a straight line next to each other. These modules are then combined in different ways to create a range of four unique apartments, which shapes one floor of a building.

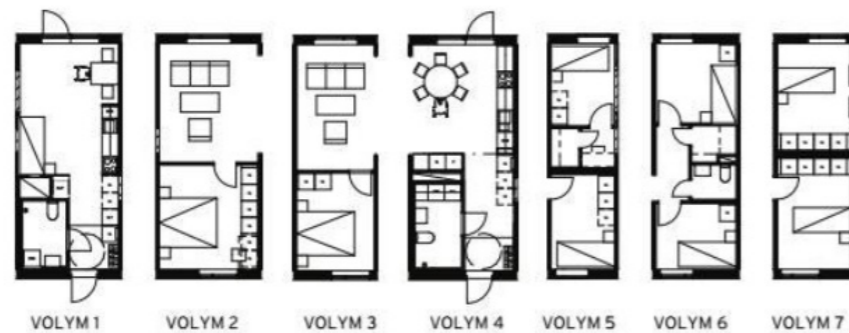


Fig 11) The seven base modules of the Stavder product line.

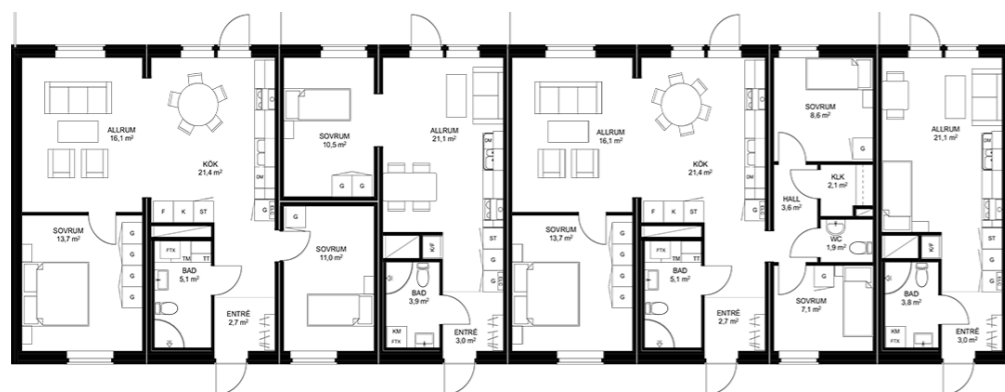


Fig 12) The base modules combined into one full floor of four unique apartments.

Figure 13 shows the floor plan of an apartment from the housing project Blåbäret in Kalmar, Sweden, which consists of (from left to right) volume #2, #4 and #6 from the set of seven base modules of the AdderaPluss system.



Fig 13) 88 m<sup>2</sup> apartment in project Blåbäret, Kalmar, Sweden.



Fig 14) Housing project Blåbäret, Kalmar, Sweden.

## 2.2 | MODULARITY

Reference system: AdderaPluss

### Comments on Adaptability

Figures 15 and 16 show the plans of two of the AdderaPluss apartments from the Stavder product line, defined as apartment A and B. Since most concepts for adaptability demands a certain amount of available space, the 28 m<sup>2</sup> and 40 m<sup>2</sup> apartments from the Stavder line are not included in this discussion. It is also worth noting that the AdderaPluss apartment solutions in general are somewhat cramped areas by design, in line with their overall goal of creating cheap dwellings in response to the housing shortage. However, discussion on adaptability with these apartments as visual examples can still serve as a valuable pre-study for the upcoming design work.

The rooms are generally of good sizes and shapes to hold several different types of activities, as well as different positionings of furniture. In terms of generality, the living room (3.8 x 4.3 m) and the master bedroom (3.8 x 3.7 m) are also somewhat interchangeable if strictly focusing on size and shape. However, the main limitation of these apartments in achieving adaptability is directly linked to the spatial configuration. They all follow the widely popular arrangement in contemporary architecture; an open connection between kitchen and living room, with this big space also serving as the main central hub for movement within the apartment. Should the master bedroom be swapped with the living room, passing through the bedroom would be the only way to reach the living room, thus isolating this social space from the rest of the common space of the apartment.

A more adaptable apartment demands a solution with more available, or better positioned neutral space to access the different rooms. Having the entrance in the short side of the modules (an entrance gallery solution) might be a limiting factor, unless the modules are lengthened to make room for a possible neutral access to neighboring modules after passing the bathroom.

Both apartments do have a second branch of rooms as well, with access from the neutral corridor by the entrance. This is a good arrangement in terms of creating private spheres and ability of hosting secondary social spaces. The secondary bedroom (2.7 x 4.0 m) in apartment A is of enough size to hold a decently sized secondary living room, albeit somewhat limited in furnishing with one relatively narrow side of 2.7 meters. For example a dedicated room for social activity surrounding a television could work well, however. The upper secondary bedroom in apartment B together with the walk-in-closet could form a similarly sized room there as well.

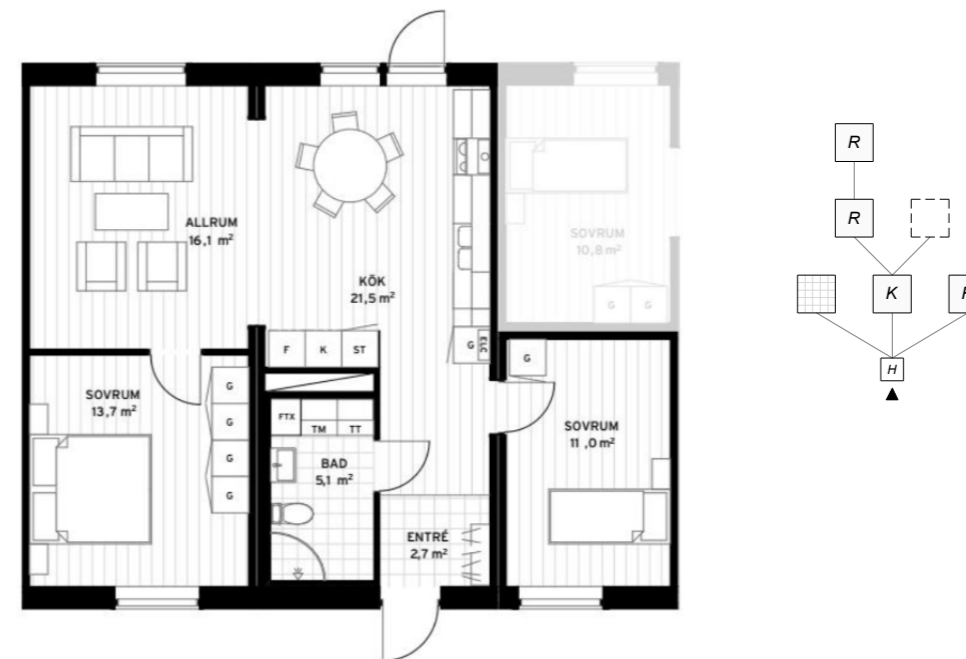


Fig 15) 74 m<sup>2</sup>, 3 rooms + kitchen  
AdderaPluss apartment A

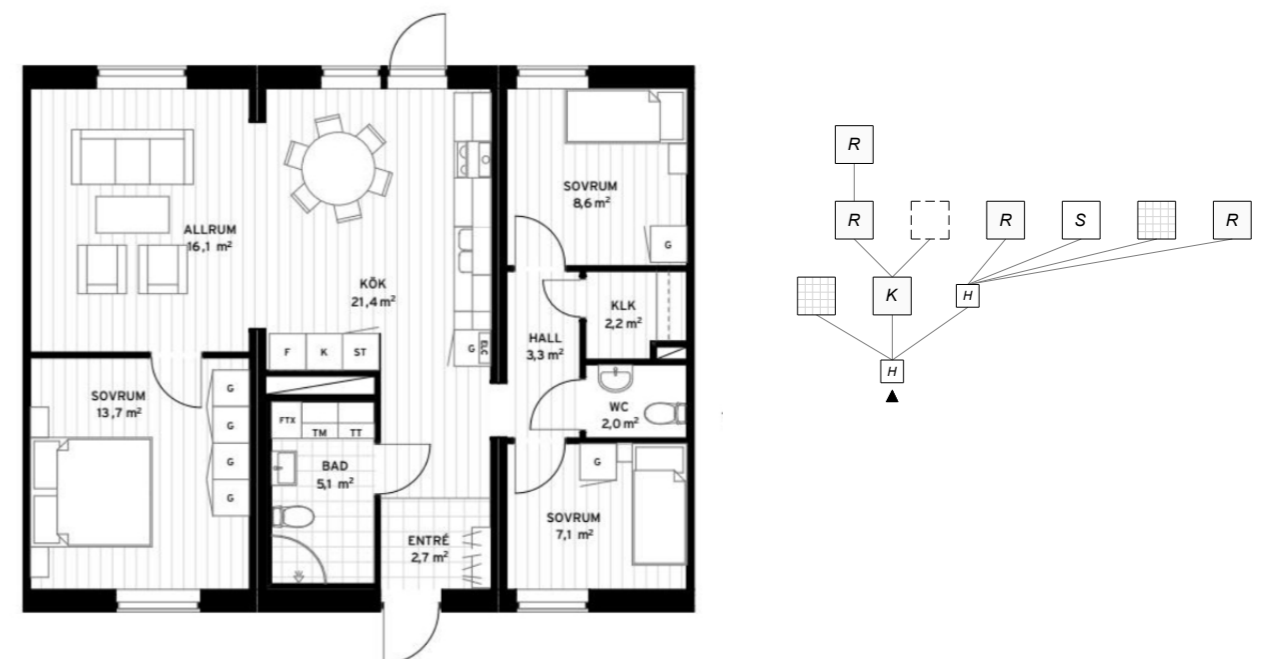


Fig 16) 88 m<sup>2</sup>, 4 rooms + kitchen  
AdderaPluss apartment B

## 2.2 | MODULARITY

Reference system: AdderaPluss

### Comments on Light

The Stavder product line of the AdderaPluss system has a gallery entrance solution in one of the short ends of the modules, and balcony access on the other. In general, a rectangular shape with only short end openings is at risk of insufficient lighting. But these modules have a relatively short length of 9 meters, creating a qualitative axiality with light coming from two directions, should the entrance door contain some glass as well.

Due to wisely positioned windows, similar axialities can be created between windows from either short side of the modules, if the doors are opened between the master bedroom and the living room, and between the two secondary bedrooms in apartment B.

With the modules stacked next to each other in a straight line, the light from one facade is coming in from only one direction. Another solution could be to shift every second module (see figures 18-21) to enable light from more than one direction. This could also create space for an integrated and more qualitative balcony solution in the void created by the shift.

