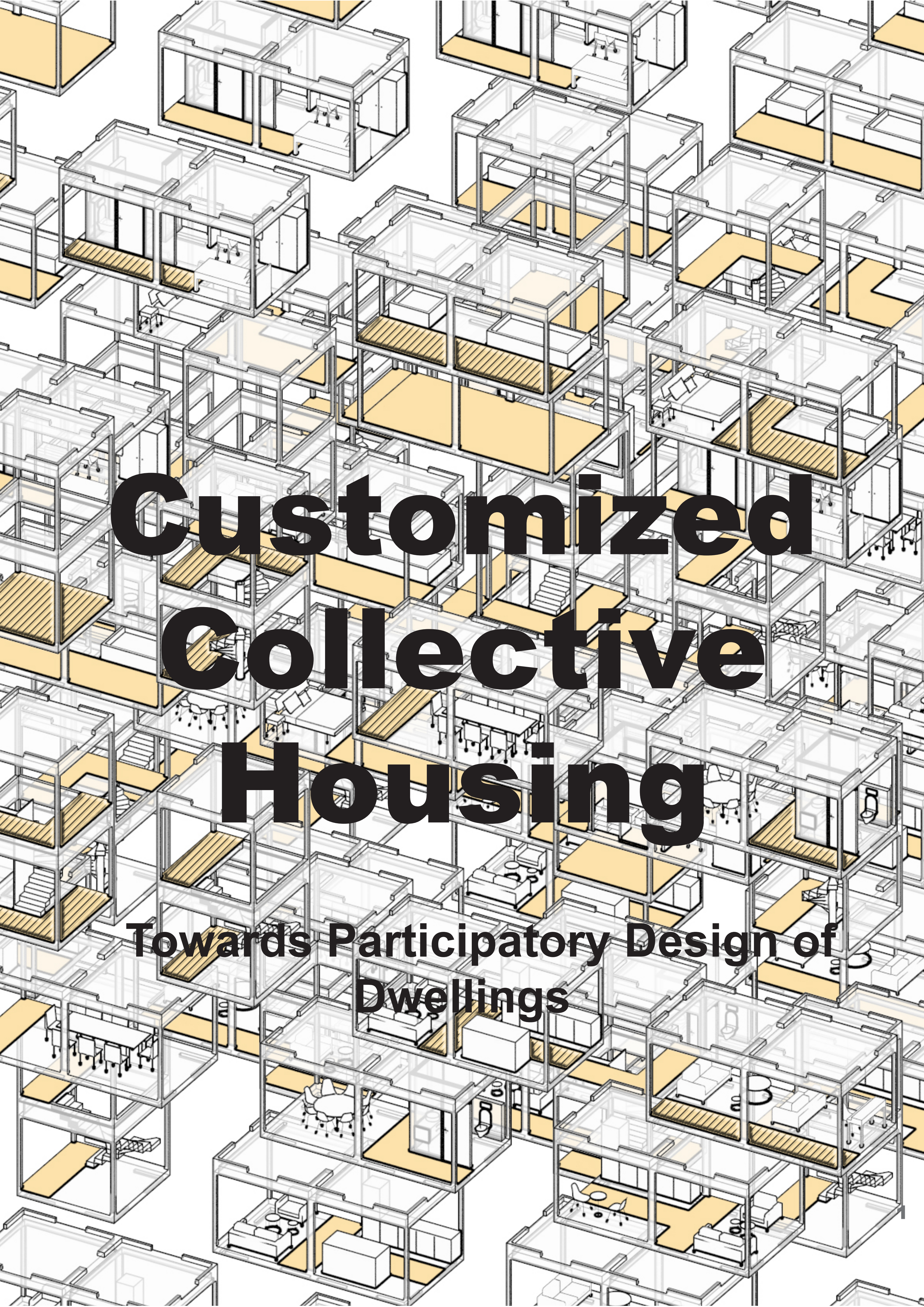

Customized Collective Housing

Towards Participatory Design of Dwellings

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Firstly, a big thank you to my mentors for their support, knowledge and care that the final product is of high quality. For accepting my weaknesses, understanding and helping me in the moments of breakdown when there was no end in sign. Roel, thank you for essential design advice. Pirouz, thank you for providing me with all the knowlage and support. Pierre, thank you for all the meetings without which the building would be unbuildable.

Special thanks to the love of my life for the mental support throughout a very difficult emotional time. For taking over household duties at times when I was too busy with work...

Many thanks to my friends. especially Michał Ruman for his contribution and help both mental and technical.

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Abstract Residents typically have a negligible impact on their living units spatial layout in mass housing projects. Building industry lacks tools for users to create space tailored to their needs. The purpose of this work is facilitate co-creation by providing a pre-configured and engineered set of spatial units corresponding to human activities, in order to lower the technical threshold for participation in the design process. This set provides an accessible search space for modular solutions allowing for free aggregation of space by people without an architectural background. The methodological approach used in this work was Design Science Research.

Content

INTRODUCTION

Context The location of a residential unit is often mentioned as the most critical factor when choosing a place to live. The decreasing variety of apartment plans of newly built blocks results in the inability to choose a flat suited to users preferences. Currently, investing entities create mass dwelling based on a clear principle: they want to make it efficient and as profitable as possible. This process results in progressing simplification of buildings structure, although modern families structures become more divers. For example the standard two parents, two children family become much less common. [1]

The complexity of creating space in the mass housing context is a challenge even for experienced architects. Therefore, a particularly tricky and interesting issue seems to be to involve users without any preparation in the process of creating a residential housing estate. As well as enable residents to make well-informed decisions on their own. An additional difficulty is a collective creation, which requires a kind of universal language.
The purpose of this work is to search for alternative solutions. To search for a way based on a system of modular components giving users the freedom to configure the spatial layout of an apartment independently, to seek appropriate solutions on their own.

Societal relevance Choosing a flat is arguably one of the most challenging decisions in human life. It is associated with enormous costs, frequently linked to a loan taken out for years. Involvement of users in the process of creating collective housing gives the possibility to create an inclusive housing environment. Creating an environment in which the end-user is positioned in the first place. For this reason, this topic seems to have significant social relevance.

Scientific Relevance Recently, projects of digital platforms such as Modrule [2] or Barcode [3] has been developed. The primary objective of those platforms is to support user participation in the process of residential housing design. They are based on the collection of information in order to generate the most appropriate layout tailored to the needs of individuals.
However, not much has been done to provide users with tools to help residents to create their spatial compositions in large scale projects. This research aims to equip the Open Building Concept with a tool to support its implementation and build a bridge between modularity and customisation in the context of the building environment and mass housing projects.

R E S E A R C H

How to structure a module in order to allow users to freely structure the spatial layout of dwellings in the context of mass housing?

Research Objective Five main aspects were addressed, to formulate an appropriate method. Firstly, users must understand the logic behind the module structure. So the research aim was to determine the elementary function of modules. Secondly, the construct of an interface between the modules needs to be set. The key is to limit the number of elements providing many configuration possibilities. Thirdly, it is necessary to set standards to universal dimensional systems suitable for the representation of residential architecture. Fourthly, a system of rules is needed to enable users to work collaboratively and to ensure that the objectives created by the architect are realised At the end, users must receive appropriate feedback on the quality of the created configurations.

Research Methodology The methodological approach adopted for the development of the framework was design science research. It is a relatively new approach to research which aims at defining innovative concepts and creating a new reality instead of explaining the existing reality or trying to make sense of it. Design science research looks to develop valid and reliable knowledge and utilises gained knowledge to solve problems, create changes or improve existing solutions. This type of research involves the construction of a method for solving a domain problem, which must be evaluated by value or utility criteria. This type of approach has its roots in the field of IT systems development. Despite this, many authors, such as Voordijk, find it widely applicable to create concepts for solving problems in the Building Environment.

Proposed Methodology This thesis explores the characteristics of the modules and checks their validity in the context of the functions found in residential buildings. For the evaluation of modules with different characteristics, an evaluation based on relevant criteria must be developed. Modularity, based on a spatial perspective, has not been extensively investigated in the context of residential buildings. Therefore it is difficult to find relevant criteria in the literature.

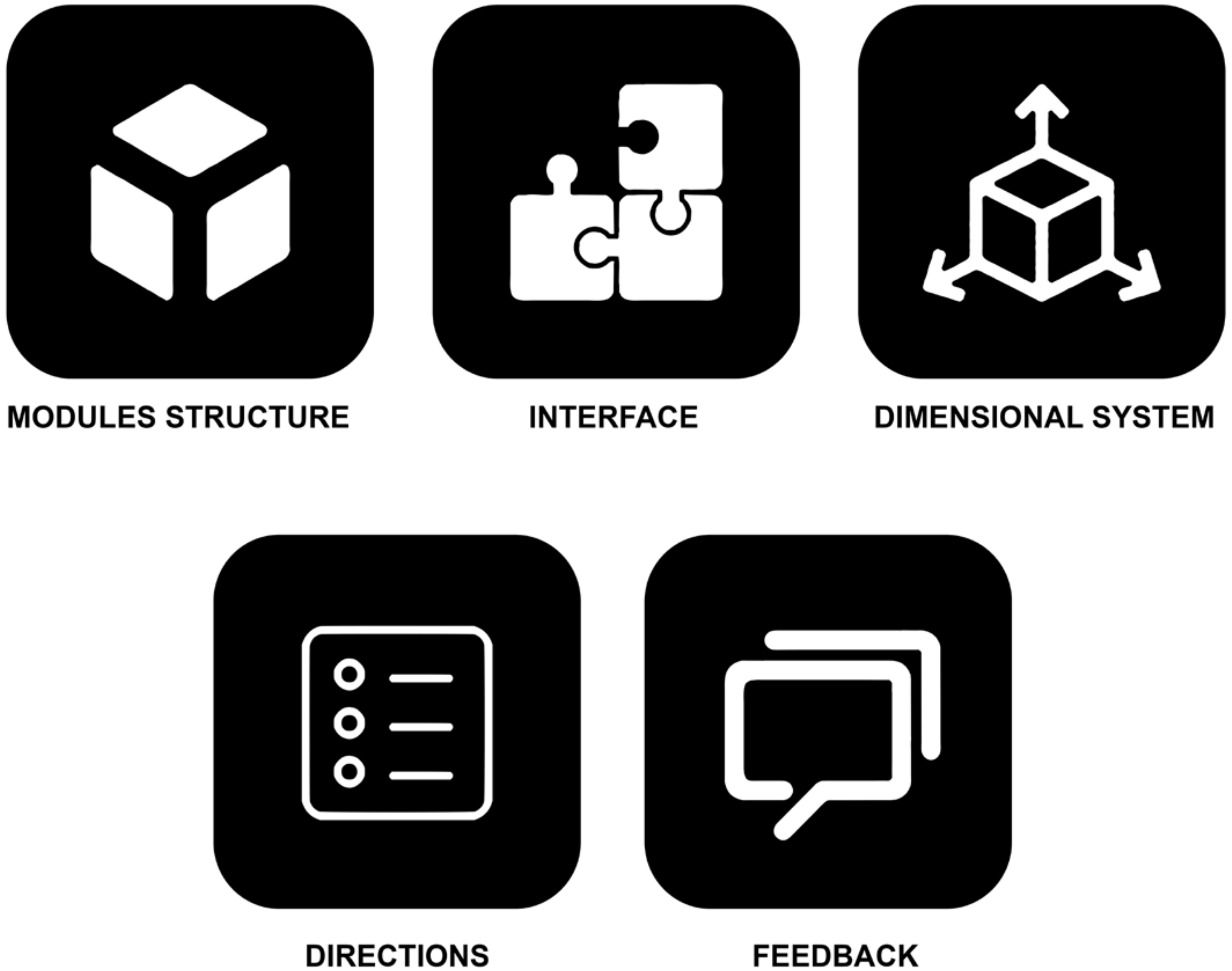
The proposed methodology includes the utilisation of product modularity as a framework for a system capable of providing the user with the possibility to create spatial layouts of apartments independently. The analysis and explanation of the product architecture allow for a deeper understanding of structuring a system to provide it with a potential of application in the building industry.

This work presents the concept for development of residential buildings, which uses the division into subsystems providing a framework for allocation of responsibilities between different stakeholders to enable users to participate in the process.

This research adopts the concept of activity included in the work of Mary, Simeon and John [9] and utilises it to determine the primary function of the modules. Also, the paper presents the concept of categorisation of functions for primary (activities) and secondary (movement, accessibility) used respectively to determine the purpose of the module as a mean for the interface creation. The classification of accessibility in a residential building was presented as a basis for spatial layouts creation. The gamification was utilised to create simple rules of system functionality. The system adopts the principle in which the creation of apartment layouts is to become as simple as laying the Lego.
The proposed methodology is based on a system of dimensions created on the basis of a 3-dimensional grid allowing for coordination of work during the design process. Horizontal dimensions of the grid were established by analysing the way a person moves in space and determined on the basis of the minimum space needed to move within the building. Vertical dimensions were determined from the dependencies related to diagonal movement and associated with the staircases.
Furthermore, an analysis of the existing systems of proportions and relationships between dimensions defining the individual essential building elements emphasising the way a person moves in space is used to propose an alternative system of dimensions on which the modules could be based.

Problem Statement The design process should be inclusive in the sense of participation of users in the decision-making process. So that mass dwellings structures become more diverse and fulfil users requirements. Unfortunately, residents do not have a significant influence on the spatial layout of their living space. This research aims to create tools which, when applied, will give the user a real chance to influence the layout of the living space.

Research Scope and Delimitations The collective creation of space is a complex issue related to many factors, such as the division of responsibility, financing, ownership, or methods of communication. This article presents only the proposed method to be part of a more comprehensive system dedicated to the participatory creation of residential buildings.



1. Which elementary function should determine modularity in the context of users' understanding of space?

2. How to structure the interface between the modules to get a system consisting of a minimum number of modules with many configuration possibilities?

3. How to create a dimensional system to achieve modular system integrity?

LITERATURE REVIEW

Open Building Concept The concept, which gained some popularity among the architectural community, and which addresses the problems of users' participation in the process of building fabric formation is the Open building Concept created by Hebraken. The concept is based on the idea of organising the design process on the basis of environmental levels. The idea of environment levels has its history, but its formulation is entirely new, formed in The Structure of The Ordinary: Form and Control in the Built Environment. [10]

Each level has a specific relationship in which higher - support level contains and limits lower - infill level, while in return, the lower level sets the requirements for the higher level. [11] For example, an urban street pattern, perhaps centuries old, defines plots of land on which individual buildings are constructed, demolished and new ones built over some time during which the street grid remains stable. [12] The distinction between levels was bound to levels of decision making. Each level was a subject to a different decision-making body.

The formalisation of the concept has led to the development of systems that aim to adapt building elements to the required modularity to create a more compatible building environment. Attempts to coordinate positional and dimensional elements have led to the creation of modular coordination system. The modular coordination system is the process of organising the dimensions which can be applied to any type of building. [13] The grid was based on the basic module of 10 cm and the 'tartan-grid' of 10-20 cm, and its introduction made it possible to cooperate between suppliers with the division of responsibility for a given environmental level into individual sectors. [11]

The changes taking place in the building industry caused a change in thinking about modularity in architecture. Systems started to develop in terms of compatibility of connections between individual elements. An example of systems developed in 1988 was Total Roof in which a fixed frame was complemented by elements of equipment such as windows, roof bays or chimneys. The system worked in a similar way to Lego bricks. The components could be freely combined and reconfigured based on users' preferences. [11]

Open building concept provides a methodology framework based on its assumptions. There has been a development of technology addressing the subject of modularity of the building tissue. However, not much has been done to provide users with tools to help them implement the concept in large scale projects. To help residents to create their spatial compositions.