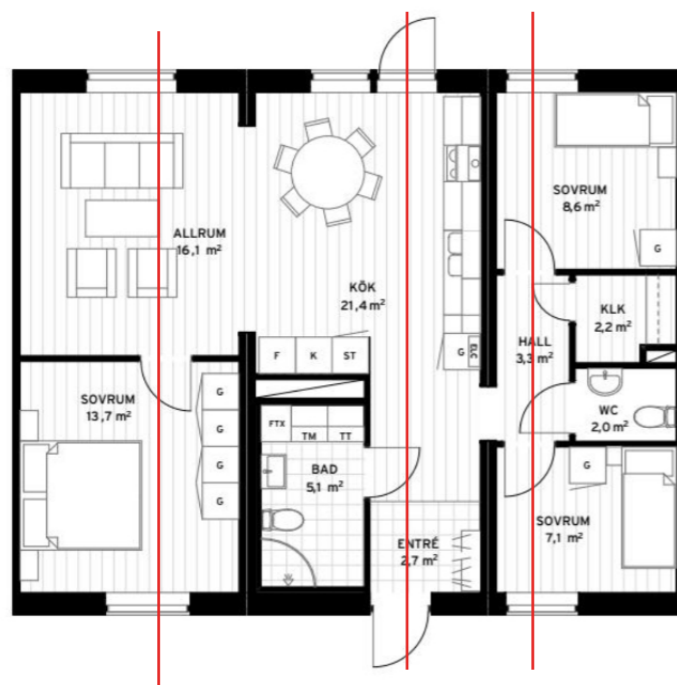


Fig 17) Sight lines  
AdderaPluss apartment B

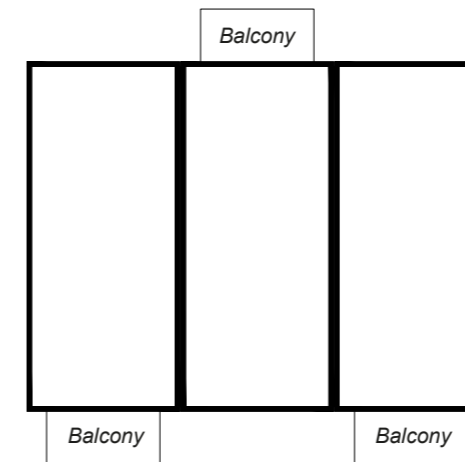


Fig 18) Straight-line modules, suspended balconies

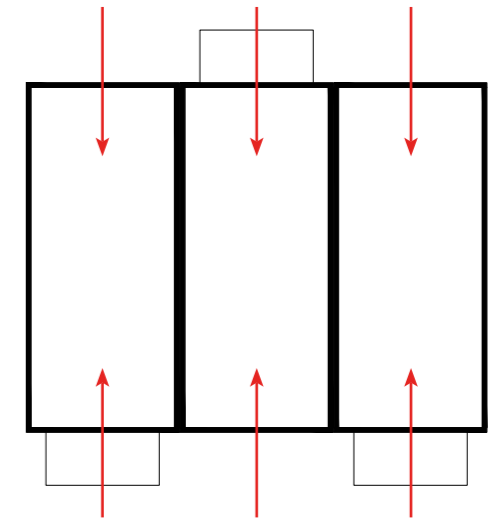


Fig 19) Possible incidence of light

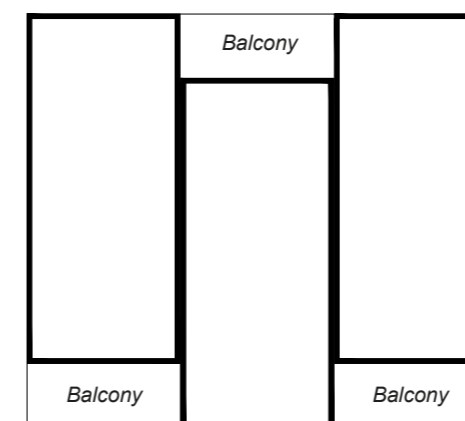


Fig 20) Shifted modules, integrated balconies

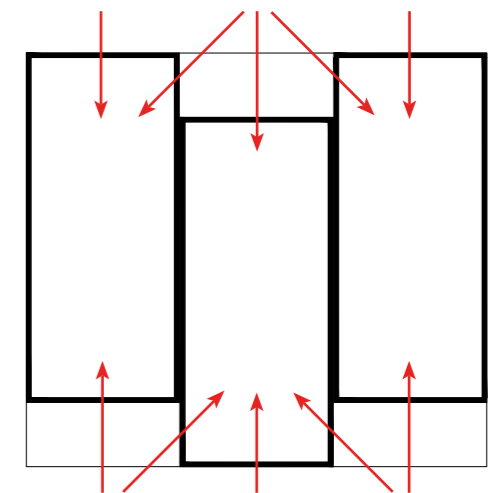


Fig 21) Possible incidence of light

## 2.2 | MODULARITY

Reference system: AdderaPluss

*Comments on visual entailments: visible beam and pillars*

When extending rooms over two modules, like the kitchen and living room solution in both apartment A and B, the construction needs to be additionally supported around these openings. This is solved by adding a frame-like construction of a beam on top of two pillars (see figure 22). The dimensions used for the beam are 45x360 mm, and the pillars are 95x225 mm. Layers of gypsum are then added resulting in visually desirable dimensions. Supposedly the designer wanted the pillars and beam to have the expression of equal dimensions all the way around.

Visually, this obviously remove the look of a big, clean, continuous volume. But at the same time, the frame could also be seen as a quality in how it acts as a subtle partitioning of space. It is a matter of taste in the end, but in any case it is a way of creating more spacious rooms within the limits of wood as material and a cost-effective modular system.



*Fig 22) Interior of an AdderaPluss apartment with visible beam and pillars around the opening.*

## 2.2 | MODULARITY

Reference system: AdderaPluss

*Comments on visual entailments: prefab facades*

In the case of pre-applied facade panels, as modules are stacked on top and next to each other, visible seams will logically occur where the modules join. This small space between modules can be covered with batten strips, but only in one direction. The principle is illustrated in figure 23; stacked modules with vertical panels will lead to horizontal seams, while stacked modules with horizontal panels will lead to vertical seams. This is something to take into account and be aware of as a designer, since it does partition the facade in clear visual patterns.

Again a matter of taste, but an aesthetic strategy for trying to hide this could be to make use of the seams and batten strips as parts of a bigger pattern. Establishing these seams as a meaningful part of the aesthetics, rather than merely a consequence of the construction method.

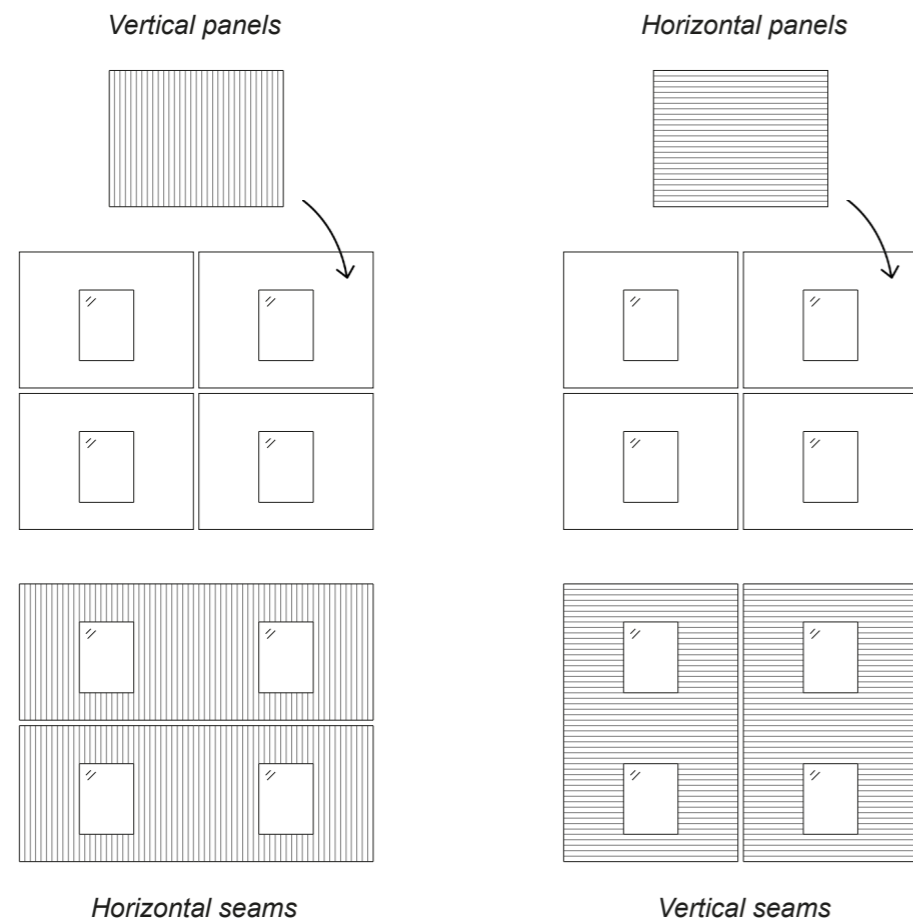


Fig 23) Prefab facade patterns



Fig 24) Visible vertical seams between modules  
Conceptual image of Derome Vendelsö



Fig 25) Visible horizontal seams between floors  
Project: Tega Ängar, Ytterby

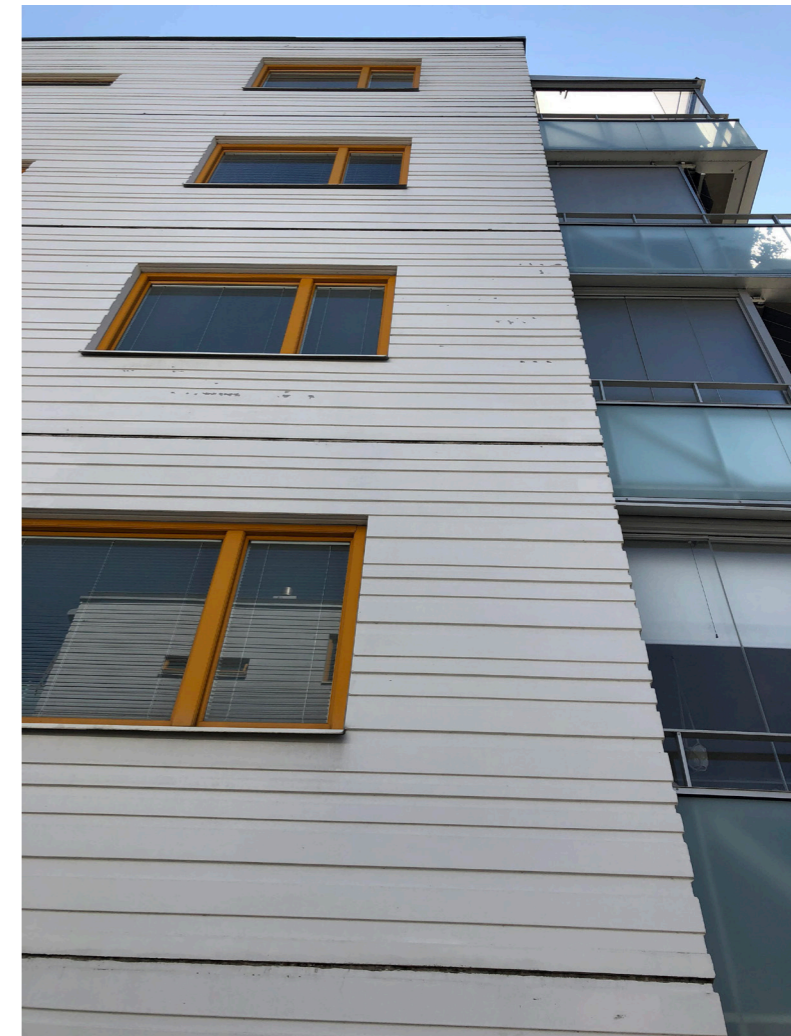
## 2.2 | MODULARITY

Reference system: *AdderaPluss*

An example from another developer, incorporating the seams as a part of the expression can be seen in project Godhemsberget from 2005 by KUB Arkitekter. Although in this case concrete elements as opposed to wood, the architects faced the same situation of visible seams in the facade. In attempting to hide the modular expression, the horizontal seams were integrated in a stripe pattern, and the vertical seams placed close to the corners of the building. Also the fact that the facade is broken down in smaller parts horizontally, with the use of integrated balconies, help minimizing the amount of vertical seams. Another way to hide vertical seams could be strategic placement of downpipes in these positions.



18 years after completion, in the dark grey parts of the facade the method has been highly successful, the seams are still barely visible. But in the white parts, the sealant have started to become more and more polluted, thus standing out versus the rest of the facade and not as effectively hiding the modular seams any longer. Illustrating the importance of execution, and how a longterm approach must be part of every detail and design decision, regardless of which method and construction that are ultimately chosen.



## 2.2 | MODULARITY

### Construction

#### 2.2.3 - Construction

The construction method used for the design proposal in this thesis inherits the methods and dimensions of the Derome AdderaPluss system and their volumetric module factory in Väröbacka, Sweden. Ensuring an already tested and approved construction in terms of regulations for fire, sound and indoor climate. By following these delimitations, the design proposal would be possible to be constructed in the Väröbacka factory.

#### Dimensional limitations

The factory is capable of producing modules with dimensions of maximum 4.10 m wide by 12 m long. These limits are due to the dimensional aspects of the facility in itself, but also for structural purposes, as each module needs to be able to carry its own weight during construction and transportation. The total height of one module is 3.03 m, of which the interior ceiling height is 2.5 m.

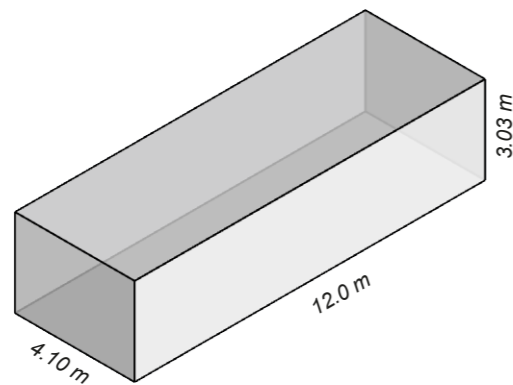


Fig 26) Maximum module dimensions

#### Technical system

Heating is supplied through the ventilation system (air heating), in contrast to a more traditional, waterborne heating system through radiators. There is also a local system for ventilation for each apartment, resulting in significantly smaller dimensions of vertical shafts as only water (100-150 mm diameter) and drain (110 mm) pipes are drawn vertically through the floors of the building, and not ventilation (315 mm) pipes.

#### Interior walls

12 mm gypsum  
95 mm wooden joist & insulation  
12 mm gypsum

= 120 mm

The single wall construction of each module is 120 mm in total and when stacked next to another module, 30 mm air is left as a buffer zone for a total of  $120 + 30 + 120 = 270$  mm. These double walls meet all demands for apartment dividing walls in terms of sound, climate and fire regulations.

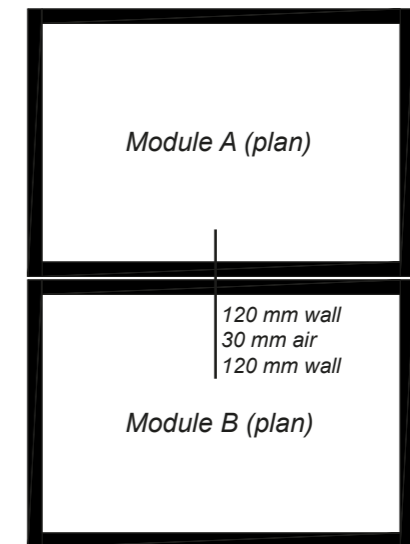


Fig 27) Interior walls formed by the stacking of modules

#### Exterior walls

12 mm gypsum  
70 mm wooden joist & insulation  
11 mm windshield  
1 mm vapour barrier  
170 mm wooden joist & insulation  
11 mm windshield  
45 mm insulation  
28 mm nailing batten  
22 mm wood panel

= 370 mm

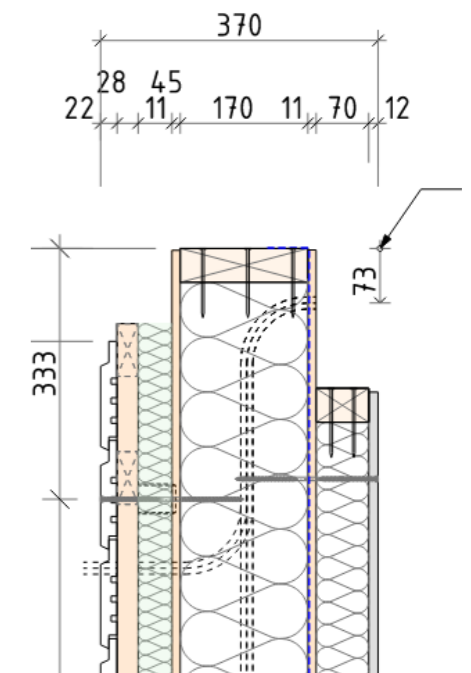


Fig 28) AdderaPluss exterior wall detail

## 2.2 | MODULARITY

### Construction

#### Floor joists

Holding drain, water and heating installations

15 mm parquet flooring

13 mm gypsum

22 mm chipboard

245 mm floor beam (installations + 100 mm insulation)

= 295 mm

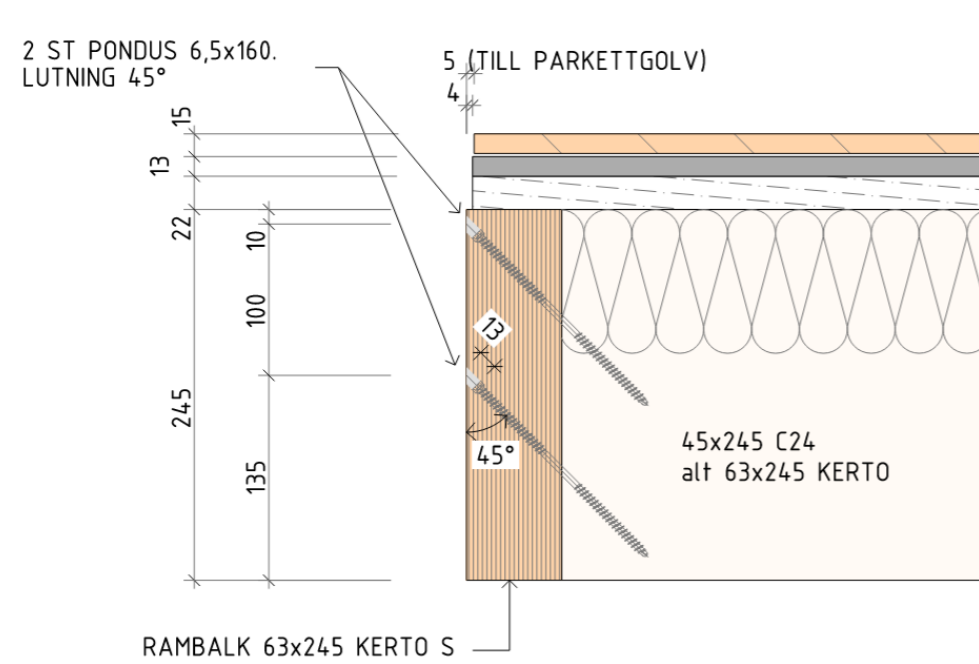


Fig 29) AdderaPlus floor joist detail

#### Ceiling joists

Holding electrical installations

145 mm wooden joist & insulation

2x15 mm gypsum

11 mm ceiling panel (Brannit)

= 186 mm

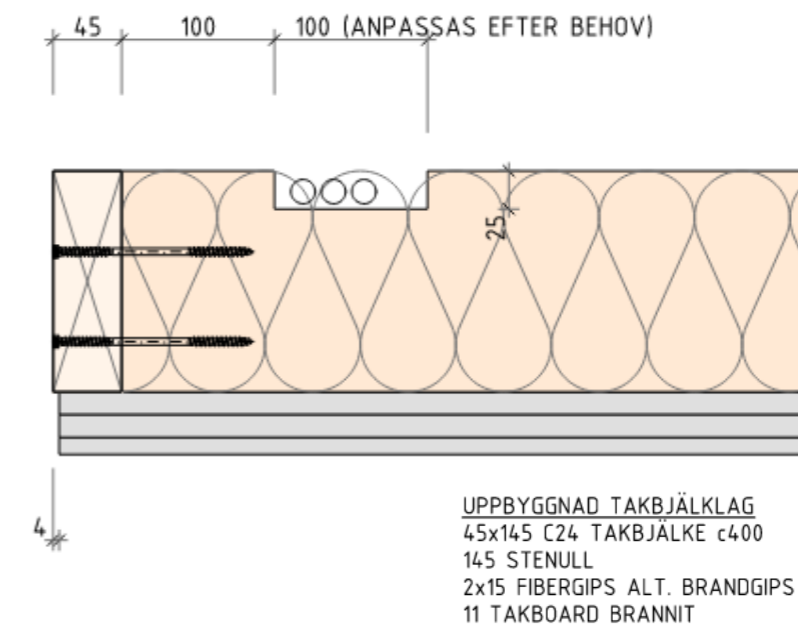


Fig 30) AdderaPlus ceiling joist detail

# 3

RESEARCH BY DESIGN

### 3.1 | DESIGN PROCESS

Research by design involved balancing theory on adaptability and listed adaptable design features (chapter 2.1.6) with the construction prerequisites of the modular system (chapter 2.2.2). This chapter highlights and discusses main topics and overall design decisions in trying to merge these two fields.

#### 3.1.1 - Module dimensions

With an overall aim for sustainability, exploring maximum efficiency in the construction method was a relevant strategy. This led to two main starting points in terms of module dimensions;

- Maximizing module size. Meaning 4.10 x 12.0 x 3.03 m volumes. Which leads to energy efficiency in transportation, by loading as many m<sup>3</sup> per truck as possible. Another aspect being the adaptable strategies demanding space in general. Explorations of generality (chapter 2.1.2) had pointed to room dimensions of around 4 meters or just below, so maximizing the construction capacity was highly relevant.

- Repetition in module size. Trying to make use of the same module dimensions for all apartments and stairwells, throughout the whole building. Mostly a matter of coherency in design, especially since I was going to try shifting the modules for better light and outlooks (see next section: 3.1.2). But same size modules also means efficiency in construction, with less changes in factory workflow.

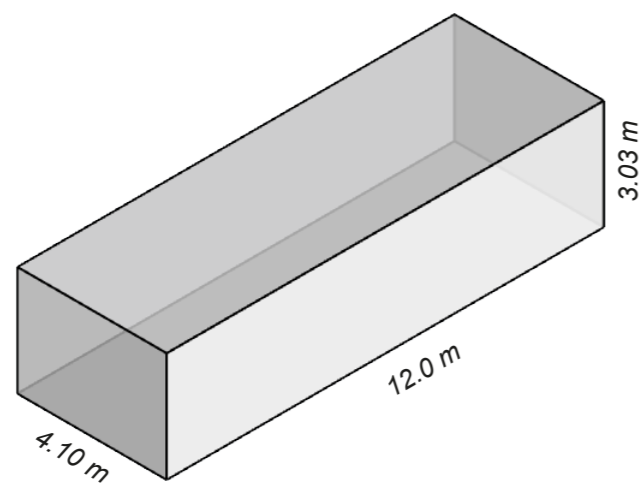


Fig 31) Maximum module dimensions

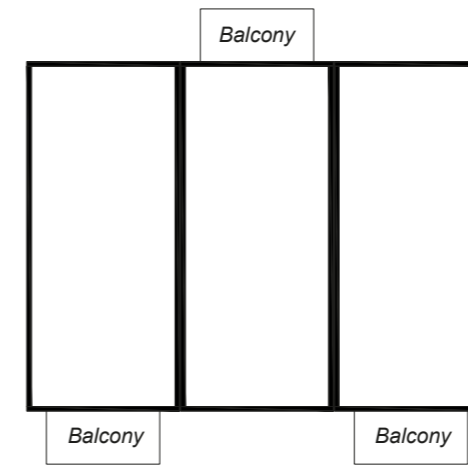


Fig 32) Straight-line modules, suspended balconies

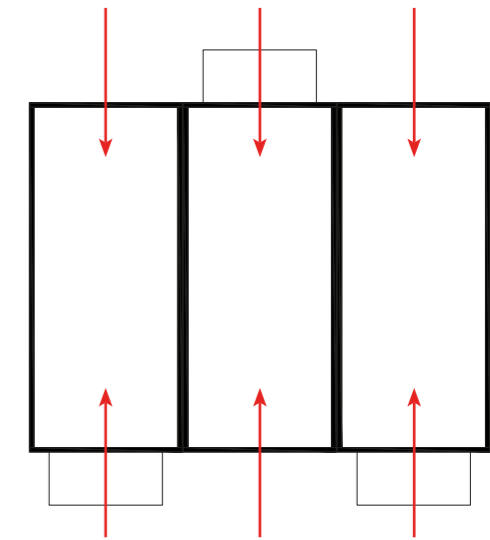


Fig 33) Possible incidence of light

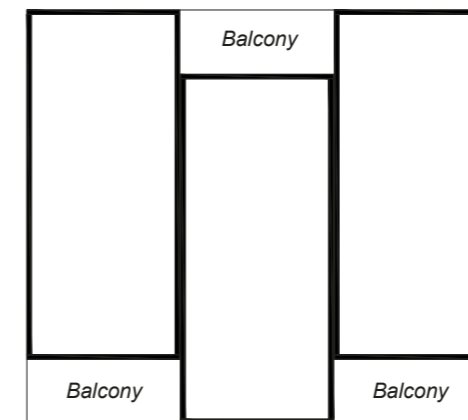


Fig 34) Shifted modules, integrated balconies

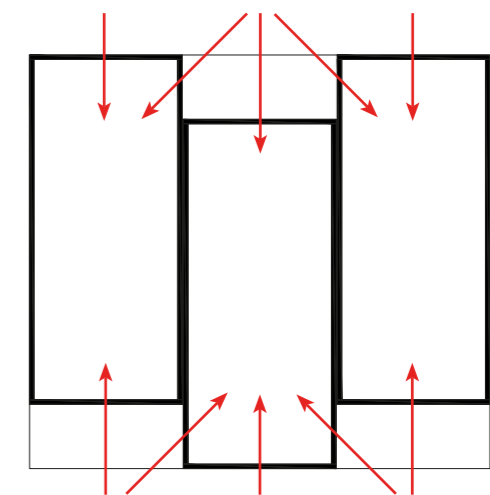


Fig 35) Possible incidence of light

#### 3.1.2 - Module shift

As discussed in chapter 2.2.1 and once again illustrated in figures 32-35, a shift in modules would lead to more light coming in compared to having the modules stacked in a straight line. Also, opening up for more directions of incoming light means more angles for views of the surroundings as well. Which makes sense for a product line system of predesigned apartments that need to fit into different contexts on different sites.

### 3.1 | DESIGN PROCESS

#### 3.1.3 - Entrance on long side of module

One of the key components of an adaptable apartment is the presence of a neutral access point. In practice, being able to reach every room from either a central point/corridor or via more than one route.

Utilizing the full length of a module (~12 m), an entrance on the short side leads to a comparatively long neutral corridor to reach the rooms on the other side of the module. The AdderaPluss reference modules do not face this issue to the same extent, since they are only 9 meters long.

Furthermore, an entrance on the short side also occupies valuable space along the facades, better utilized by activities such as socializing, eating, cooking and sleeping.

#### 3.1.4 - Spatial scheme

Showcased in figure 37, an interior width of 3.8 meters per module is a good fit for being divided into a spatial scheme of 0.6 m storage/kitchen space, followed by 1.2 m corridor/movement and then 2.0 m (incl 0.12 wall) for utilities such as bathroom and laundry. By having the space for utilities form a central core of the dwelling, corridors on either side can connect the rooms along either facade. These rooms are 4.42 x 3.8 m on one side and 4.3 x 3.8 m on the other, providing good possibilities for interchangeability of functions - adaptability through generality.

For even better possibilities of neutral access points to all rooms, the 4.3 x 3.8 m room can also be turned into one room of 3.0 x 3.8 m plus a 1.2 m wide corridor, which then also takes care of movement perpendicular to the long side of the module. This option is highlighted by the dashed lines representing a possible wall in this position, which creates the corridor. The 4.42 x 3.8 m room along the other facade could possibly form a kitchen with its 0.6 m interior along the long wall.

An arrangement of modules with these dimensions and spatial configuration results in an apartment of approximately 91 m<sup>2</sup>. Slightly bigger than what is usually seen for 3 rooms and a kitchen today, but also arguably within reason in this context, as adaptable design strategies and neutral access points demand space by nature.