Providing residents with the possibility of filling the space without equipping them with a set of appropriate tools forces the need for cooperation between the architect and the user. Undoubtedly, it has many advantages for users, such as the possibility of consulting their ideas with an experienced person. However, it is not time efficient and results in an extension of the design process. Therefor courses significant difficulties in the implementation of participatory solutions in complex, large-scale buildings.

Product Architecture Product architecture is relevant because its analysis may allow understanding on what basis to create elements to make their configuration understandable for the user. According to Urlich [14], the architecture of the product is the scheme by which the function of the product is mapped onto physical components. He defines product architecture as three different elements: the arrangement of functional elements, the mapping from functional elements to physical components and the specification of the interfaces between interacting physical components.

The functional elements determine the purpose of the product. Physical elements are created to perform a given function.[15] Depending on the scale of abstract analysis, we can define a particular hierarchy of levels. [16] [17] In the most general level, a functional structure can be one functional element provided by the whole product and, for a more detailed assessment, can be divided into many functional elements based on smaller-scale parts. [14] When designing product architecture, it is necessary to define a set and scales of sub-products somewhere in between these extremes to find a solution closest to the customer's expectations. [7] Modules defined by the selected criterion can be combined to perform more complex user-defined functions.

The mapping from functional elements to physical components as the name states consists in determining a set of physical elements belonging to the performance of a given function. The mapping between may be one-to-one, many-to-one, or one-to-many. [14]

The interface specification is responsible for the determination and compatibility of the individual modules. The larger the number of interface types, the less freedom to create configurations. Urlich [14] specifies several types of module architecture. The most desirable type is sectional, where each element has an interface of the same type, and there is no need to have an element that connects all the others.

Formalising apartment requirements from the user perspective Every physical object, regardless of its size or shape, can be presented as volume. In the paper "Formalising building requirements using an Activity/Space Model" [9] created to search for a modelling standard of a product of building, the authors present a reasoning path oriented from activities to their spatial requirements. The paper presents the concept of activity decomposition,

which is the division of complex activities into individual spatial envelopes. Or instead as a simplified approximation of their spatial envelopes by rectangular parallelepipeds. [9] This way of presenting elementary activities together with their relations is a method of describing a given set of activities related to the primary activity and as a result of the distribution of a given space of an object is possible, separated by physical elements or imaginary boundary, into elements assigned to a specific human activity.

Human Dimensions and dimension systems For many centuries, representatives of many scientific and artistic fields have shown interest in the dimensions of the human body. This topic is suitable for this research because many interior dimensions are adapted to the dimensions of the human body. Especially important for this research are the functional dimensions ("dynamic") describing human dimensions measured during the activity.

Attempts to combine ergonomics and architecture through the medium of geometry have been applied in the work of Vitruvius, Alberti and Le Corbusier. [18] It is possible that the depiction of the "Vitruvian Man" by Leonardo da Vinci and Alberti's understanding of harmonic proportions were the inspiration for Le Corbusier to create and propagate a system called "the Modulor". [19]

The basis for creating the Modulor system was to standardise and rationally organise production based on a universal dimensional system and to define the system as having an unlimited number of combinations using the ideal number. After many experiments, Le Corbusier developed a system based on six-foot-tall (1,828m) English male body with one arm upraised. This dimension is transformed on the principle of geometric constructions with golden division creating a sequence of numbers following the logic of the Fibonacci sequence.

The Le Corbusier modulator is a brave attempt to introduce dimensional unification in architecture, but it also proves that there is no limit to such an approach.[18] Einstein commented on the attempt as a will to create "scale of proportions which makes the bad difficult and the good easy". [20]

Despite successful attempts to implement the system in the Unite d' Habitation in plan, interiors and facade detail, it was not widely adopted. Opponents accuse Le Corbusier of basing the system on the imaginary number, lack of cohesion or unawareness of actual human proportions. The Modulor has also been criticised for very impractical values to smaller dimensions and not favouring ease of construction. [19] Nevertheless, his works record the practical and metaphysical problems of this approach and show how difficult it is to combine human shape with geometry and architecture. [18]

EXAMPLES FROM PRACTICE

Architect Influence

Degree of User Creation

Cocreation Possibilities

Degree of Completion Offside

There are several examples from practice relating to users' participation in the design process of residential buildings. In addition to the apparent differences associated with the aesthetical appearance, the way the system is structured defines the flexibility significantly for users to create their own space. Moreover, it determines the nature of the influence and control of the architect and other stakeholders on the final shape of the building. In other words, it defines the responsibility of individuals in the design process. I decided to divide the found examples into several groups. Main factors of my focus during the analysis of specific solutions were the designer's influence on the final effect of the building, the freedom of creation available to users and the possibility of interaction between users. I was also analising the degree of completion offside.

Fig. 1 Visualisation, "Modular affordable housing envisioned for "abandoned" New York airspace", source: www.dezeen.com.

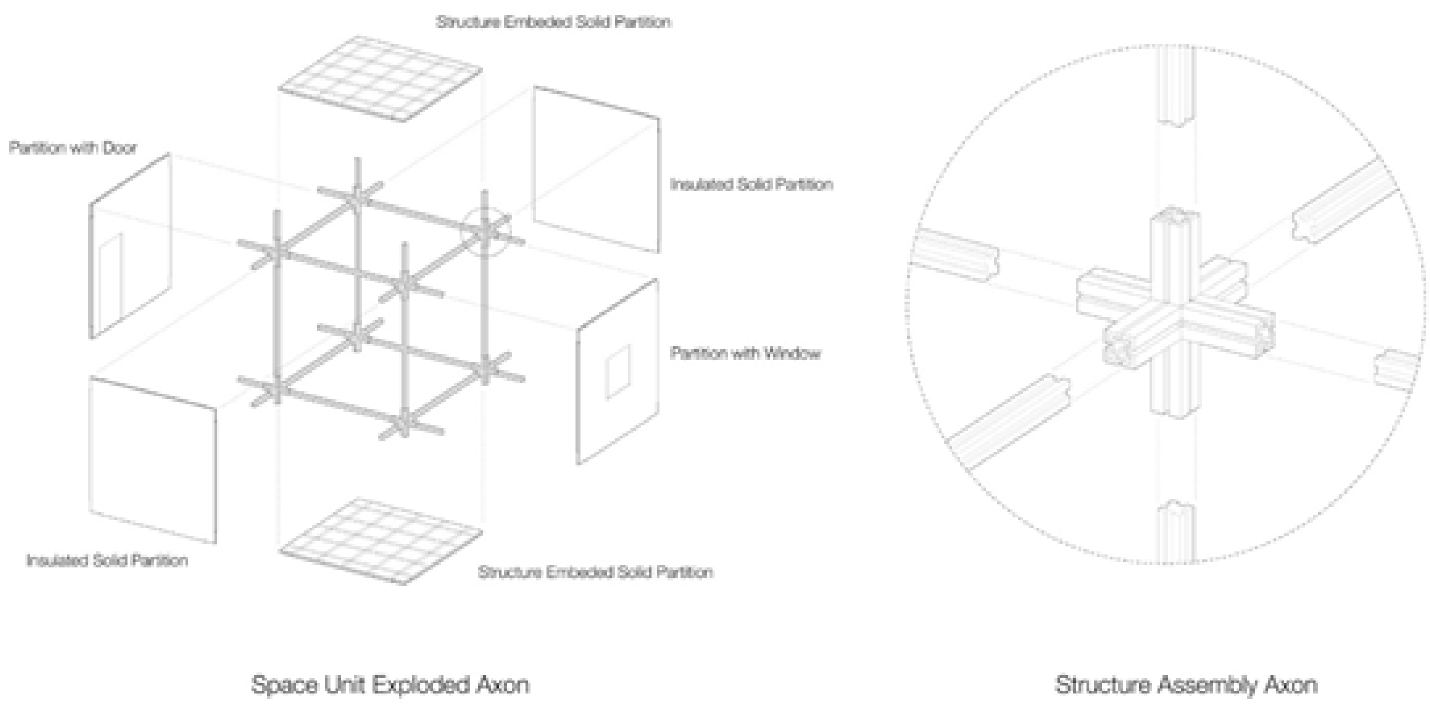


Fig. 2 Diagram of system functioning, "Modular affordable housing envisioned for "abandoned" New York airspace", source: www.dezeen.com.

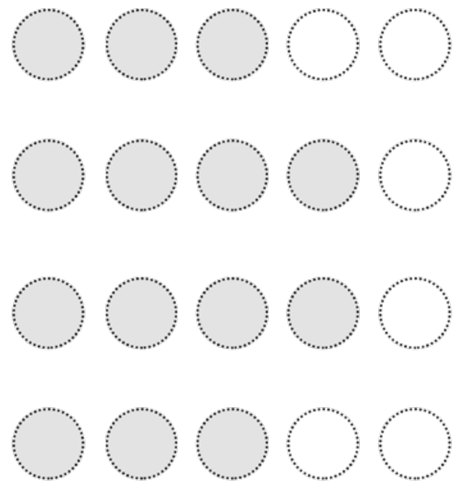
GRID + INFILL

Architect Influence

Degree of User Creation

Cocreation Possibilities

Degree of Completion Offside



The first example of the approach is based on a modular grid assembled from structural components complemented by physical parts of the building's structure, namely horizontal and vertical partitions. The selection of filling elements is based on users' preferences. This system ensures flexibility in shaping the internal space. It also provides control over the final effect by the architect, in the case of which the given object has a controlled outline. An example of such a solution is a project called "Modular affordable housing envisioned for "abandoned" New York airspace" designed by Jenna McKnight.

Fig. 3 Photo by Wladyslaw, Habitat 67, Safdie Architects, source: www.archdaily.com.

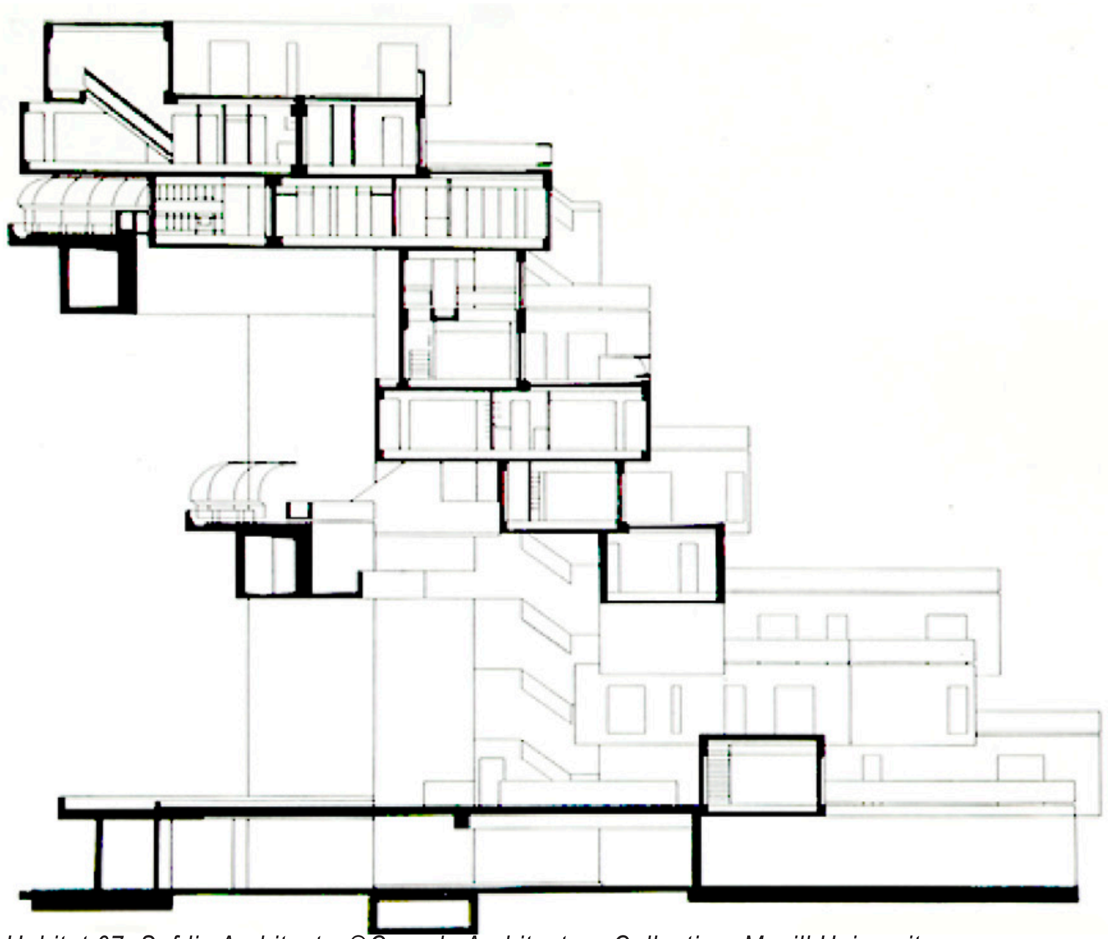


Fig. 4 Section, Habitat 67, Safdie Architects, ©Canada Architecture Collection, Mcgill University, source: www.archdaily.com.

SELF – BEARING UNITS

Architect Influence	●●○○○
Degree of User Creation	●●●○○
Cocreation Possibilities	●●●●○
Degree of Completion Offside	●●●●○

Another example of an approach to user participation is a system in which each of the modular components is an independently functioning load-bearing unit. Thanks to multiplication, it can be the basis for larger arrangements. A project used as an example is Habitat 67 designed and built-in Montreal for Expo 67 by Moshe Safdie.

The concept was not to involve residents in the design process but to provide affordable, modular housing with the essential benefits of suburban houses, namely gardens, fresh ar and multilevel environments. Nevertheless, it is a system that could work well with the participation of residents.

The system is built on two necessary subsystems: housing modules and a system of vertical and horizontal accessibility routes.