Fig 36) Module stacking

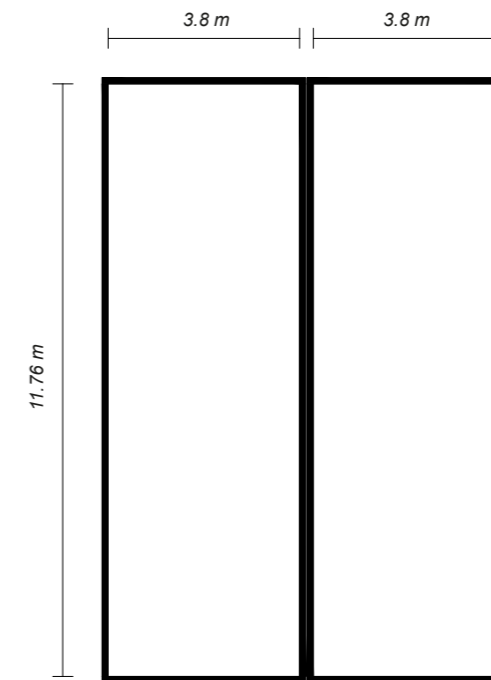
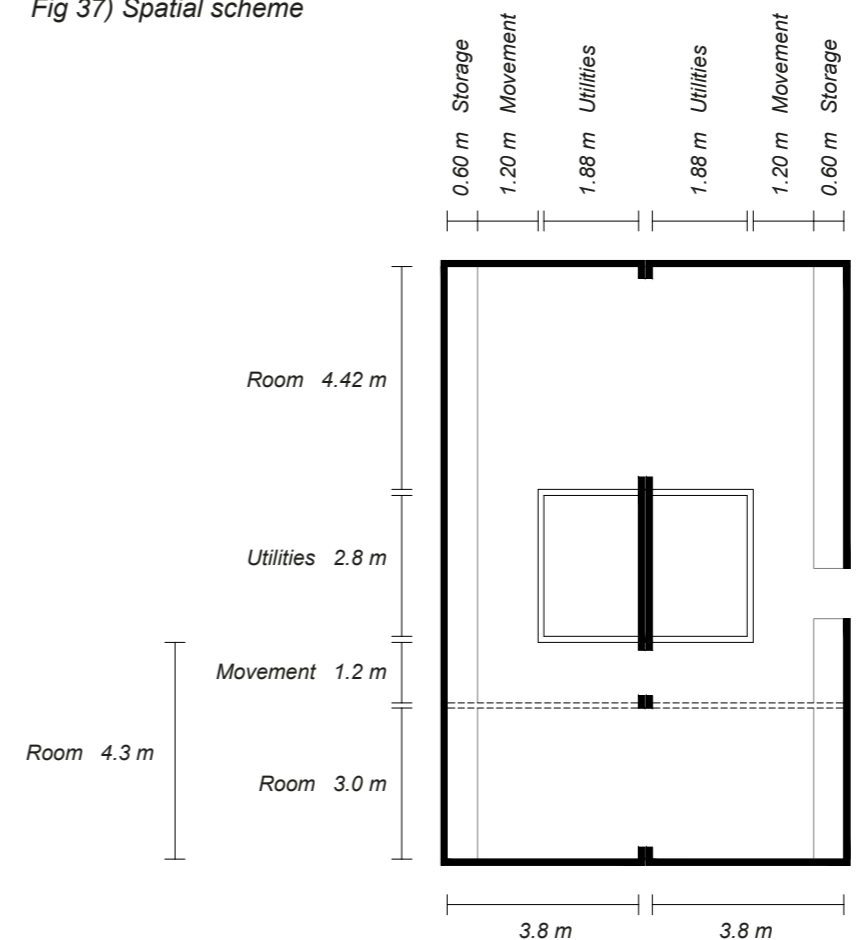


Fig 37) Spatial scheme



## 3.1 | DESIGN PROCESS

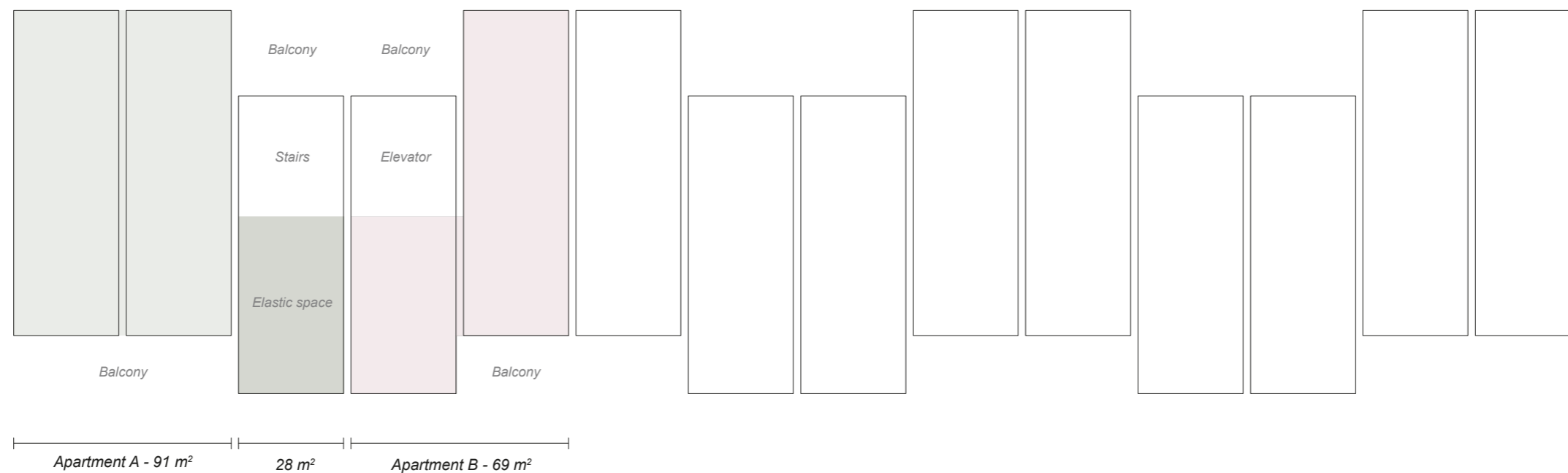
### 3.1.5 - Modular scheme

Combining the spatial scheme of the base 91 m<sup>2</sup> apartment with the idea of shifted modules resulted in a modular scheme illustrated in figure 38. Fourteen modules, with module number 3,4,7,8,11 and 12 shifted in relation to the rest, creating space for integrated balconies in the void left behind.

The third module from the left holds half the stairwell space, along with an elastic space of 28 m<sup>2</sup> that both could be an adaptable part of the 91 m<sup>2</sup> apartment, or for example an entirely independent student apartment. Since the entrance to the 91 m<sup>2</sup> apartment works well positioned around the center of the long side of the module, the shifting of modules also helped make room for this elastic space along with a separate entrance to it from the stairwell.

The fourth module from the left holds the second half of the stairwell, along with 28 m<sup>2</sup> out of the total 69 m<sup>2</sup> of the next apartment. These three apartments are then repeated throughout the building.

Fig 38) Modular scheme concept



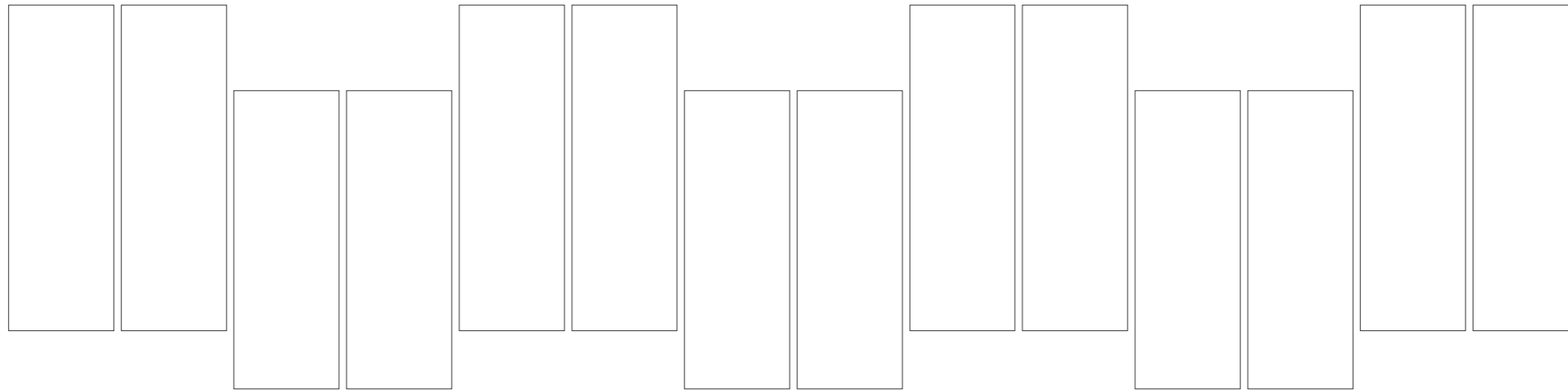
# 4

## DESIGN PROPOSAL

# 4 | DESIGN PROPOSAL

Standard floor 1:200

Modular scheme



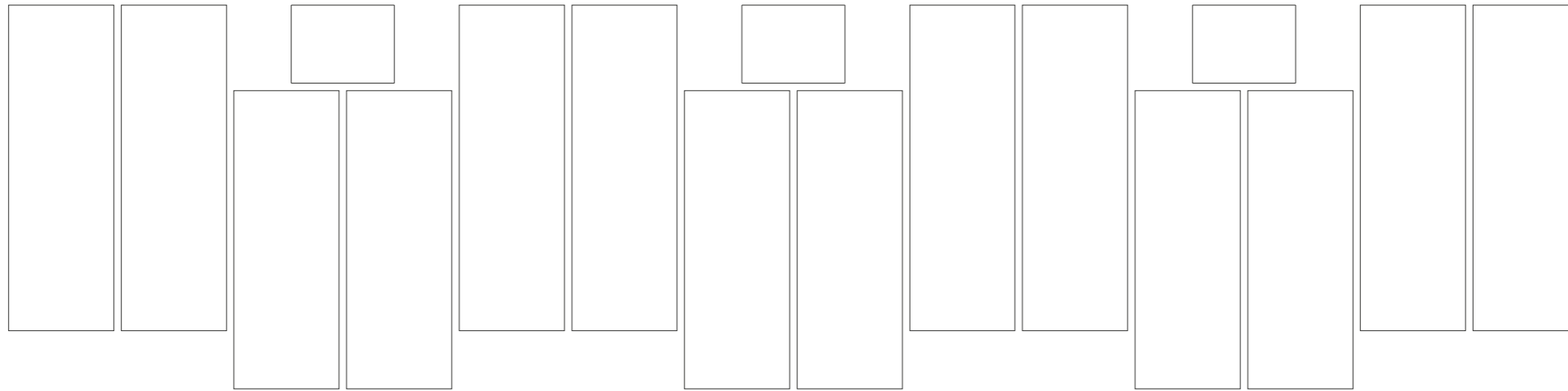
Standard floor



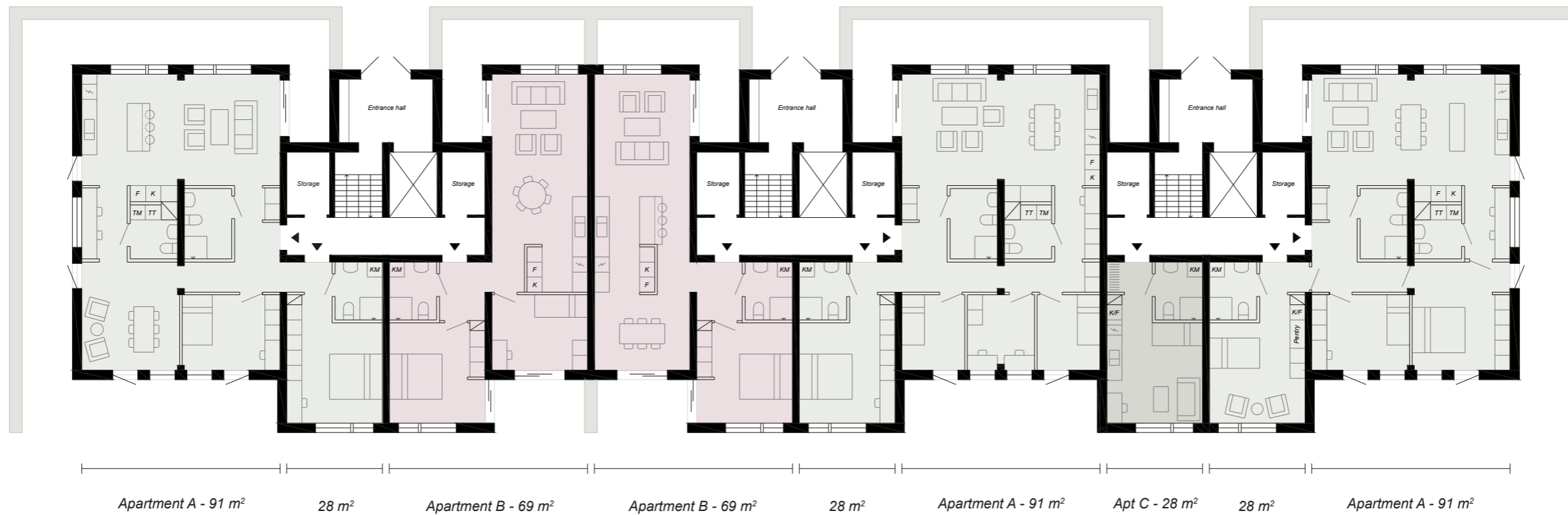
# 4 | DESIGN PROPOSAL

Ground floor 1:200

Modular scheme



Ground floor



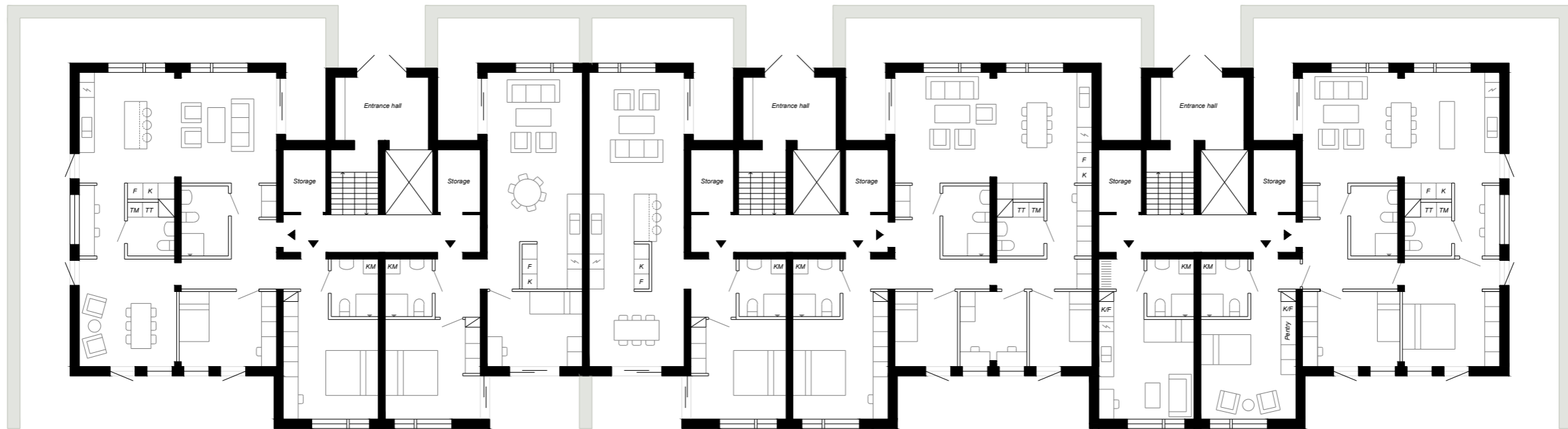
# 4 | DESIGN PROPOSAL

Facades 1:200

Entrance side



Ground floor



Apartment A - 91 m<sup>2</sup>

28 m<sup>2</sup>

Apartment B - 69 m<sup>2</sup>

Apartment B - 69 m<sup>2</sup>

28 m<sup>2</sup>

Apartment A - 91 m<sup>2</sup>

Apt C - 28 m<sup>2</sup>

28 m<sup>2</sup>

Apartment A - 91 m<sup>2</sup>

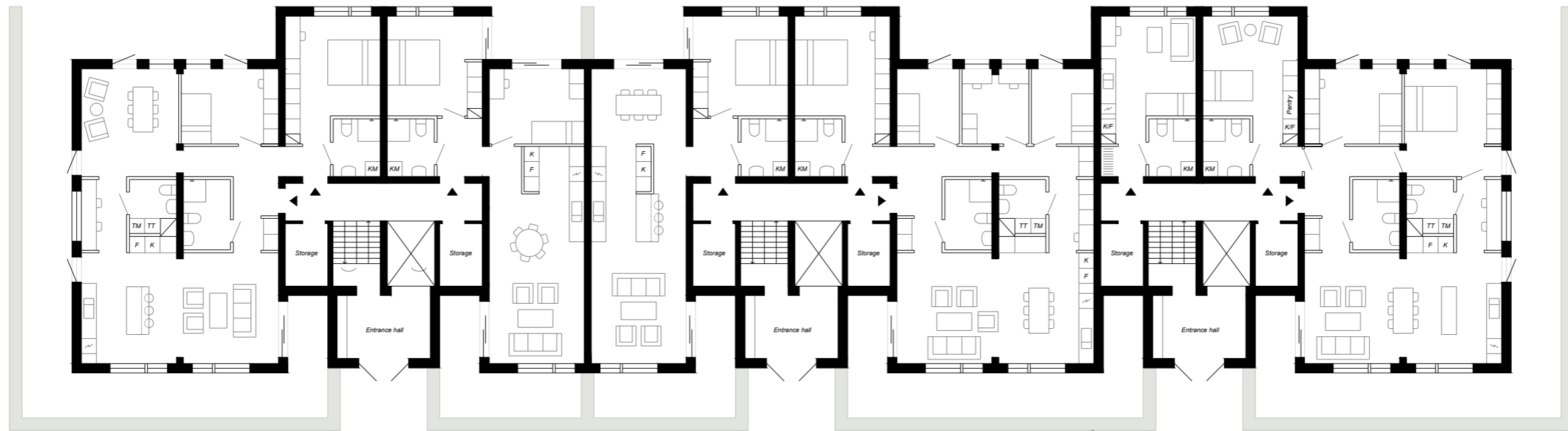
# 4 | DESIGN PROPOSAL

Facades 1:200

Back side



Ground floor



Apartment A - 91 m<sup>2</sup>

28 m<sup>2</sup>

Apartment B - 69 m<sup>2</sup>

Apartment B - 69 m<sup>2</sup>

28 m<sup>2</sup>

Apartment A - 91 m<sup>2</sup>

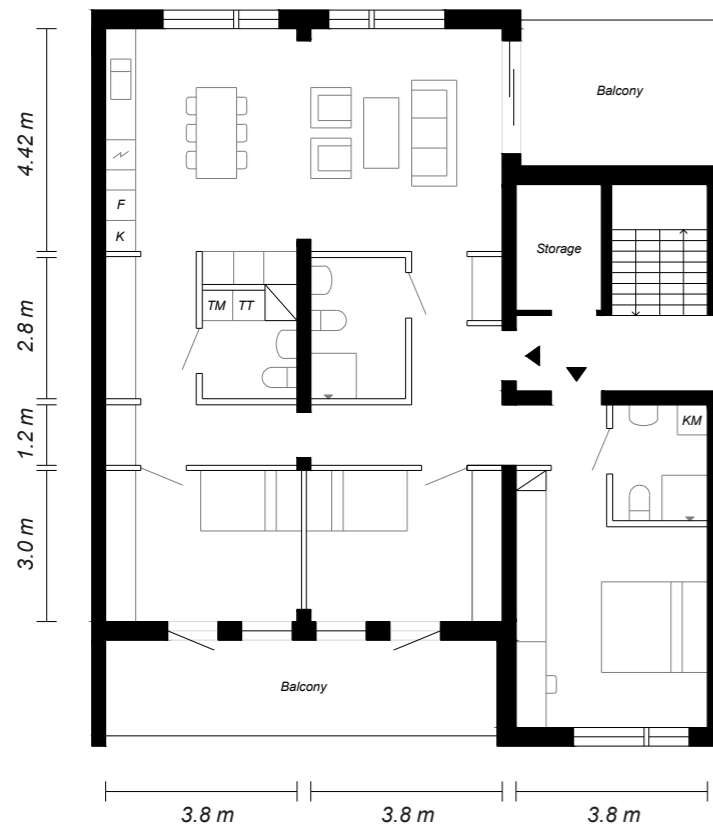
Apt C - 28 m<sup>2</sup>

28 m<sup>2</sup>

Apartment A - 91 m<sup>2</sup>

## 4 | DESIGN PROPOSAL

### Apartment A



### Apartment A

3 rooms + kitchen | 91 m<sup>2</sup>  
4-5 rooms + kitchen | 116 m<sup>2</sup>

91 m<sup>2</sup> or 116 m<sup>2</sup> depending on use of the elastic space.

Neutral access points to all rooms.

Overall spatial scheme of storage walls along one of the sides of each module, which also can hold workspaces or kitchen interior.

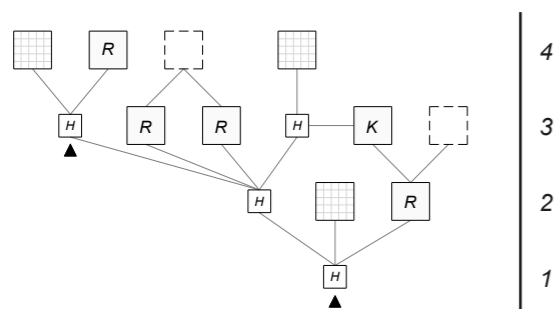
Sightlines connecting windows on both facades.

Circulation around a central core.

Balcony access from both secondary bedrooms, unlocking another circulation route including the balcony.

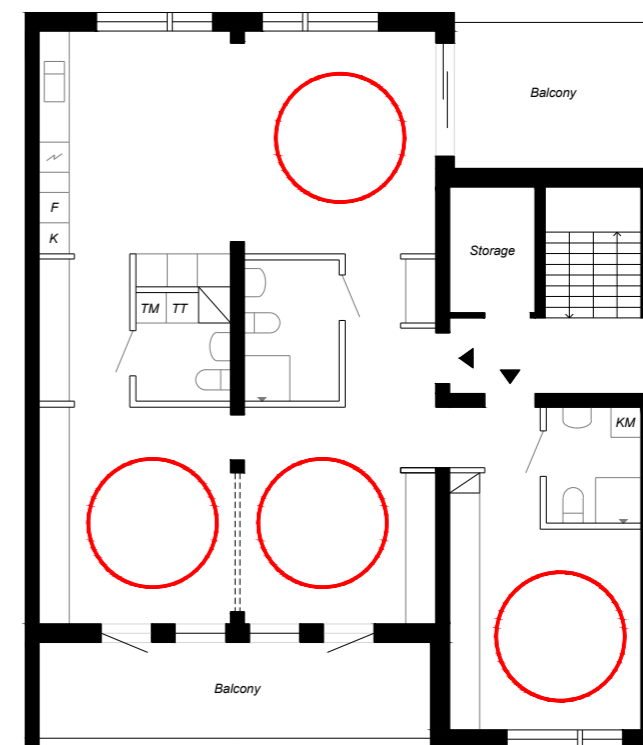
Integrated balcony outside the stairwell space, providing more light and views in another direction.

Space syntax: 4 level system of spatial configuration. However, the only "room" on the fourth level is the elastic space, so if making use of the alternative entrance as the starting point, that room is only on level 2.



### Generality

If excluding the kitchen space which is locked in place, all rooms are of very similar measurements (between 4.0 and 4.4 m, times 3.8 m), which supports a complete interchangeability of functions between these rooms. But naturally, some changes will affect the spatial configuration and available neutral movement. A bedroom could be placed in the space next to the kitchen, but that would also limit possible size and/or use of the two rooms on the other facade, since you would want a neutral access to the kitchen without having to pass through a bedroom.



## 4 | DESIGN PROPOSAL

### Apartment A

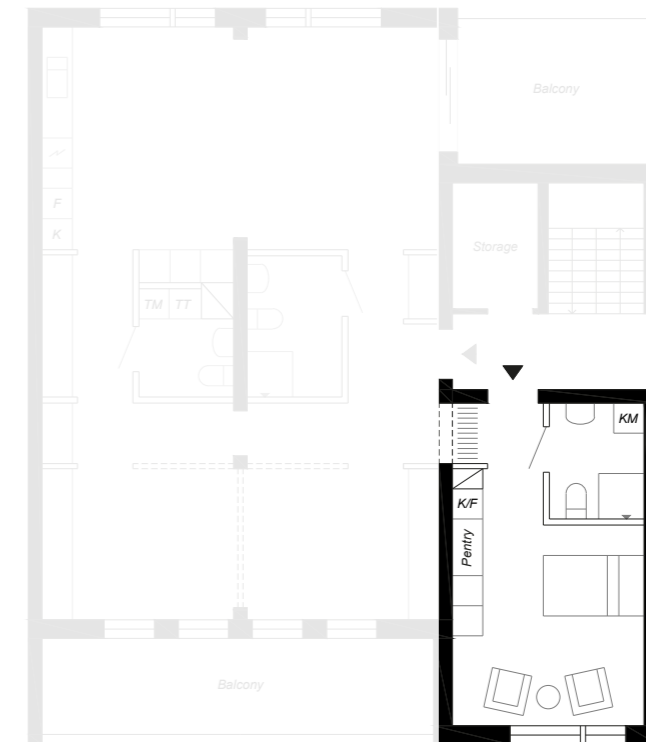
#### Elasticity

The 28 m<sup>2</sup> elastic space of the apartment can either have closed or open connection to the stairwell and to the rest of the apartment, supporting a variety of uses depending on need. The following examples show three different combinations of open and closed connections, and how the elastic space potentially could be used.