Fig. 5 Diagram 1, Superlofts Houthavens, Marc Koehler Architects, 2016, Amsterdam, The Netherlands, source: www.marckoehler.com

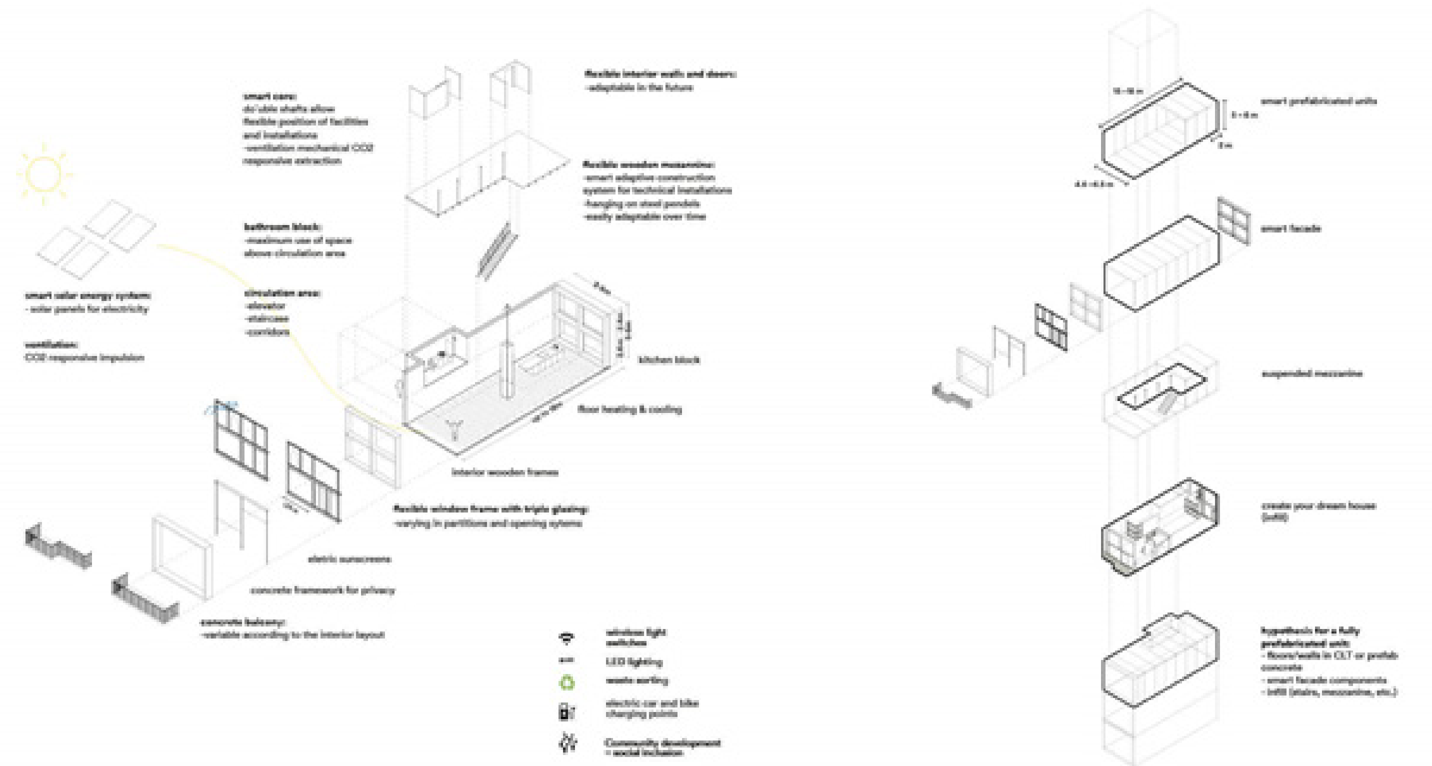


Fig. 6 Diagram 2, Superlofts Houthavens, Marc Koehler Architects, 2016, Amsterdam, The Netherlands, source: www.marckoehler.com

SHELL-LIKE BOXES + INFILL

Architect Influence	●●●●●
Degree of User Creation	●●●○○
Cocreation Possibilities	●○○○○
Degree of Completion Offside	●●●○○

Another way to include the users' preferences in the layout of their apartment is to provide them with space that is, in fact, a freely customisable envelope. It is a relatively simple method used by architects following the Open Building Concept. There are many examples of such a solution. One of the offices using this type of solutions is Marck Koehler Architects.

The method allows the architect to have the same impact and control over the shape and appearance of the building as conventional methods. On the other hand, it limits the possibility of users participation.

Fig. 7 Visualisation, Beyond the Shell, Liana Wu, The Bartlett School of Architecture, source: www.dezeen.com.

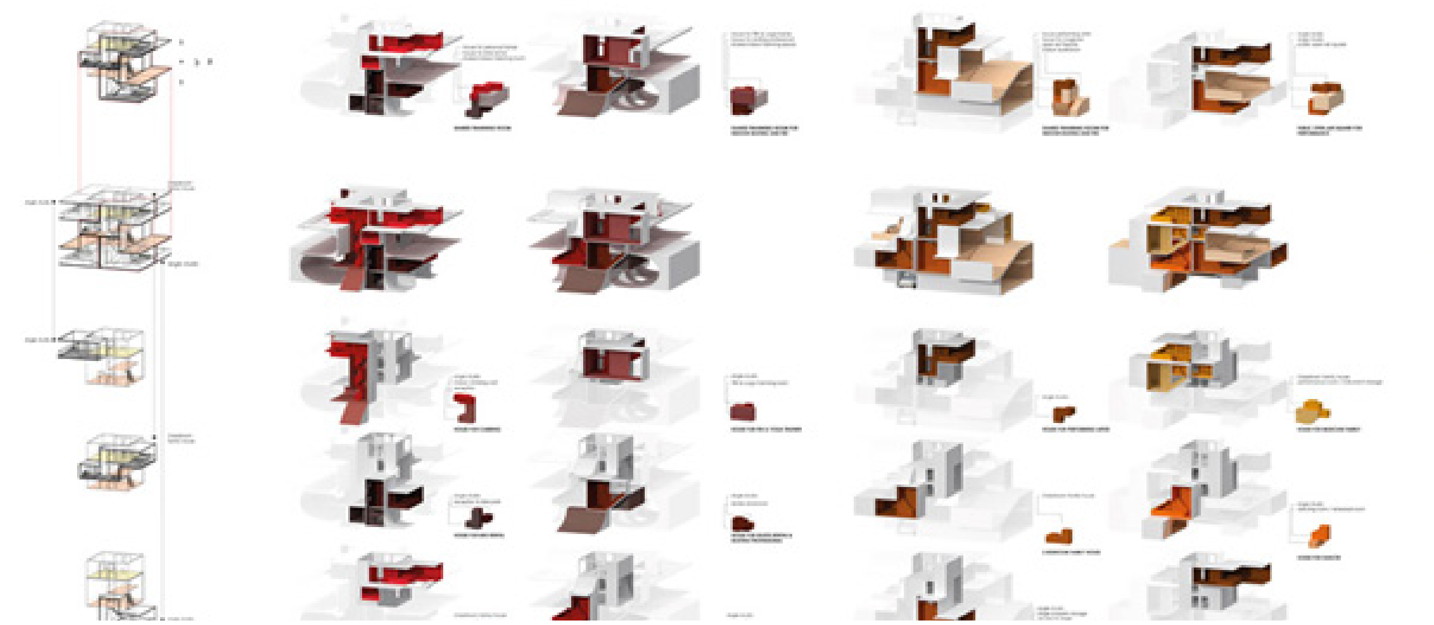


Fig. 8 Diagram, Beyond the Shell, Liana Wu, The Bartlett School of Architecture, source: www.dezeen.com.

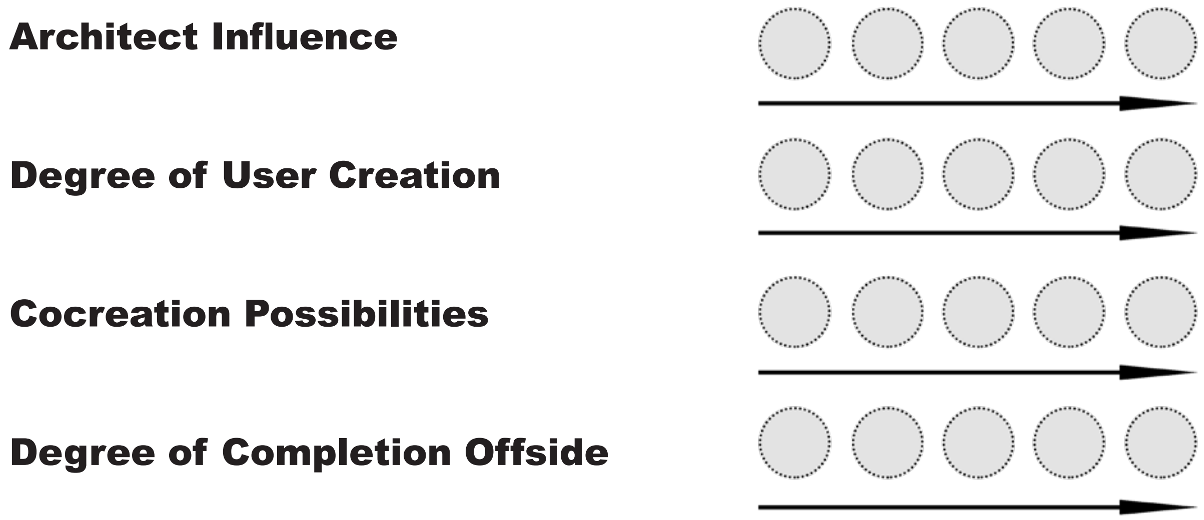
ADD TO CORE

Architect Influence	●●○○○
Degree of User Creation	●●●●●
Cocreation Possibilities	●●●●●
Degree of Completion Offside	●●○○○

The last example is the concept proposed by Liana Wu in a project called Beyond the Shell.

The project is based on a self - build scenario, in which modular components are used to create the possibility for users to configure living units. Components are added to the structural core, which includes stairs and lifts. An essential element of the concept is the desire to create a community through the appropriate use of the system.

Undoubtedly, this system gives the users incredible freedom to create configurations. However, similar to Habitat 67, it provides little control over the result for the architect. Besides, creating functional layouts from structural elements can exceed the ability of people without the appropriate background.



In my work I tried to find a balance between all these factors. Maximize the influence of the users as well as the architect's influence on the end result and create conditions for the cocreation. So as to create an environment for participation while respecting the place where the building is constructed. In addition, I wanted to maximize the degree of completion offside in order to reduce the time needed to complete the building.

PROPOSED CONCEPTUALISATION

A Dimensional System Similarly to the modular coordination system, the proposed concept implements the construction of a 3-dimensional grid that favours the possibility of cooperation between many different stakeholders with different responsibilities. Usually, the building plan is based on a very fine grid, typically 1 x 1 cm or even 0.5 x 0.5 cm, with such a grid the size of the rooms can be varied. Although each of the rooms can be of any size, proportions and shape, in reality, the size of the rooms is limited. Such knowledge can help to limit useless room layouts.[21] Diversity based on a few centimetres difference does not significantly affect the perception of the space and the possibility of its configuration. The functional grid of objects is based on an arbitrary unit usually close to the minimum corridor width.

Subsystems need to be geometrically and spatially coordinated to enable functions to be appropriately carried out. A universal dimensional system and positional control should result in establishing a common language when making decisions at different levels. Therefore, the system requires a division into different scales depending on the level and scope of decision making.

Scale	Level of Decision Making
Macro	Building
Meso	Apartment
Micro	Detail

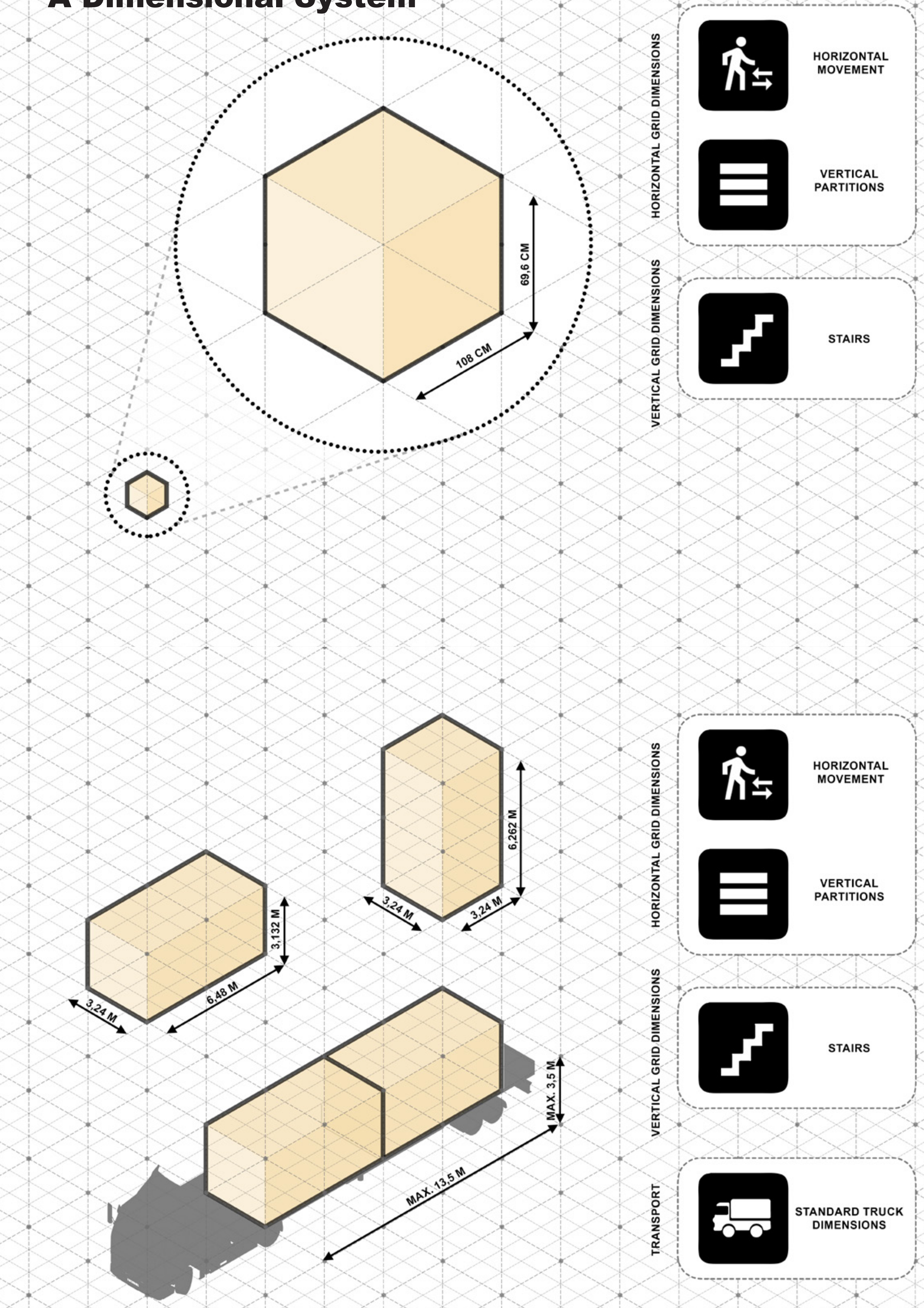
Decisions concerning the whole building are made based on the macro-scale, which is determined by the fundamental parts of each residential building – stairs, corridors and apartments scheme. Decisions related to apartments is made on a mesoscale in which the essential elements are hidden corridors - unmanaged spaces in the apartment used to move around in it. The microscale should be based on finishing. The microscale has not been widely studied in this research.

The size of the three-dimensional grid should be determined in such a way that it can contain elementary characteristic for the scale and the dimensions of the individual system components.

The basic dimensions of the grid are based on the human activities related to diagonal movement, which essentially provides the proper functioning of the building.

Several basic dimensions such as the width of main corridors (min. 120 cm) or corridors hidden inside dwellings (min. 90 cm) should be taken into account to allow unrestricted movement around the building. When creating a functional layout, the most appropriate dimension would be 30 x 30 cm, which takes into account the previously mentioned dimensions.

A Dimensional System



However, such a grid may create layouts which cannot be directly translated into the architectural plan because the dimensions of physical building elements such as vertical partitions are not taken into account. To create a properly functioning system, it is, therefore, necessary to take into account the physical elements of building structures.

Determining the dimensions of the grid requires prior determination of the thickness of vertical and horizontal physical building elements. However, this process usually involves numerous re-iterations and re-considerations before the project is completed. These dimensions are dependent on many factors, such as the load-bearing capacity of the individual elements and the type of material used. Nevertheless, it is possible to estimate maximum values, and additional space obtained could enlarge potential rooms. The system adopted the thickness of the structural layer of the vertical partitions should be maximum 24 cm, while the structural layer of the horizontal partitions should not exceed 20 cm.

Attention should also be paid to a particular division of the horizontal accessibility within the residential building. This article distinguishes three basic types of spaces used for movement:

1. Shared communication – main corridors
2. Hidden corridors
3. Rooms with a movement function

Hidden corridors Corridors used for communication within the apartment. Space included in a part of a room intended for a function other than movement.