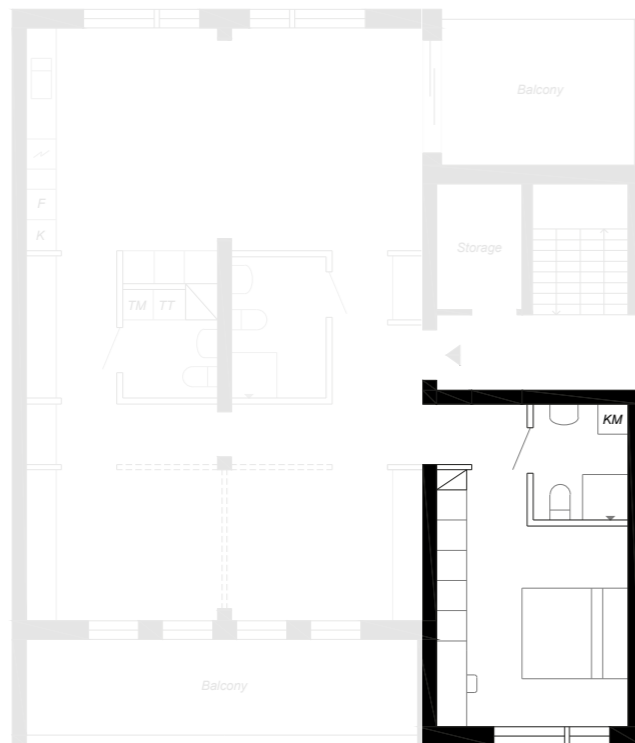
With an open connection to the rest of the apartment, it could become a master bedroom and a logical end of a bedroom area corridor, ranging over the three modules around the balcony.

With a separate entrance from the stairwell, coupled with an optional connection to the rest of the apartment, the space could serve as a more secluded teenager area or a generational living.

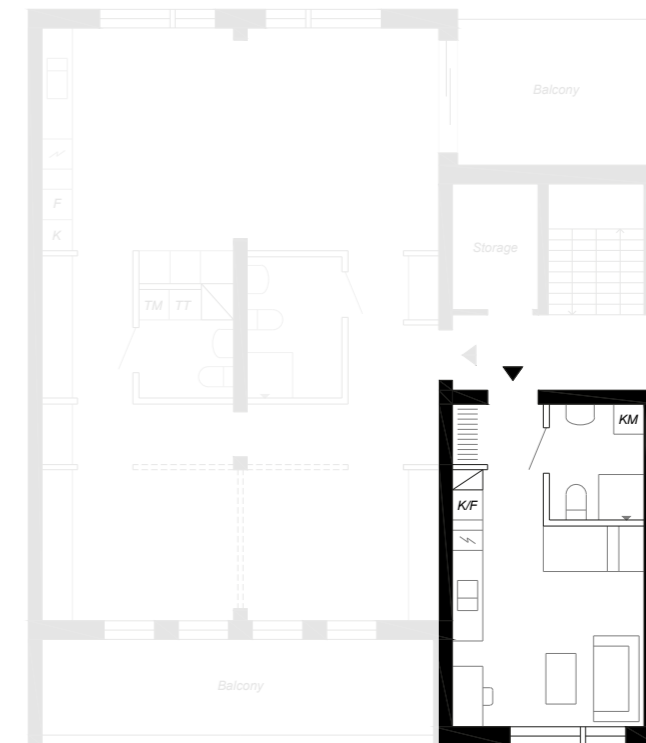
With a closed connection to the main apartment, the space can serve as an entirely autonomous part, with enough room for a kitchen setup meeting Swedish standards for a student apartment. This is the solution named apartment C of the design proposal.



Teenager area  
Generational living



Master bedroom



Student apartment  
Rentable space

## 4 | DESIGN PROPOSAL

### Apartment A

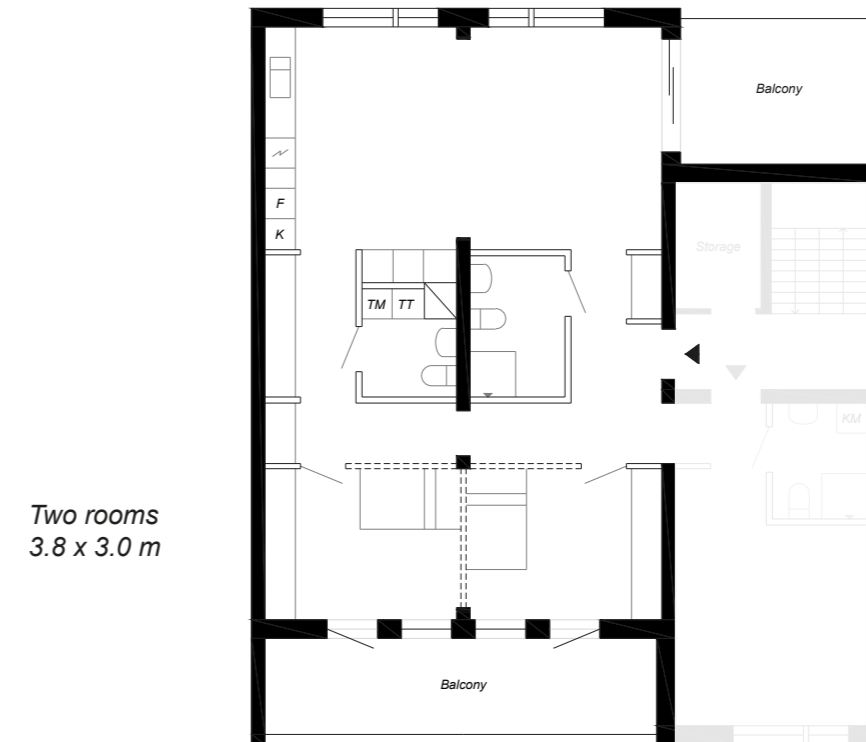
#### Flexibility

Specific spacing and positioning of the four windows facing the balcony allows for flexible walls to meet the facade in three different spots. The following examples show how such walls could divide the space into different room constellations. Depending on inclusion or exclusion of the previously mentioned elastic space, the apartment could thereby range from 3 rooms+kitchen of 91 m<sup>2</sup> to 5 rooms+kitchen of 116 m<sup>2</sup>.

In the first illustration below, two rooms (of 3.8 x 4.3 m) absorb the area of the possible corridor to form two bigger spaces, suitable for a master bedroom, living room or a more spacious, dedicated dining room.

The second illustration is a variation of the first, but with a corridor providing neutral access to both rooms. These could for example be a rather spacious secondary bedroom, home office or a dining room.

The third illustration shows three smaller rooms which could be bedrooms for a big household if the master bedroom is situated in the elastic space of the apartment. The 2.6 x 3.0 m room could for example also serve well as dedicated home office.



## 4 | DESIGN PROPOSAL

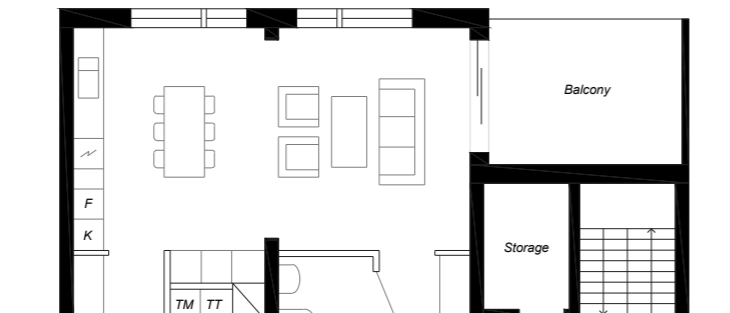
### Apartment A

#### Flexibility - kitchen and living room

In similar manner as on the opposite facade, room sizes and the window placements dictate the possibility of changing between an open plan between kitchen and living room, or a closed off kitchen. The difference here being the flexible walls connecting to window posts, as opposed to against the wall between two windows.

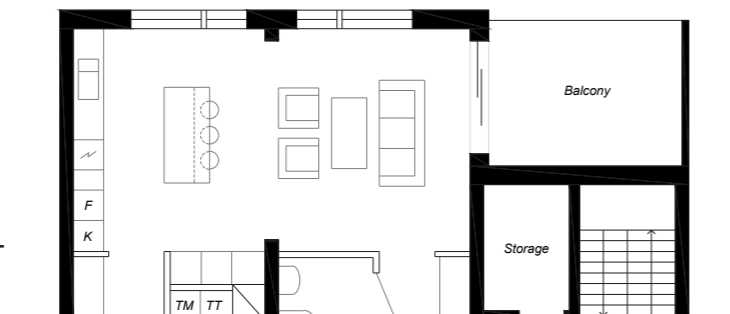
Highlighted in illustrations A-F below, positioning of flexible walls can change the relative size between kitchen and living room depending on needs and preferences, further enhancing the adaptability of the apartment.

A) Open plan  
36 m<sup>2</sup> space



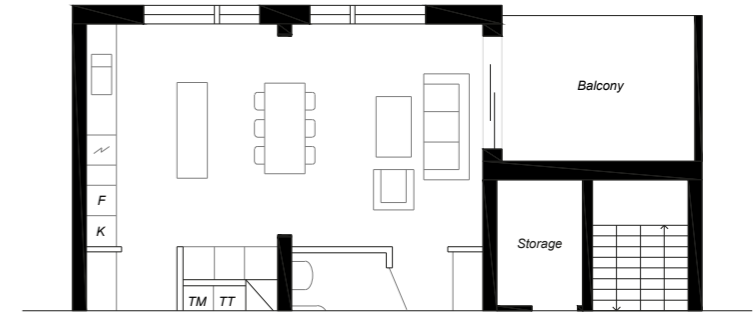
B) Open plan

Kitchen island with bar stools connecting kitchen and living room. For more spacious arrangements of the apartment, with a dedicated dining room located elsewhere.



C) Open plan

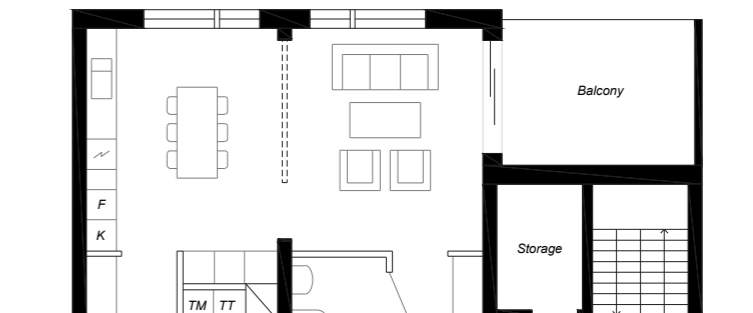
Slightly more cramped solution with kitchen island, kitchen table and sofa all fit into the space.



D) Closed big kitchen

18 m<sup>2</sup> kitchen  
17 m<sup>2</sup> living room

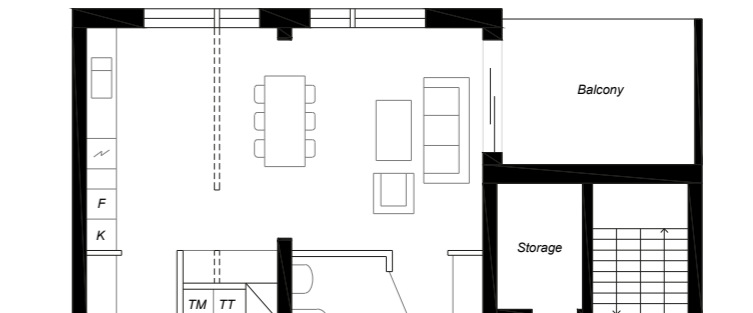
The flexible wall also providing an extra TV wall for the living room area.



E) Closed small kitchen

11 m<sup>2</sup> kitchen  
24 m<sup>2</sup> living room

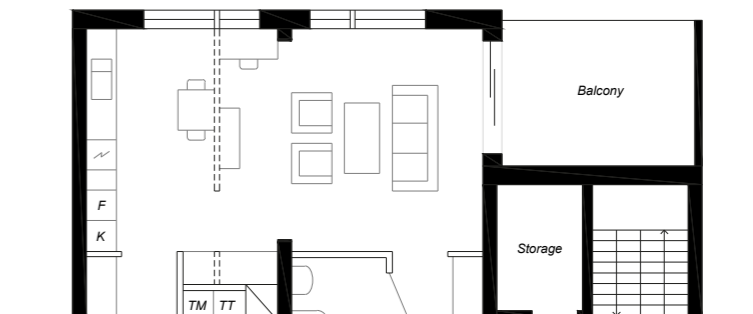
Both kitchen table and sofa occupying the living room.



F) Closed small kitchen

Variation of E, suitable if a separate dining room is available elsewhere. However still possibility for a small 2-seat kitchen table inside the kitchen.

More spacious 24 m<sup>2</sup> living room with space for additional furniture.