Another example of elements that should be taken into account when creating a universal system of dimensions is stairs. Stairs are one of the fundamental modular elements used in the buildings. The height and depth of stair steps should be consistent to avoid the potential risk of tripping over inconsistencies. A regular flight of stairs provides a safety factor. Inconsistencies or variations in risers or treads could interfere with the rhythm of the individual using the stairs.

It is considered that the most appropriate angle of stairs is in the range of 30 to 35 degrees. Using the effective formula 2R+T=60/65 developed by French architect François Blondel, which allows determining the correct dimensions of a comfortable and efficient staircase according to its use we can specify the dimensional range in which the stairs rise, and tread should be located.
(R denotes rise size of the step and T denotes tread of step). The values given have been rounded to the nearest millimetre, the vast majority of construction techniques are not more precise.

For step rise = 30°
tan30°=0,5774=R/T
for 2R+T=60 R=28,0 cm and T=16,2 cm
for 2R+T=65 R=30,4 cm and T=17,5 cm
For step rise = 35°
tan35°=0,7002=R/T
for 2R+T=60 R=25,0 cm and T=17,5 cm
for 2R+T=65 R=27,1 cm and T=19,0 cm

When considering a universal system that can be implemented anywhere, it is necessary to take into account national regulations. The legal regulations regarding the dimensions of stairs and fire protection vary from country to country. Some countries set a maximal step rise depending on the application in particular building types. The mega-scale was determined based on the primary dimension. (multiplication of the height and width of the step, the width of the landing)

Vertical dimensions of the grid have been determined based on dependencies occurring in stair dimensions. The dimension, which is three times the primary dimension (108 cm) was adopted as a dimension that is subject to further transformations. It is the dimension closest to the width of the hidden corridor. By substituting this value to the formulas, a range from 62.5 to 75.6 cm was received. This research defines the primary vertical grid size as 69.6 cm. This value ensures the angle of stairs to be 33° which is considered to be the most comfortable angle. As a result, four and a half times this dimension determines the gross height of the room (313.2 cm). The resulting stairs would have 18 steps with dimensions of 17.4 cm high and 27 cm deep.

The maximum dimensions of modules depends on transport conditions matching the previously presented grid. The final size of modules was adopted to standard truck dimensions so that two modules fit into a standard truck.

The uniform system of dimensions, despite some limitations, provides the possibility to create a system that makes the configuration of space as easy as laying Lego.

Structuring Spatial Layout of Components How space is used has a huge and, in most cases, a fundamental impact on how it is organised. It is impossible to imagine space without specifying the activity performed by a human being. [22] It is common to call rooms based on the activity associated with it, for example, a sleeping room or a bathroom. Therefore, it is reasonable to consider a set of tools supporting the user's space configuration by aggregating modules whose level of a functional structure is based on the activity or the set of activities performed in it.
In the building environment, there is a division into two fundamental functional elements: primary and secondary functions. Primary functions are responsible for activities carried out in space and operate with physical elements such as spatial voids. Secondary functions performed by solid masses are supporting physical elements such as walls, structural elements and roofs. From space configuration by users, it seems appropriate to base components on the primary functions they serve.

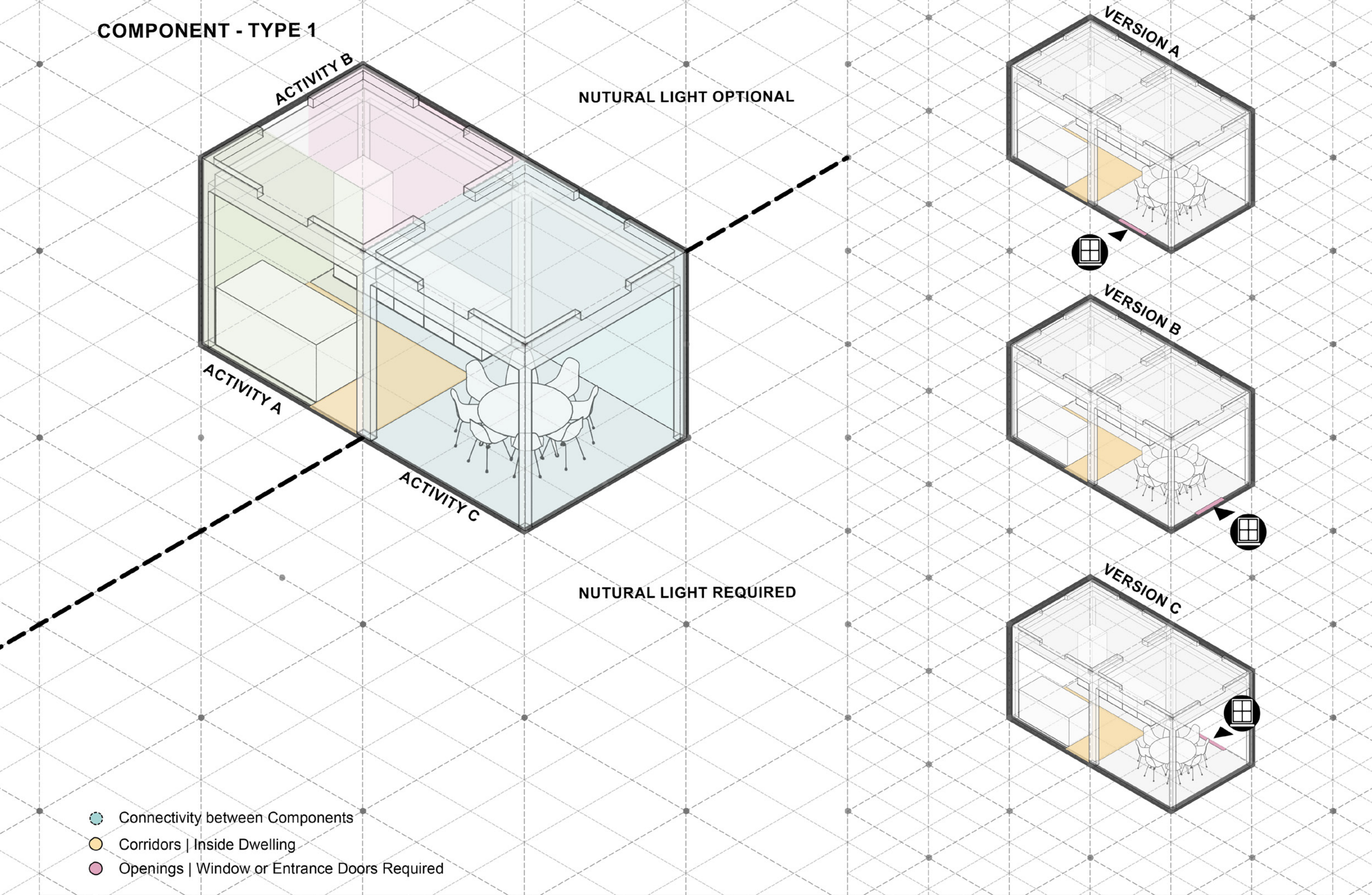
To create components that can be configured by future users, the method assumes the categorisation of primary functions into two subgroups. The main functions resulting from human activity in space and the supporting function focused on the human movement in space and the accessibility within space. The main functions, similarly to the Activity/ Space model, is described based on a spatial envelope containing a combination of all spatially related activity requirements. Human activities are considered as modifiable spatial units. Supporting functions are created as a corridor with a minimum width of 90 cm. The main functions determine how a given module is used, while the side functions are the basis for compatibility between the modules.

The concept investigates the modularity of residential architecture from a spatial perspective. In which each module consists of a wide range of interconnected components. Modules are not considered at the level of specific equipment but the level of interaction between them, such as goods and supplies exchange. This work defines modules as built as separate entities that can function independently.

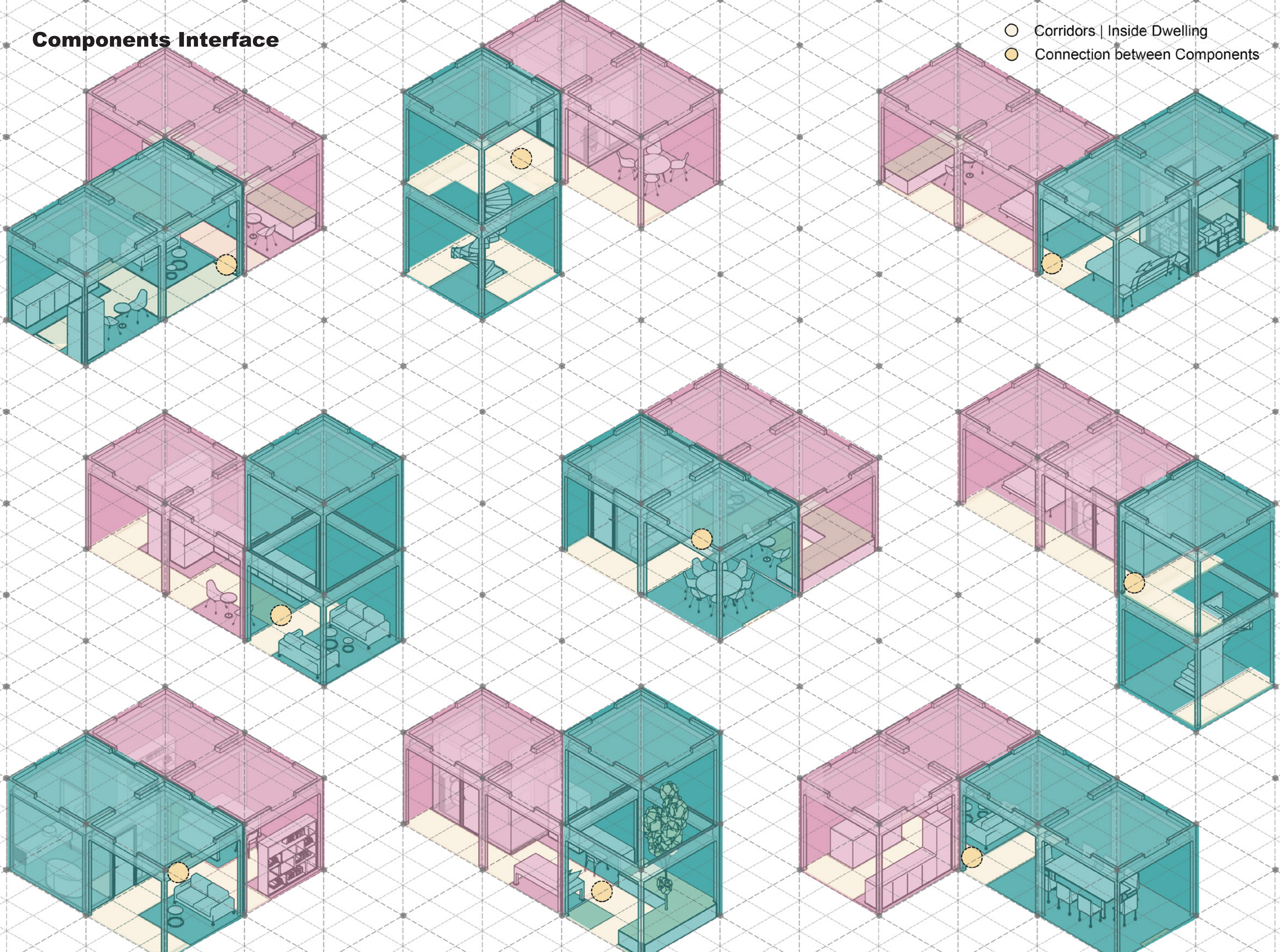
Each module is based on a single activity or aggregation of activities in both cases must be equipped with a support function. The reason for this is the desire to achieve an appropriate level of system complexity and scale of elements tailored to the user capabilities. It is operating on complex activities such as cooking or personal hygiene requiring an appropriate combination with related activities. This process requires precise knowledge, and what is more, it does not have a positive impact on the number of possible compositions obtained by combining the modules. The concept proposes the implementation of ready-made aggregation of activities to obtain modules equipped with pre-designed bathrooms and kitchens.

It is possible to create many hidden corridor layouts, such as I - shape, L - shape, H - shape, O - shape and combined layouts. The more possibilities of connection contain a component, the easier it is to create configurations in which this component is to be used. However, a too large amount of corridor area results in the creation of spatial layouts that use space inefficiently. The solution is to create a group of components based on the same activity or a cluster of multiple activities, which contains components with different corridor sizes and shapes. In a computer-aided system, the user would receive information on how effectively his space is used in the context of the space consumed by corridors. Such information would be encouraging for the user to reconfigure the system or change the components.

Components Structure



Components Interface



Interface Formatting The concept includes module interface based on the ability to move between the modules through the corridors. The idea was taken from the tile-placed multiplayer game Carcassonne. In which each player receives a set of modular puzzles which are arranged to create a board. The puzzles contain four essential landscape elements (city, field, roads and rivers). To add an element, players have to match it with the other ones already arranged so that the landscape elements fit together.

The concept utilises rules of the game. Modules can be connected by matching corridors positions so that the path is continuous.

Openings An important aspect that needs to be taken into account is to provide sufficient daylight, and thus the location of window openings. Users cannot be expected to be able to determine the appropriate window area and its location on their own. It should be taken into account that the room for permanent occupancy should have windows with an area determined according to local regulations. In other rooms (bathroom, closet) the windows are not a requirement but only an option of choice.

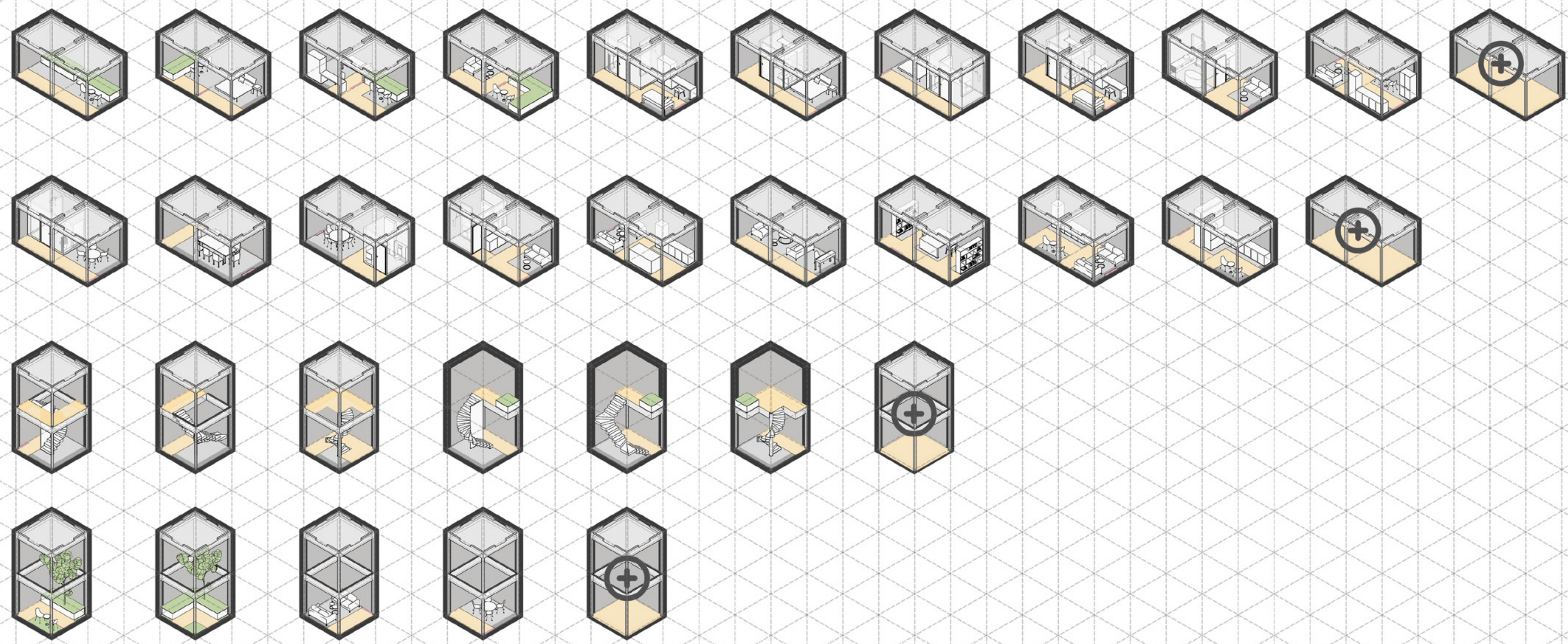
The location of openings often determines the possibilities of spatial arrangement or makes specific arrangements more desirable. An example is the position of a TV or monitor to the window. Thus, the system presupposes that each of the components has a specified location and the minimum area of windows. The information is indicated in the outline of the component. Components cannot be placed next to each other if the openings are adjacent to the wall of another component. In practice, a single spatial arrangement could form the basis for multiple components with different window positions.

Another aspect is that some functional parts requiring natural lighting (dining or cooking) can be indirectly illuminated by others adjacent to them (leisure - living room). There is, therefore, a need to create components with no windows, which would receive an additional requirement for indirect illumination. Another solution is to create systems as clusters of many activities.

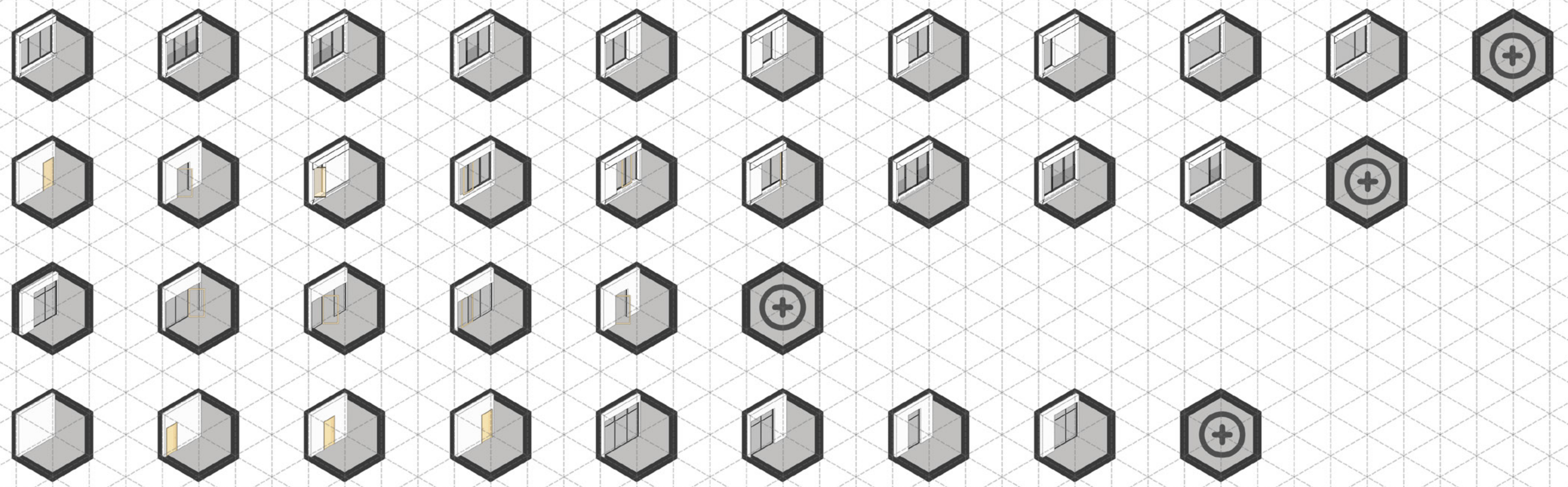
The orientation of windows and the type of activities performed in a given space is also a vital issue. In the computer-aided system, to enable users to make informed decisions, an indicator would be introduced to determine the quality of proposed layouts in the context of room orientation.

Components The system would consist of an unlimited number of components. It could be enlarged in case the user wants to use a custom layout. A considerable number of components is associated with an apparent difficulty in the configuration of layouts by users. However, in a computer-aided system, it would be possible to create a set of filters to assist users in their choice and to give proposals depending on their layout. Here are examples of possible components. Components are based on a 108 x 108 cm grid. It is possible to create many versions by changing the location of the windows.