## 4 | DESIGN PROPOSAL

### Apartment A

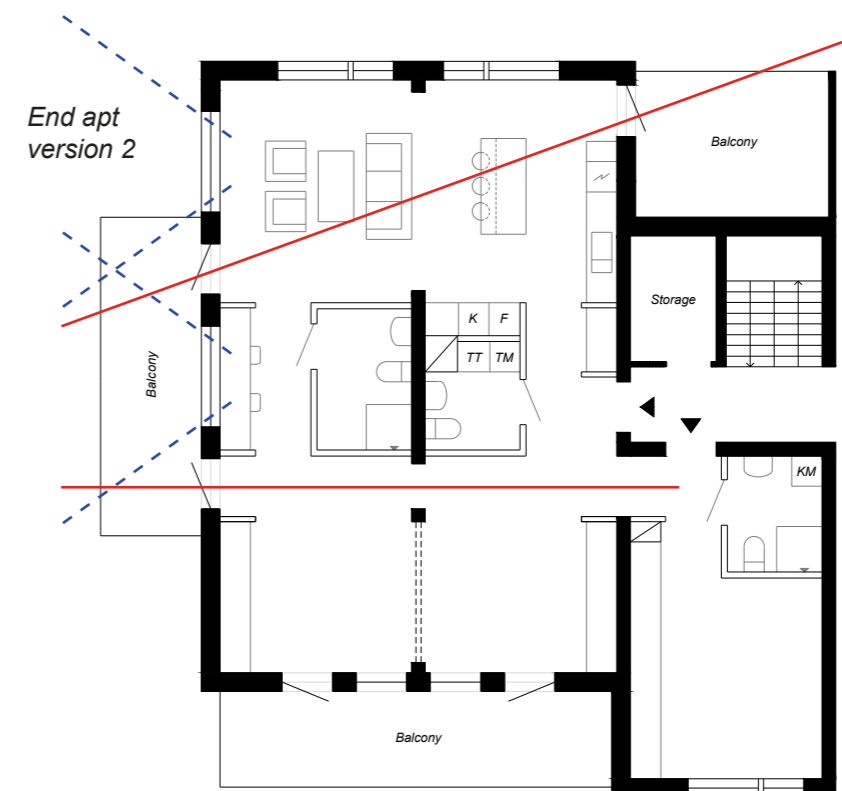
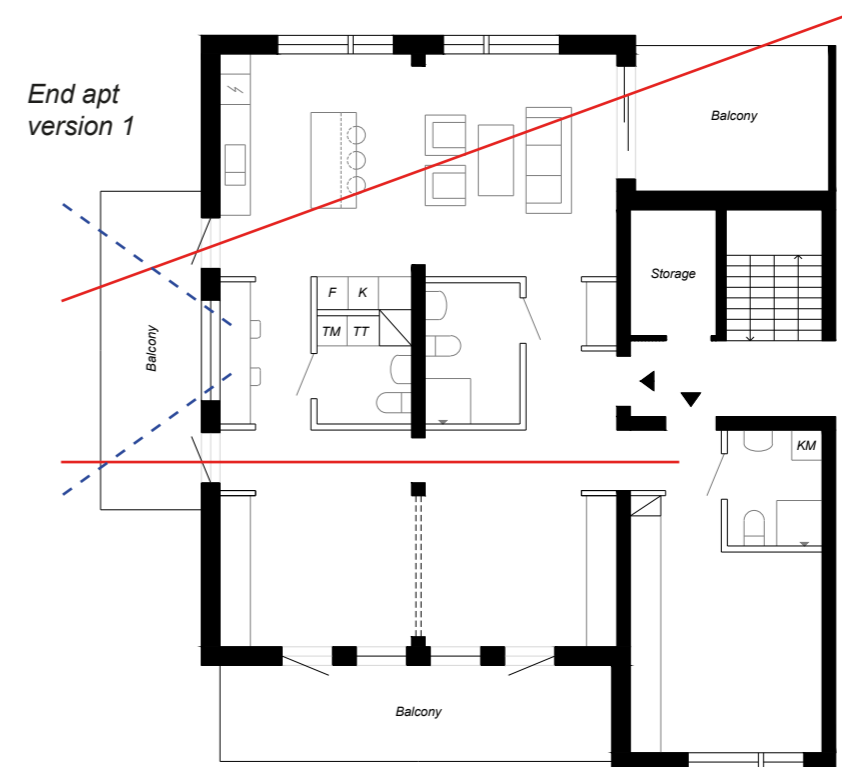
#### End apartment

Not all building plots allow or are suitable for it, but not having the apartments on either end of a row open up towards a third direction when possible, could be considered a missed opportunity. It's an added cost to a project compared to only stacking the standard modules, but potentially adds plenty of quality depending on site.

As illustrated in version 1 on the next page, a reshuffling of the fridge and freezer together with removal of some room for storage along the facade opens up for a third balcony, more light, and new sightlines across the apartment. The spot in front of the new 2 meter window could be used as a workspace with a view, or a niched window seat for relaxation in a prime spot.

There is value in keeping the altered end apartment schematically similar to the standard version and only redesigning one out of three modules, the outermost one in this case. However, if altering of two modules is a plausible action, mirroring the positions of the kitchen and the living room allows for even greater advantage taken of the possible outlooks, views and light conditions by instead placing the living room in this position. This solution can be seen in version 2.

With the non-site specific nature of a prefabricated design line of standard modules, the possibility of adjusting to context is of course a great architectural quality if it can be part of the system. The choice between the two versions of end apartment could essentially boil down to suitable directions of outlooks and light for each individual project site. Perhaps the workspace window, the new balcony and its glazed openings for access are not suitable in some cases, but the big window in the living room still is.



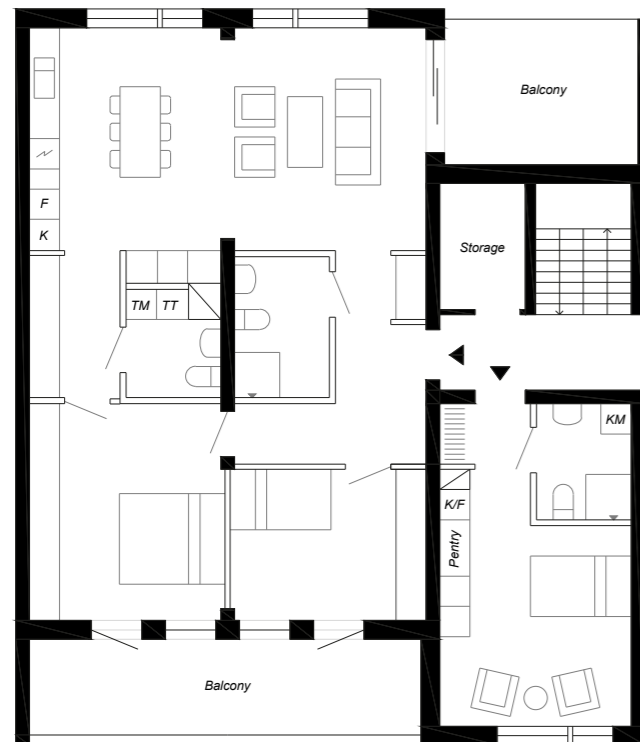
## 4 | DESIGN PROPOSAL

### Apartment A

#### Time-space model

The adaptable capabilities unlocked by generality, flexibility, elasticity and the use of neutral access points are here exemplified and illustrated in better detail in a time-space model. A fictional scenario of 7 different spatial arrangements and uses of the same apartment over the course of around 40-50 years. The constant is a man who initially rents the elastic space from an older couple, but then goes on to take over the dwelling as they move out, and end up staying for his entire adult life.

The human figures next to the plans illustrate amount of people in the household. A solid line between figures represents a social situation which is not particularly close, and separated spaces are needed. A dotted line represents a situation where some social spaces can be shared but there is also need for private spheres. If there is no line at all between figures, it represents a uniform household that can share all spaces.



① ② ③ ④ ⑤ ⑥ ⑦



An older couple decides to rent out the elastic space of the apartment to a young student.

They keep one extra bedroom for when long distance friends and relatives come to visit.

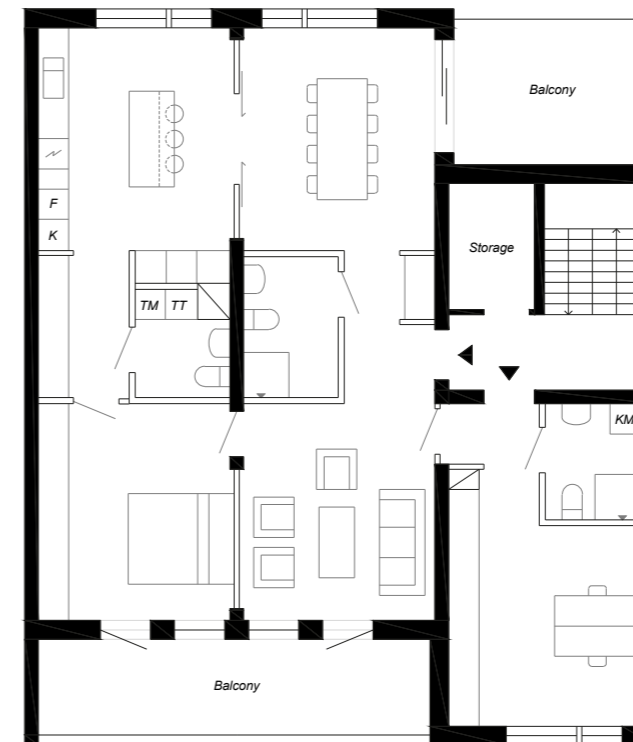


① ② ③ ④ ⑤ ⑥ ⑦



The old couple moves out and the student gets offered to take over the full apartment. The student loves the area and wants to keep living here, he accepts but rearranges it to a co-living apartment together with two fellow students to be able to afford the rent.

The room between the bedrooms is turned into a small office for more available private spheres and better possibilities of undisturbed studies.



① ② ③ ④ ⑤ ⑥ ⑦

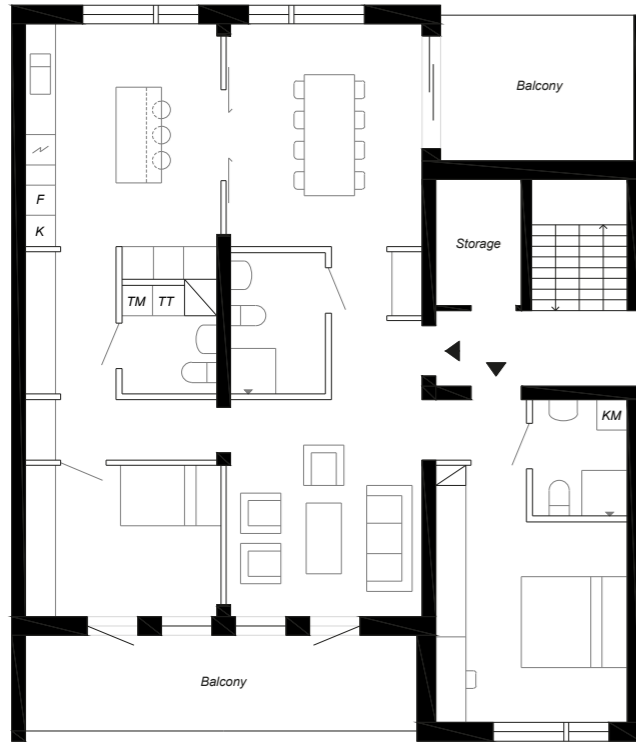


Both friends move out but his girlfriend moves in and they create a more sizable master bedroom. They don't fancy open floor plans and share a great interest in cooking. They close off the kitchen and add a kitchen island for extra storage and work surface. The living room is moved to the other facade and is replaced by a spacious dining room for hosting dinners.

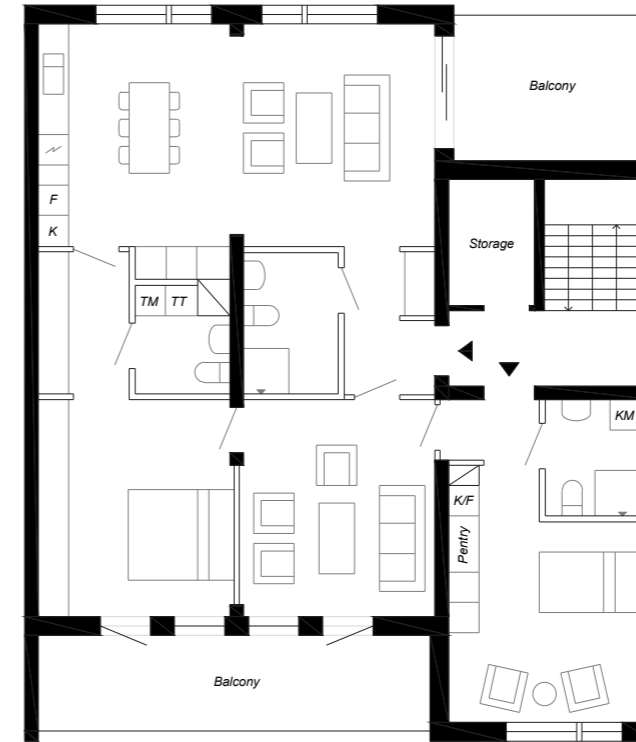
The girlfriend has a business with one employee and need a cheap office. The elastic space is turned into a workplace with a separate entrance for the co-worker.