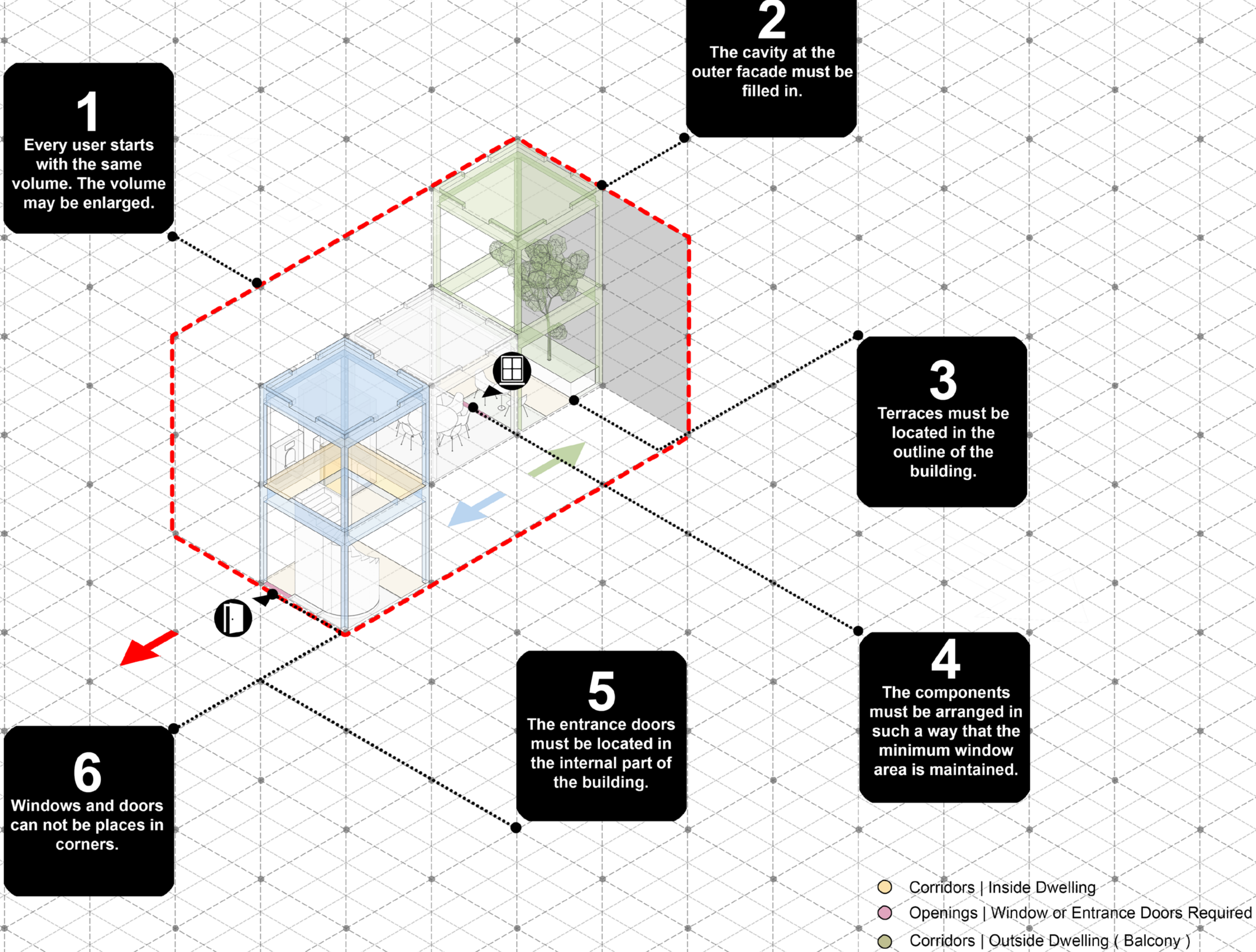
Parts Catologue



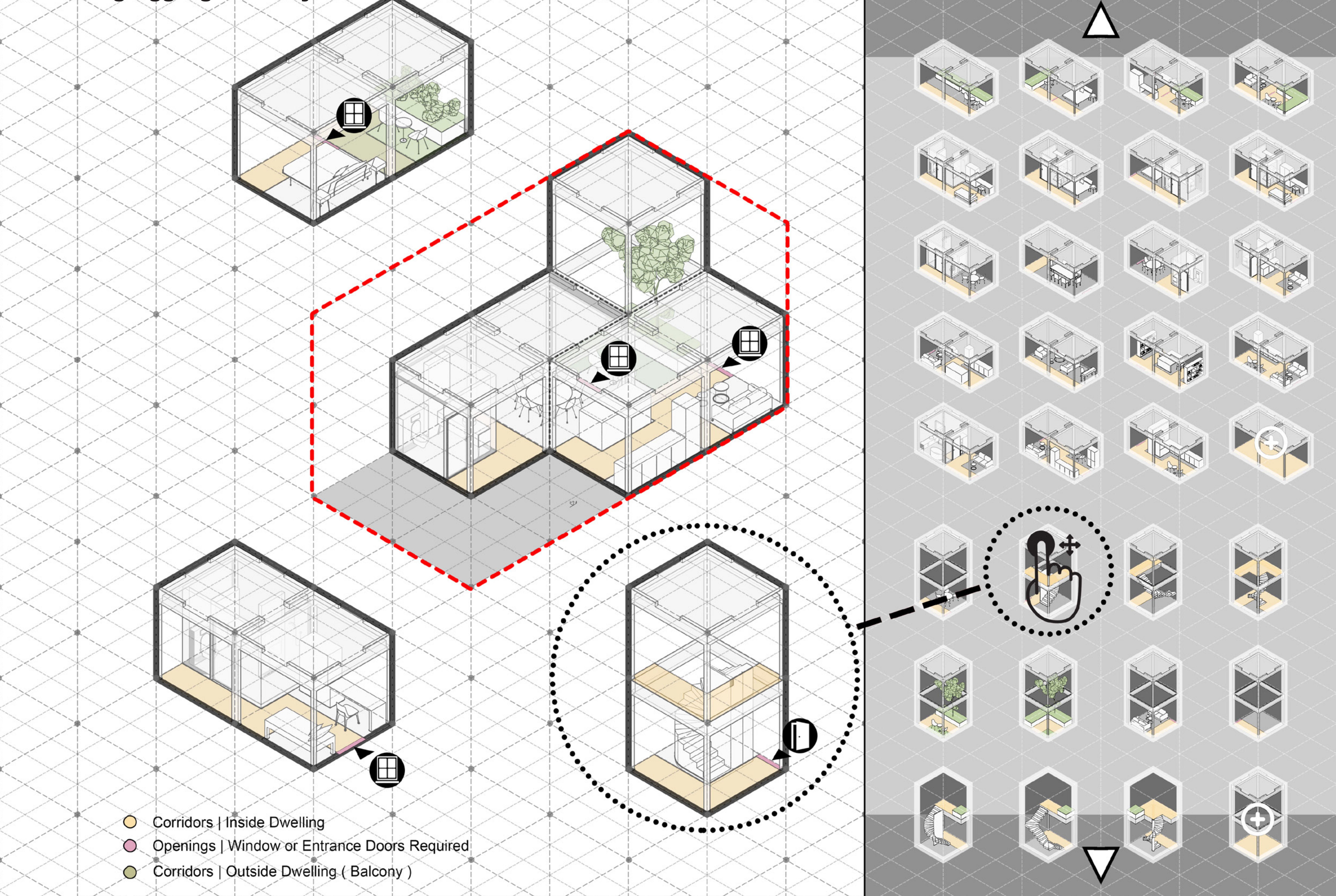
Partitions Catologue



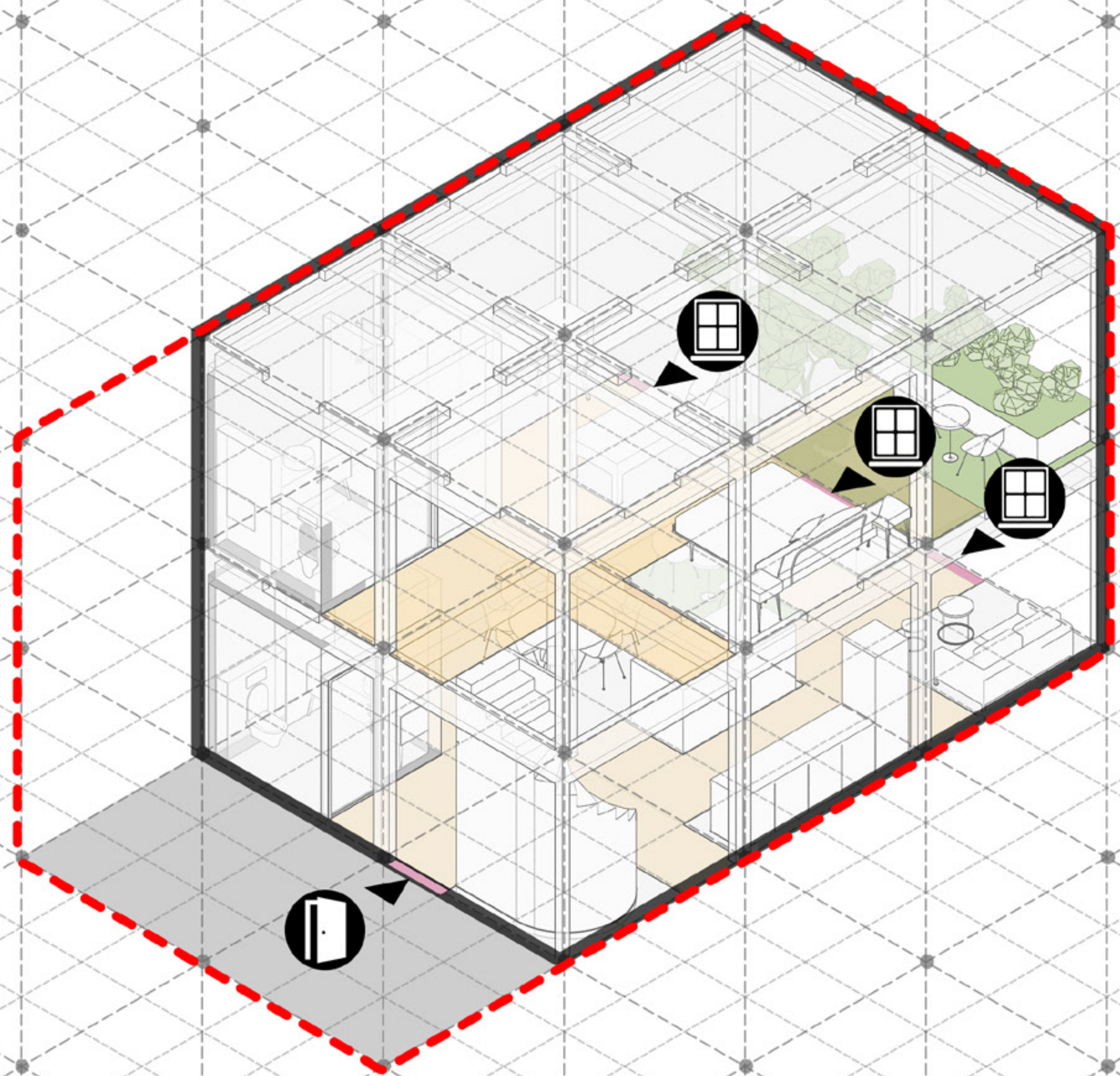
Rules for Apartments Aggregation

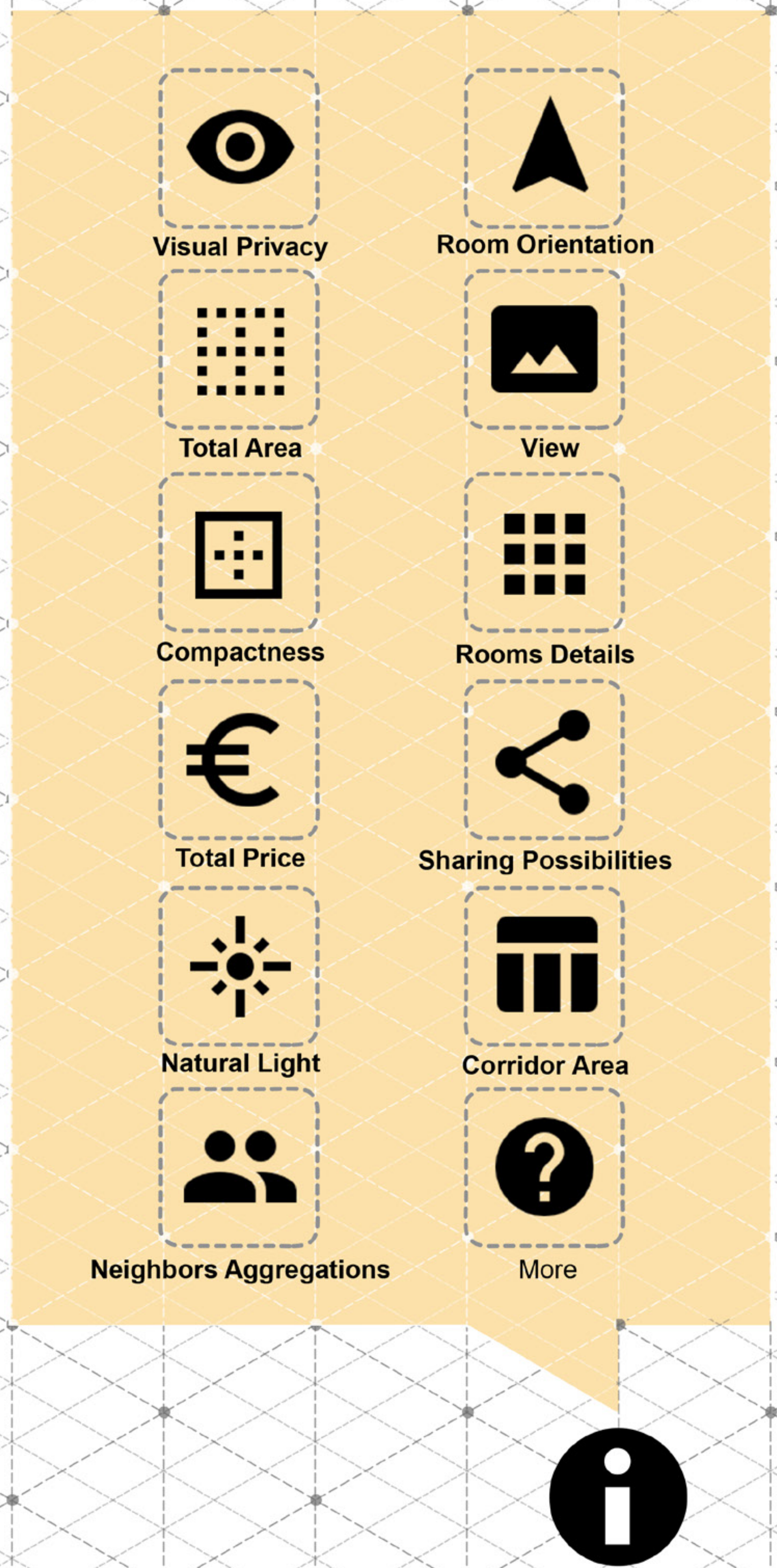


Creating Aggregations by Future Inhabitants



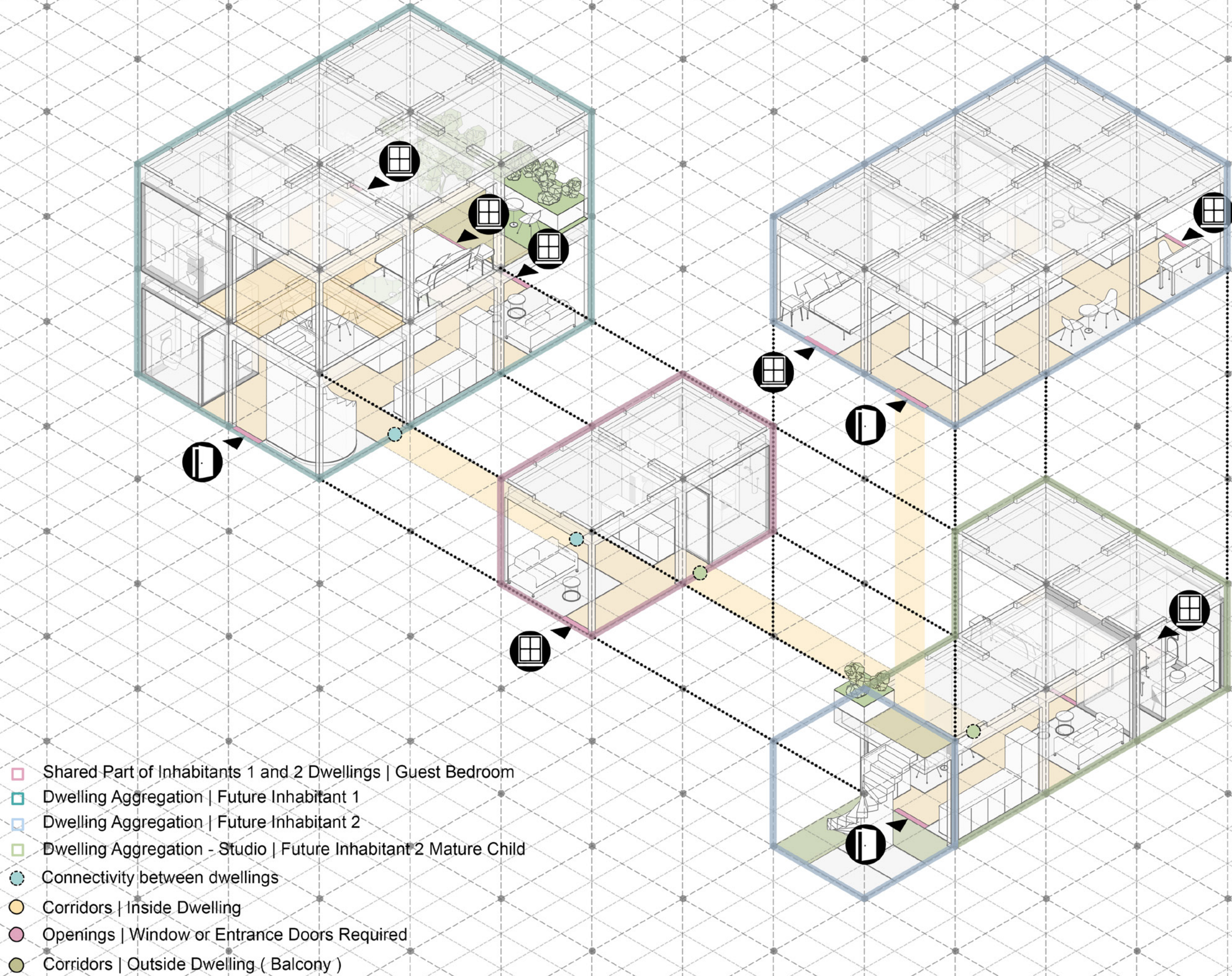
Getting Feedback



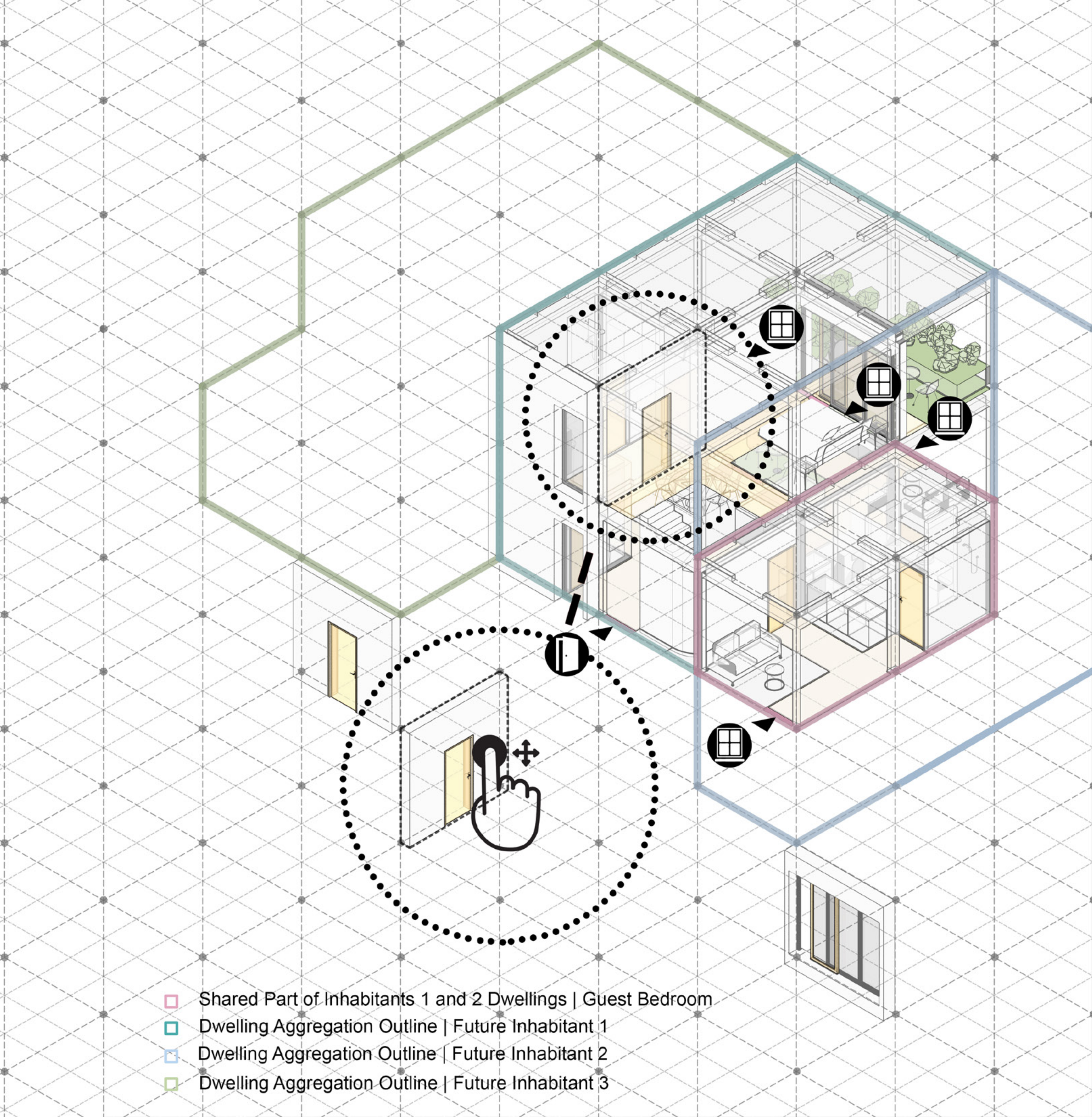


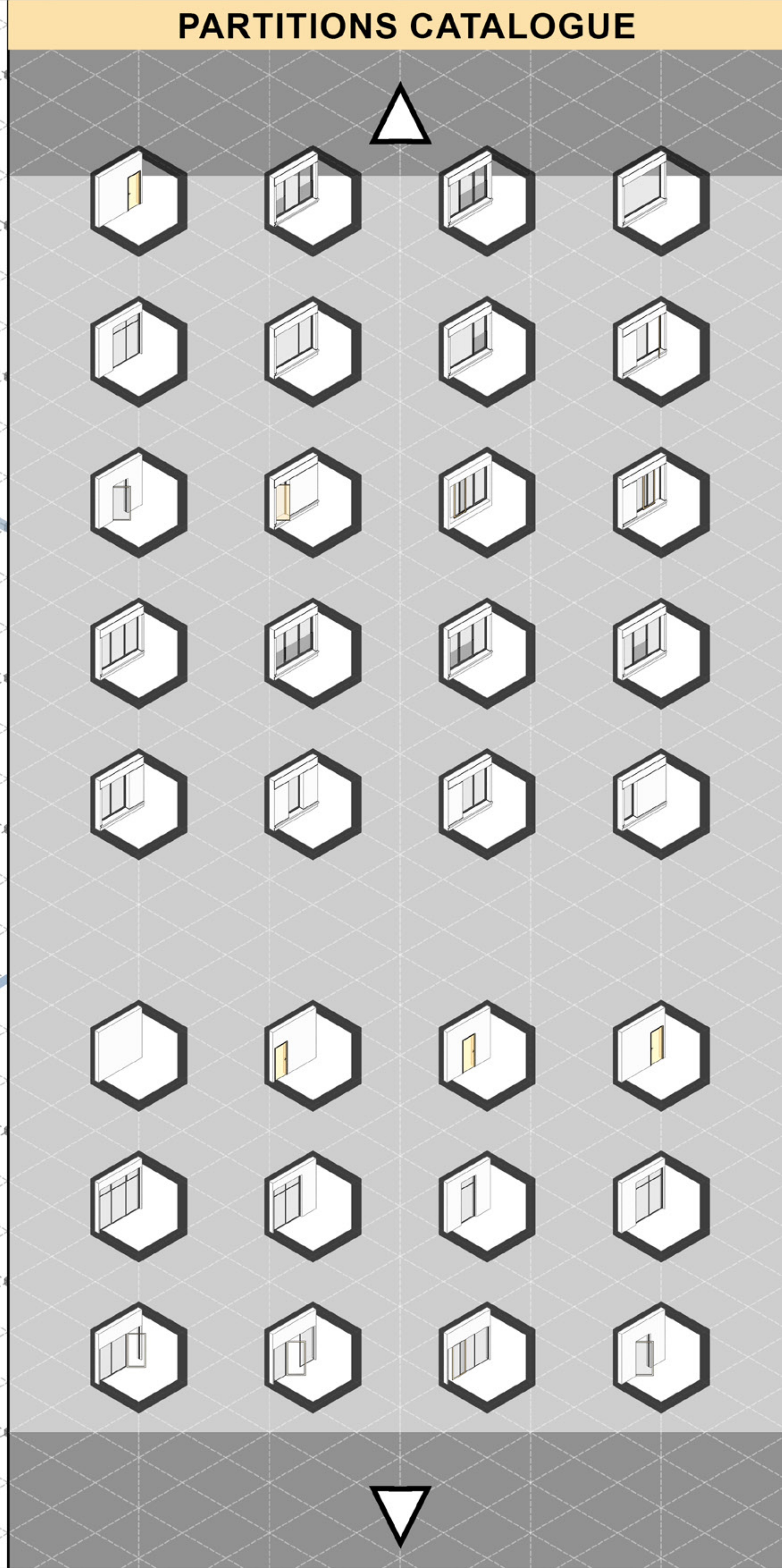
- Corridors | Inside Dwelling
- Openings | Window or Entrance Doors Required
- Corridors | Outside Dwelling (Balcony)