## 4 | DESIGN PROPOSAL

### Apartment A

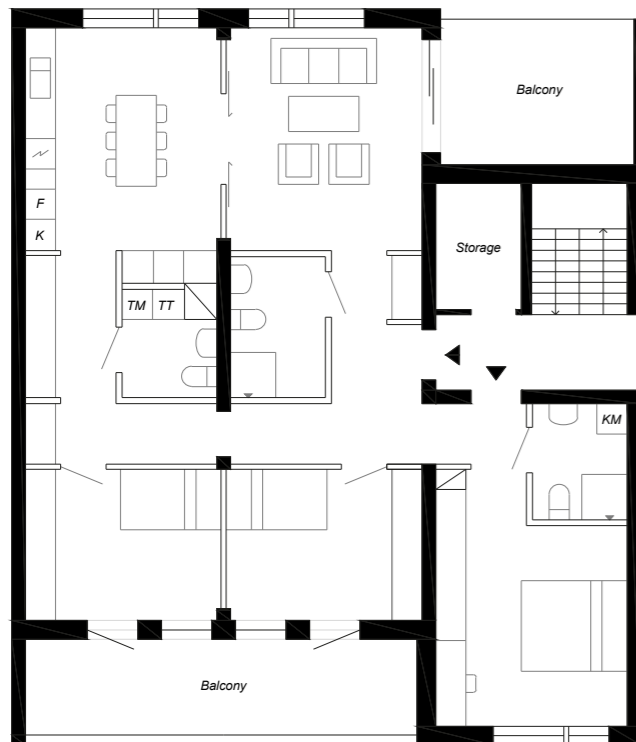


The couple get a child. They move the master bedroom to the elastic space and the child gets the former master bedroom. However, it is made smaller to make room for neutral access to the laundry room and kitchen.



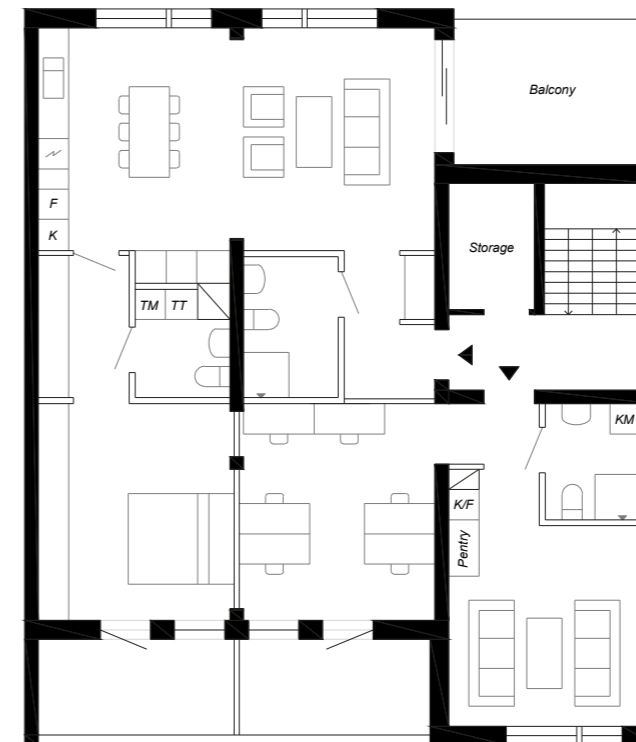
The kids have moved out, but a senior family member is in need of support, so the couple reorganize the elastic space to keep him close. When domestic health service come visit the senior, they can use the separate entrance directly from the stairwell.

The neighboring room is turned into a secondary living room which works as a shared space, while the main living room by the kitchen is more private to the couple.



The household grows with another child, and the living room is remade to another bedroom.

In turn, the kitchen island is removed in place for a kitchen table and the living room moved back next to the kitchen.



The senior relative has moved out, and the couple don't need much space at this point, but want to keep living here. 40 m<sup>2</sup> of the apartment including the elastic space is turned into an office with up to 6 workspaces and a room for breaks and simple lunches.

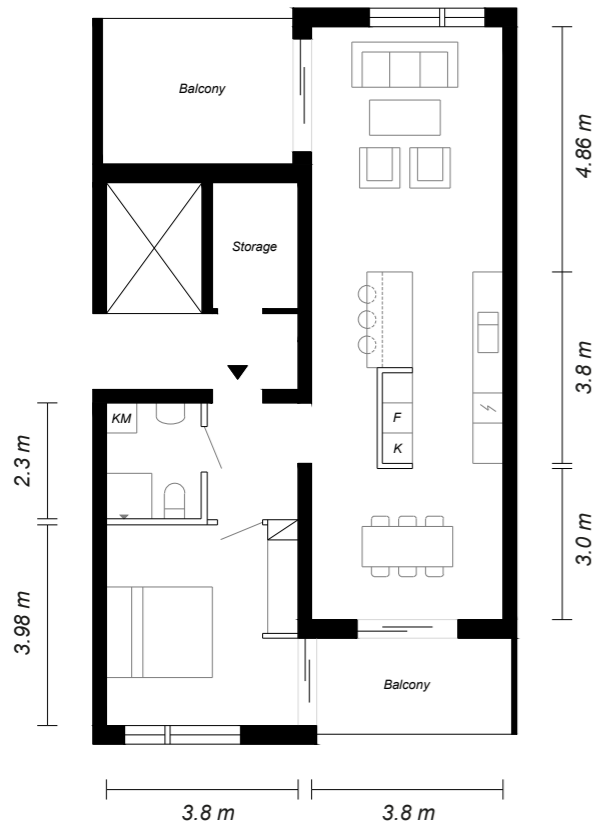
## 4 | DESIGN PROPOSAL

*Interior perspectives*



## 4 | DESIGN PROPOSAL

### Apartment B



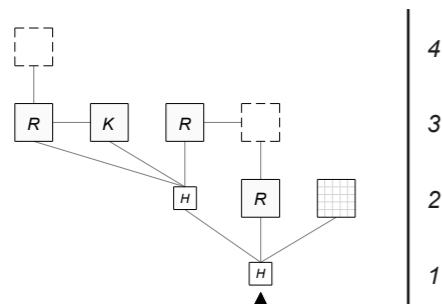
#### Apartment B

2 rooms + kitchen | 69 m<sup>2</sup>  
or  
3 rooms + kitchen | 69 m<sup>2</sup>

Balcony access directly from both bedroom and kitchen, unlocking a 5-space route of circulation.

Integrated balcony outside the stairwell space, providing more light and views in another direction.

Orientation of kitchen allowing light to come through from both directions.



Space syntax: 4 level system of spatial configuration. However, there is only a balcony on the fourth level, leaving all rooms within 3 steps from the entrance.

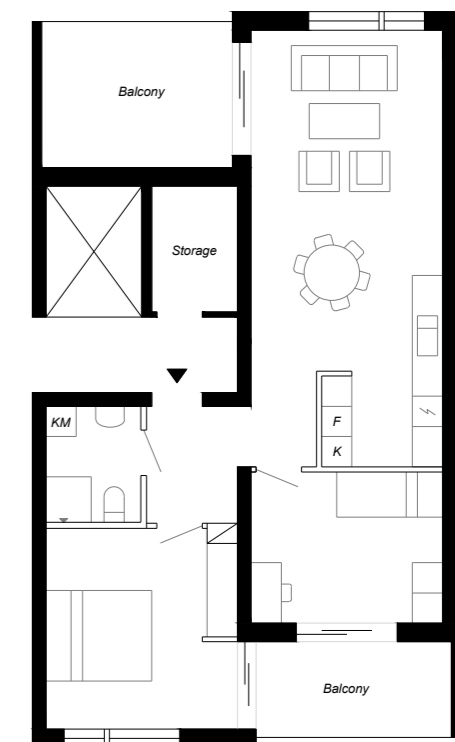
Note; when moving from the second hall towards the living room, the border to the kitchen are somewhat blurred in this open plan. Since the movement occur along the module wall, it is not considered moving through the kitchen to reach the living room in this particular case.

#### Adaptability

As square meters go down, so do the possibilities for adaptable design strategies. Also, when using only one module for the main part of this apartment, you get only 3.8 m of facade to work with on either side. To leave some level of adaptability, a kitchen interior which does not occupy any facade space is a logical solution. The plan below shows how this setup allows flexible walls to create another bedroom, resulting in a 3 room and kitchen apartment of 69 m<sup>2</sup>. Although with the effect of a darker kitchen, which also would not meet the standards in Swedish building regulations (BBR) regarding separable kitchen and daylight.

In terms of generality, the master bedroom and the living room are interchangeable, but would have to be executed with the original plan seen on the previous page. Or the kitchen would be left without any window connection.

However, replacing the balcony by the living room with another room results in a 3 room + kitchen apartment of 81 m<sup>2</sup>, which could be considered rather space efficient and more in line with contemporary practice for that amount of rooms. This is something that could be explored in further iterations.



# 5

## DISCUSSION

## 5 | DISCUSSION

One purpose of this thesis was to investigate the potential of the adaptable design strategies, put in a contemporary context, highlighting what it can do to help meeting needs and demands of today. In a vacuum, there is no question that adaptability is a highly sustainable concept. Capable of responding to changes in needs of a specific household, but also how it can accommodate different types of households, as well as to some extent be resilient to what an unknown future might bring. But the fact is there, that design strategies for adaptability do entail a certain inefficiency in use of space. For example a general room, able to function as both a master bedroom and a living room, often leads to a slightly overdimensioned master bedroom, at least compared to contemporary practice. A spatial configuration of neutral access points, instead of using rooms such as kitchen and living room as a hub for movement through the dwelling, also eats up extra space. With each square meter directly connected to a cost, there is an economic reality which hinders these design strategies to an extent.

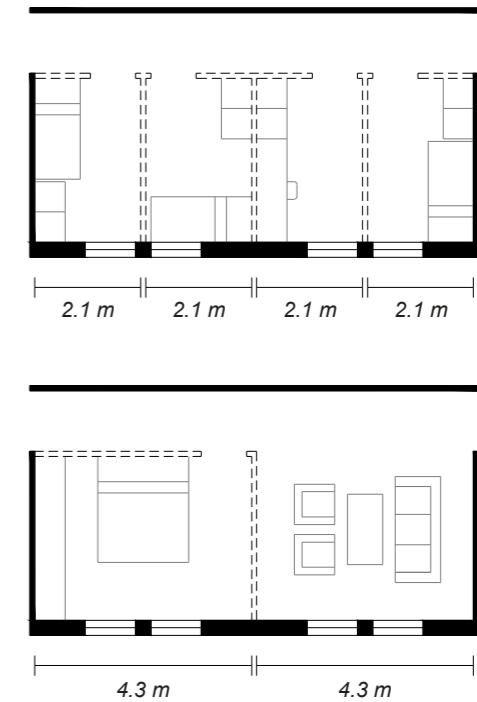
Therefore, the construction method of prefabricated, standardized modules with all its inbuilt cost- and energy efficiency is a highly interesting pairing. Could this efficiency in construction be what helps adaptable design strategies overcome its main weakness - that it demands space - thus leading to better possibilities of implementation of these adaptable strategies on a broader scale? Here lies the second overall purpose of this thesis, to investigate this merge.

Other than potentially the limitation of module interior width of 3.8 m in this particular construction system, which is slightly limiting the furnishability in some cases, the thesis did not point to any significant limiting factors in realising the design strategies for adaptability. In that sense, there is arguably more to investigate in terms of overall aesthetics of a modular system, what the construction entails visually. The thesis touched on this subject through a couple examples in exterior facade seams and interior beams and pillars. This topic of rationality and efficiency balanced with aesthetics is a subject to investigate further, since if modular construction is to be implemented on a broader scale, at least in terms of architectural qualities it likely needs to fit more seamlessly into a range of contexts and surroundings. Without much trace that it is actually a prefabricated, standardized system being used.

Both adaptability and modularity share the task of convincing stakeholders of their potential versus their drawbacks. Modularity of its cost- and energy efficiency in relation to aesthetics. Adaptability of the longterm benefits and resilience in relation to its relative space inefficiency.

Comparing apartment A and B of the design proposal serves as an illustrating example of how strategies for adaptability demands space. Especially space along a facade, if different sizes of rooms should be able to be shaped by flexible walls, for instance.

In regards to this, there is clear logic in finding size relations between rooms by looking at multiples. Say the smallest type room (could be small bedroom or home office) demands just above 2 meters width, to be able to place the bed also along the facade, and for the office to have a 0.6-0.8 m desk and then 1.2 m space for maneuverability. If working with flexible, removable walls, two of these rooms side by side could then be turned into the next size room, which is double in width; around 4 meters. As discussed in this thesis, this is a reasonable approximate size of a general room that could hold either a living room, a master bedroom, a shared bedroom or a dining room.



*Flexibility with traces of modularity.*

The design proposal of this thesis was limited by the maximum dimensions of the module width, hence could not utilize this concept fully. Instead, a total of 7.87 m interior width over two modules was altered between two rooms of ~3.8 m or three rooms of ~2.6 m in average. 7.87 m being just below a reasonable width to work with in a possible split of four rooms; 7.87 minus 0.3 of flexible walls means  $7.57 / 4 = 1.89$  m wide rooms.

Certainly, the fields of adaptability and modular construction share a kinship in terms of this modular thinking of multiples showing to be a plausible method for adaptable strategies. Modules with the sizes of suitable multiples with adaptable strategies as starting point instead? That is an angle to this merge of adaptability and modularity worthy of further exploration.

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### Figures

Figures 2-4) Svensk Standard SS 91 42 21:2006

Figures 11-17, 22, 24-25, 28-30) © Derome AB

All other figures are produced by the author.

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*Resilient Modules*

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*Master's thesis 2023*

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