Sharing Possibilities

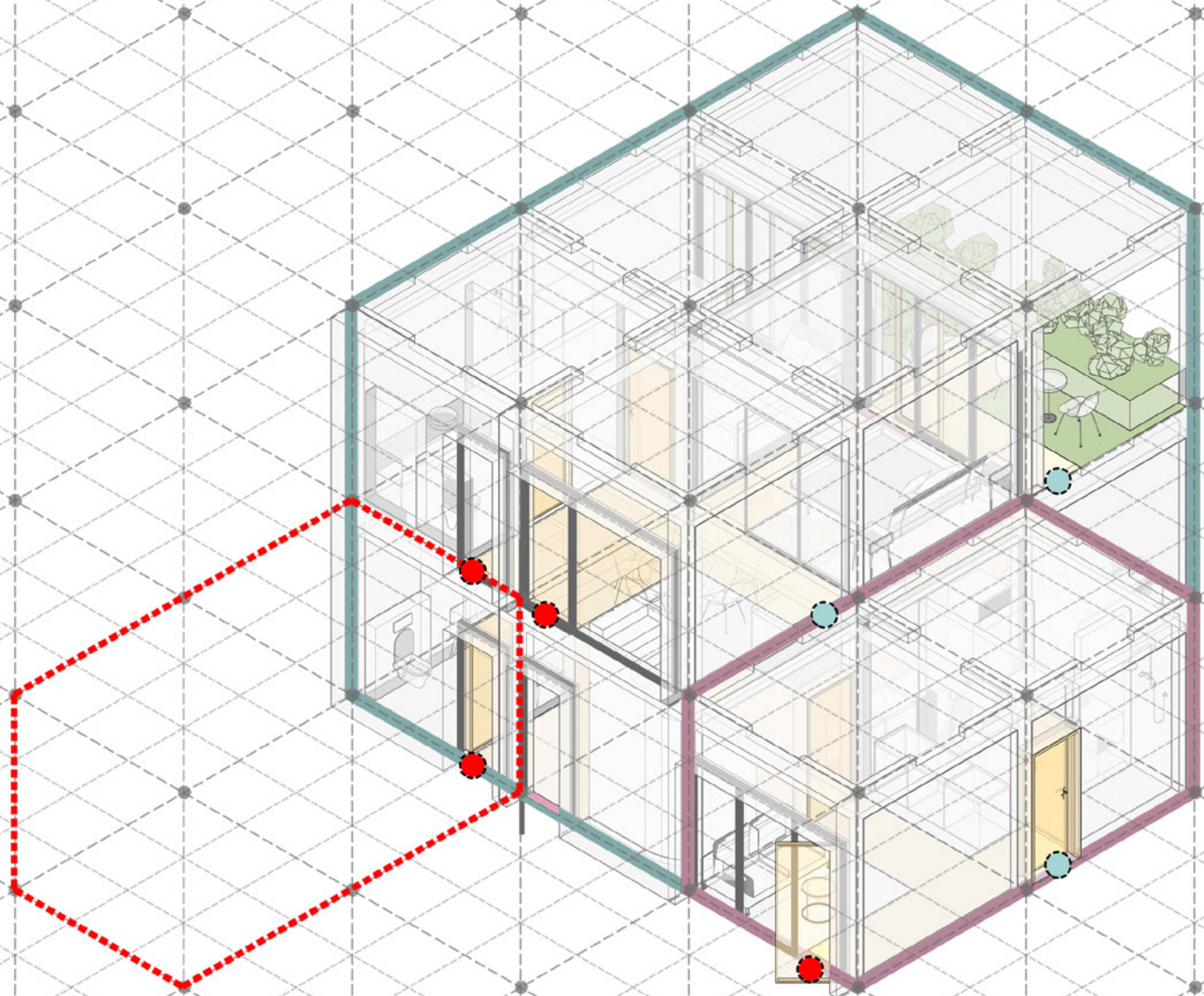


Completing Aggregations with Vertical Partition Elements





Future extensions possibilities



Shared Part of Inhabitants 1 and 2 Dwellings | Guest Bedroom

Dwelling Aggregation Outline | Future Inhabitant 1

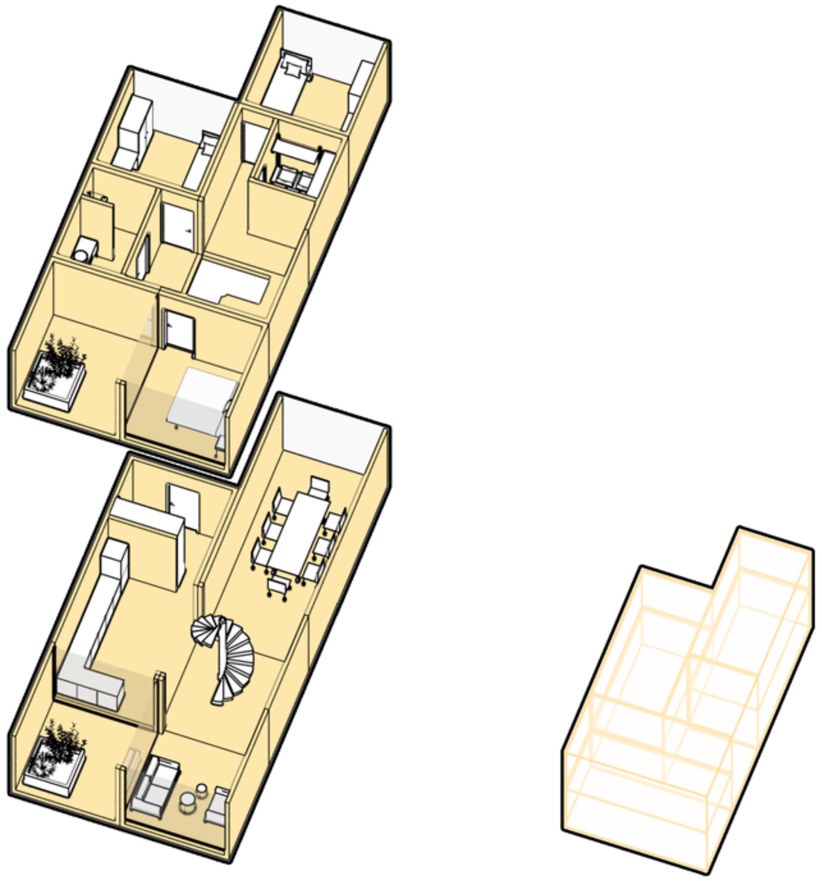
Possible Extension Outline

Connectivity | Possible Future Extension

Connectivity | Possible Future Sharing

Pick Your Own!

Possible configurations



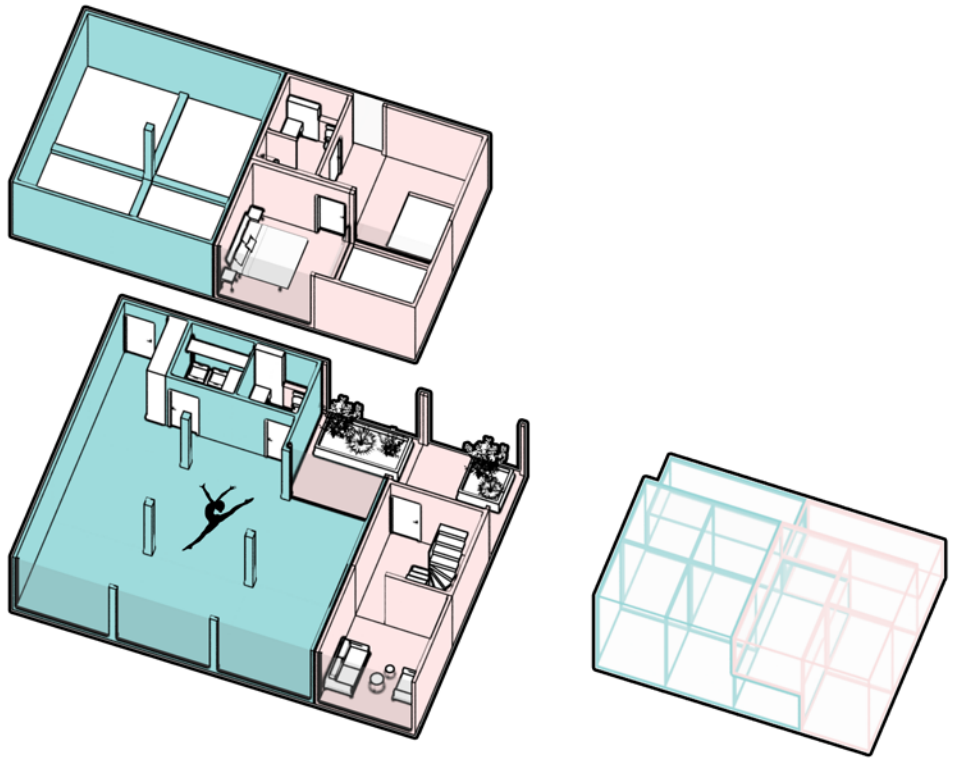
Simple configuration

Number of participants: 1

Modules in use:

x1

x6



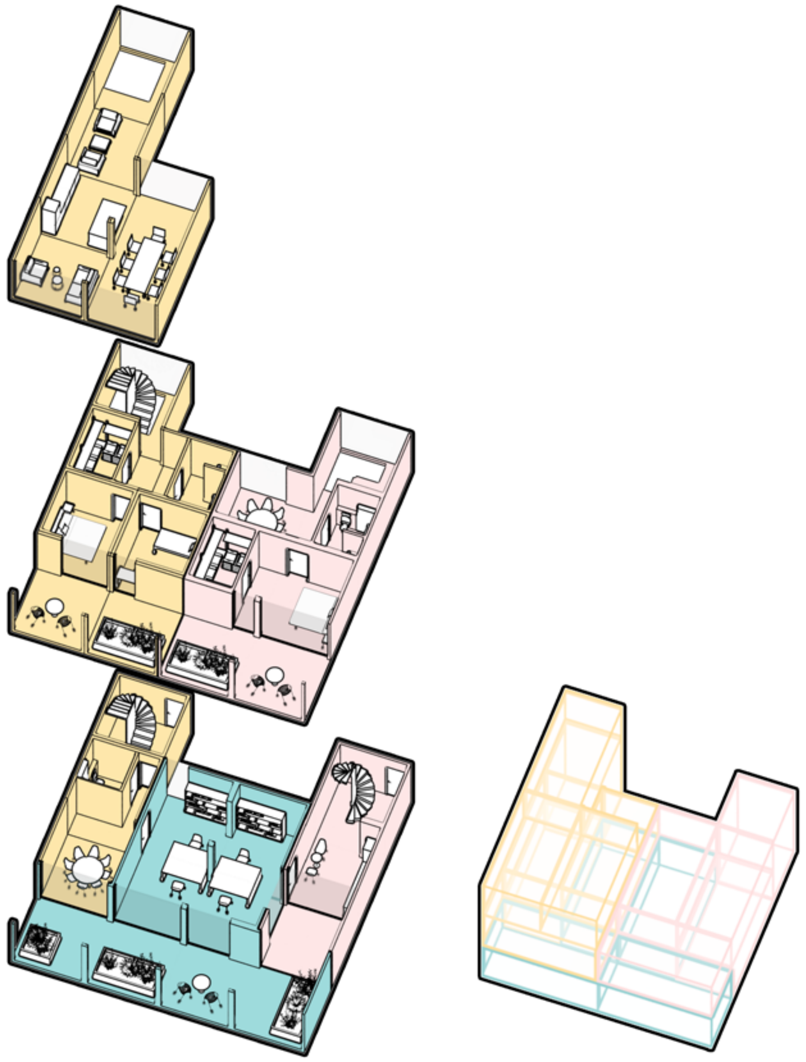
Space shared with community Shared space function selected by owner

Number of participants: 2 + community

Modules in use:

x2

x15



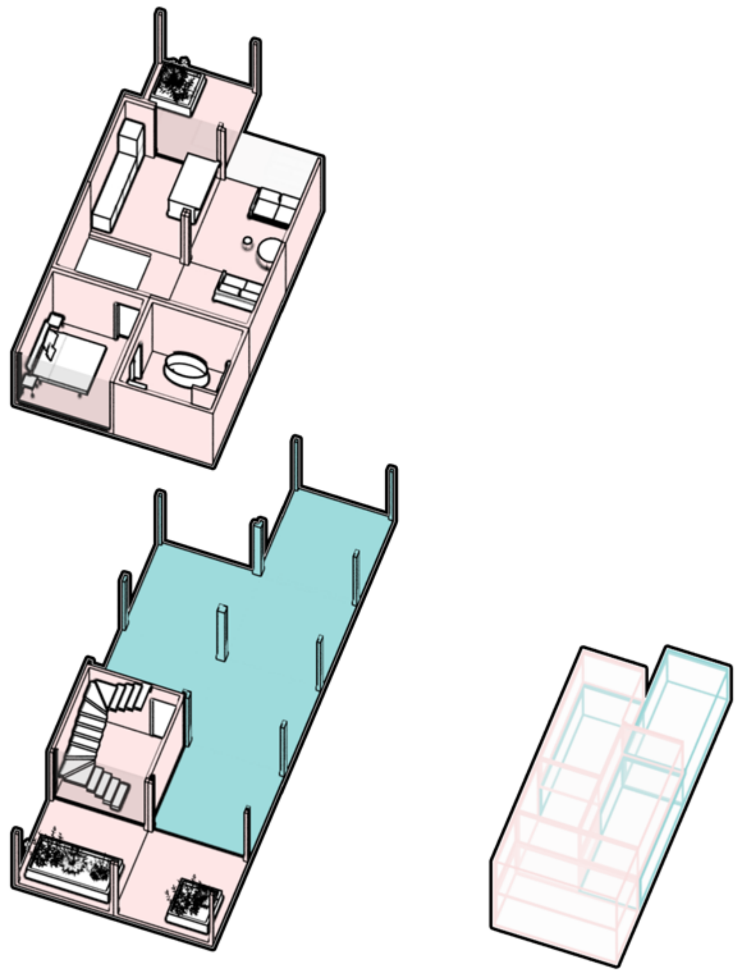
Space shared by neighbours

Number of participants: 2

Modules in use:

x2

x15



Space shared with community Shared space function selected by community

Number of participants: 1 + community

Modules in use:

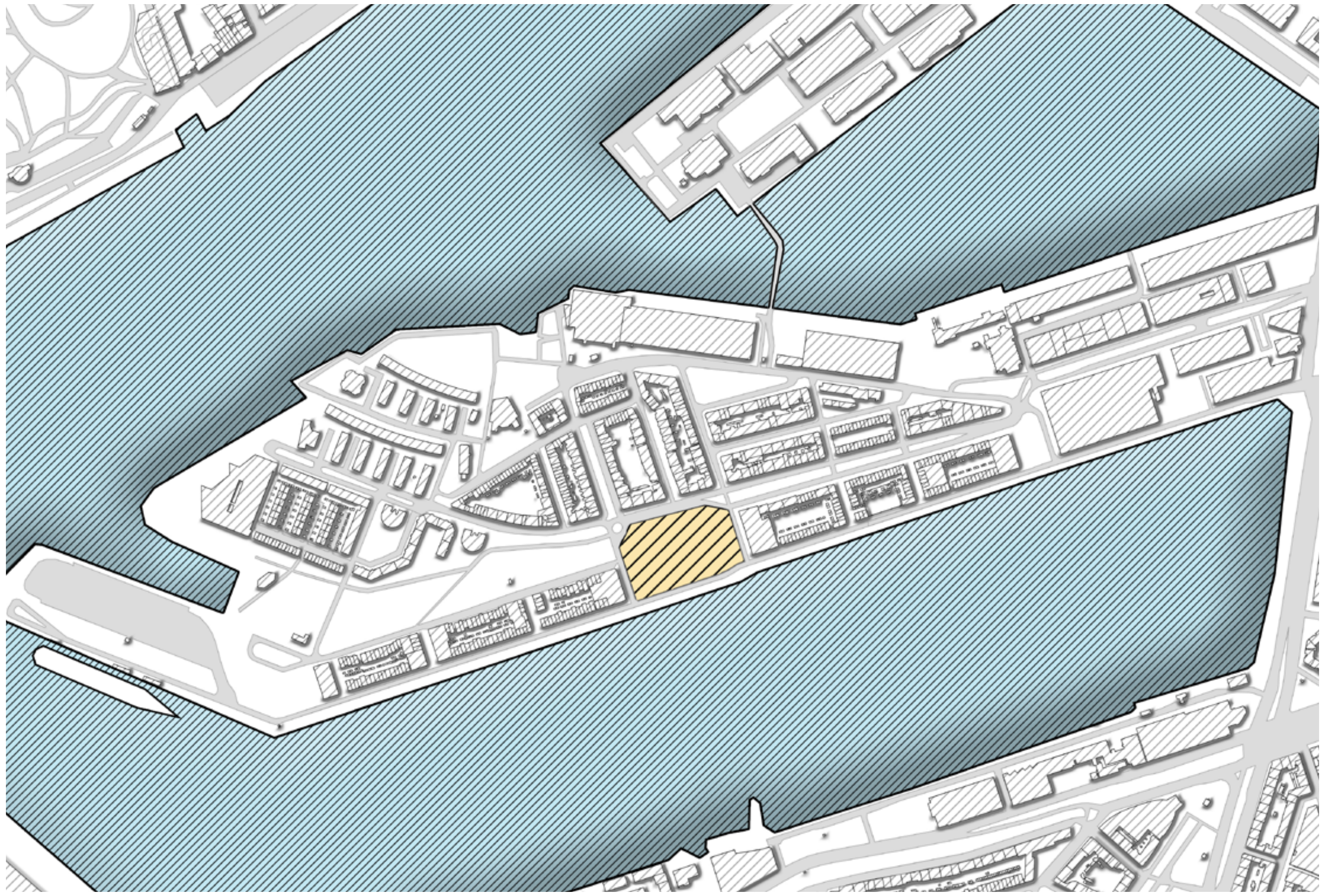
x1

x14

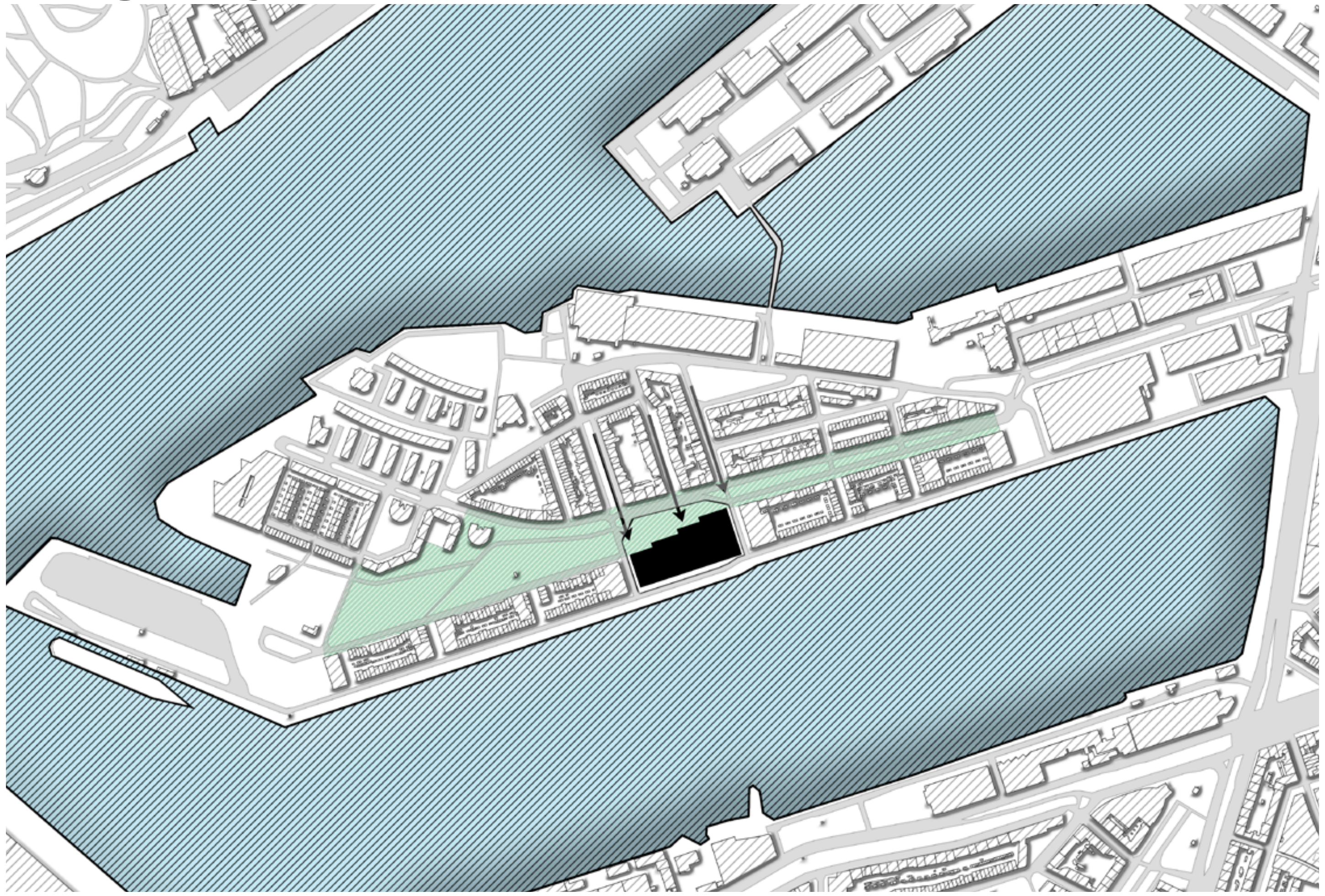
D E S I G N

SITE

Location



Design Objectives



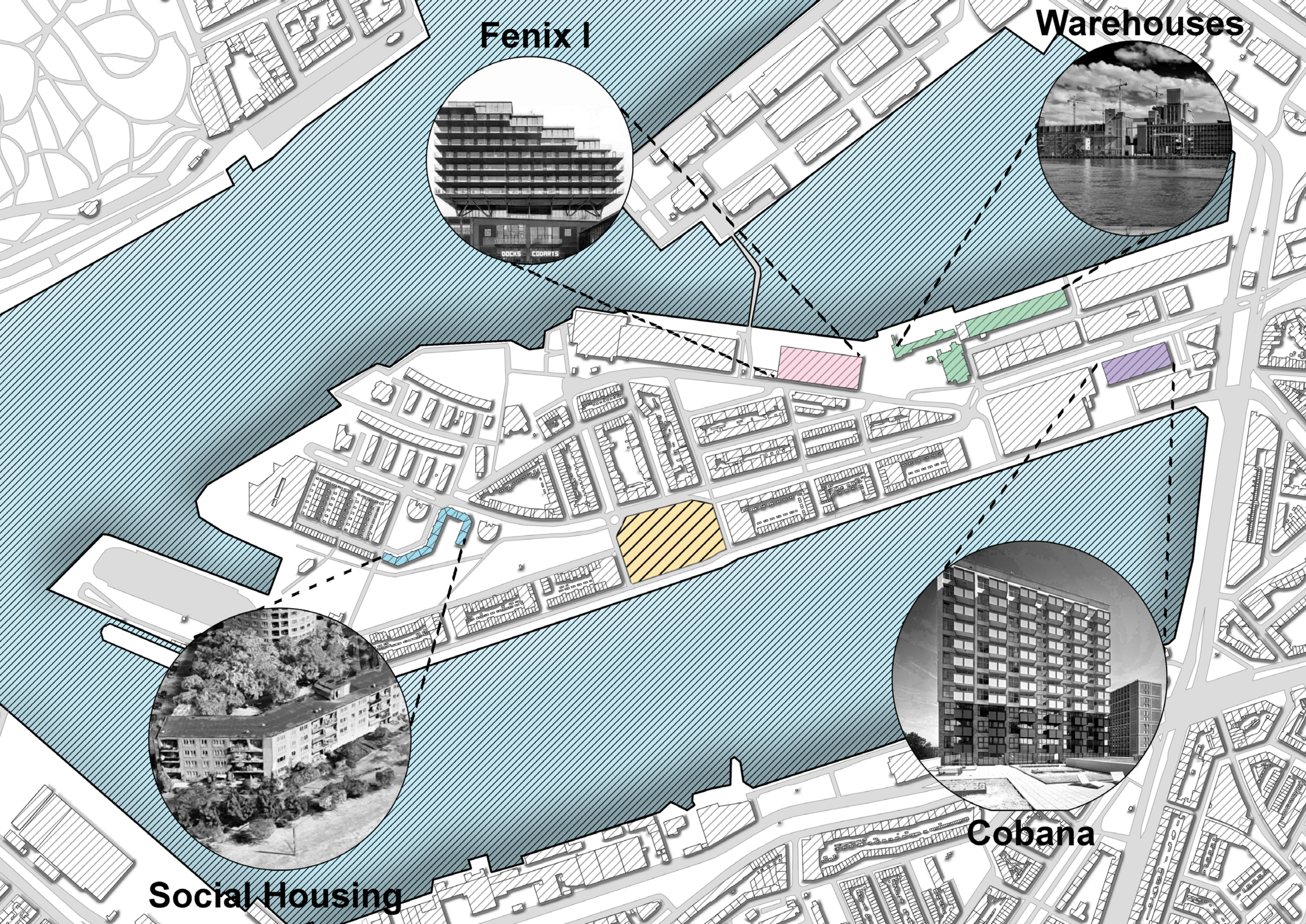
Site Katendrecht is a place with a rich history. Started as a village that turned into a harbour, served as a wearhouse until finally became a city island which is undergoing very rapid development.

The element that connects all these historical plots is a place that is always alive and ready for change.

Design Objectives The main design objectives are to preserve the green alley and to organize the space on the northern side of the facility as a recreational space with a large share of greenery. In addition, the object will have different heights so as to create dominants closing the streets. The southern part of the facility has a smaller height in order to fit into the surrounding buildings and maintain the character of the pedestrian zone running along the harbor. This solution is used also to provide appropriate lighting conditions in the apartments.

Current Urban Environment Currently, it is a place where what belonged to the port infrastructure is mixed with tipical dutch social housing and newly constructed residencial buildings such us Fenix I or Cobana, equipped with many additional functions.

I believe that, the character and history makes a perfect match for a place for my project. Thanks to its adaptability, the building will maintain the character of this place.


Fenix I
Warehouses
Social Housing
Cobana
DOCKS
CODARTS

P R O J E C T

Procedure

The design process should be multi-stage; here are the main steps:

1. 1.1 Analysis of the plot and local conditions by the architect.
   1.2 Determining the outline of the building, the appearance of the façade modules, creating a set of components to be configured, determining the location of accessibility cores.

2. Determining the type, quantity and location of shared parts based on users' preferences. Preferences determined based on a survey.

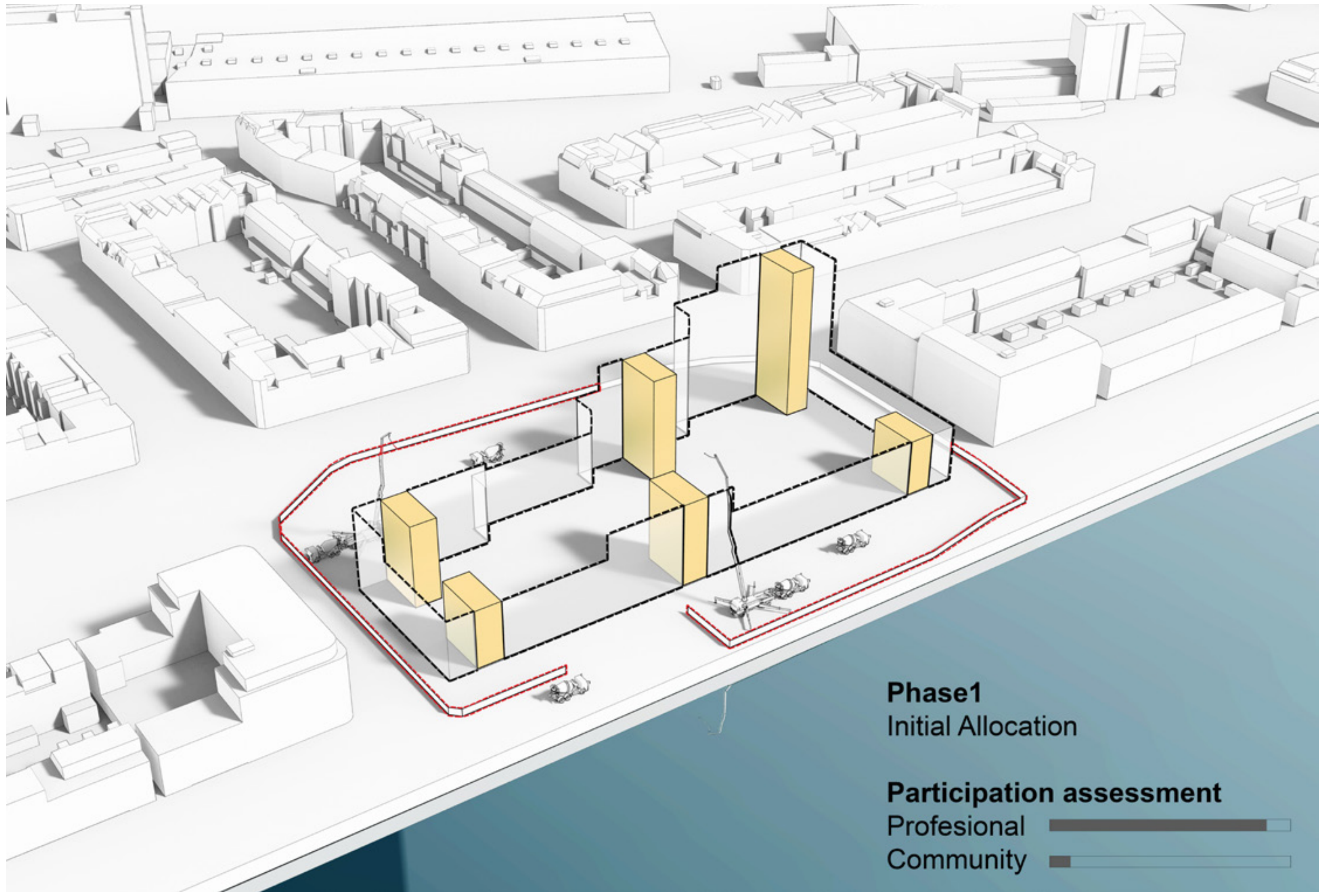
3. Dividing the building into spaces assigned to users

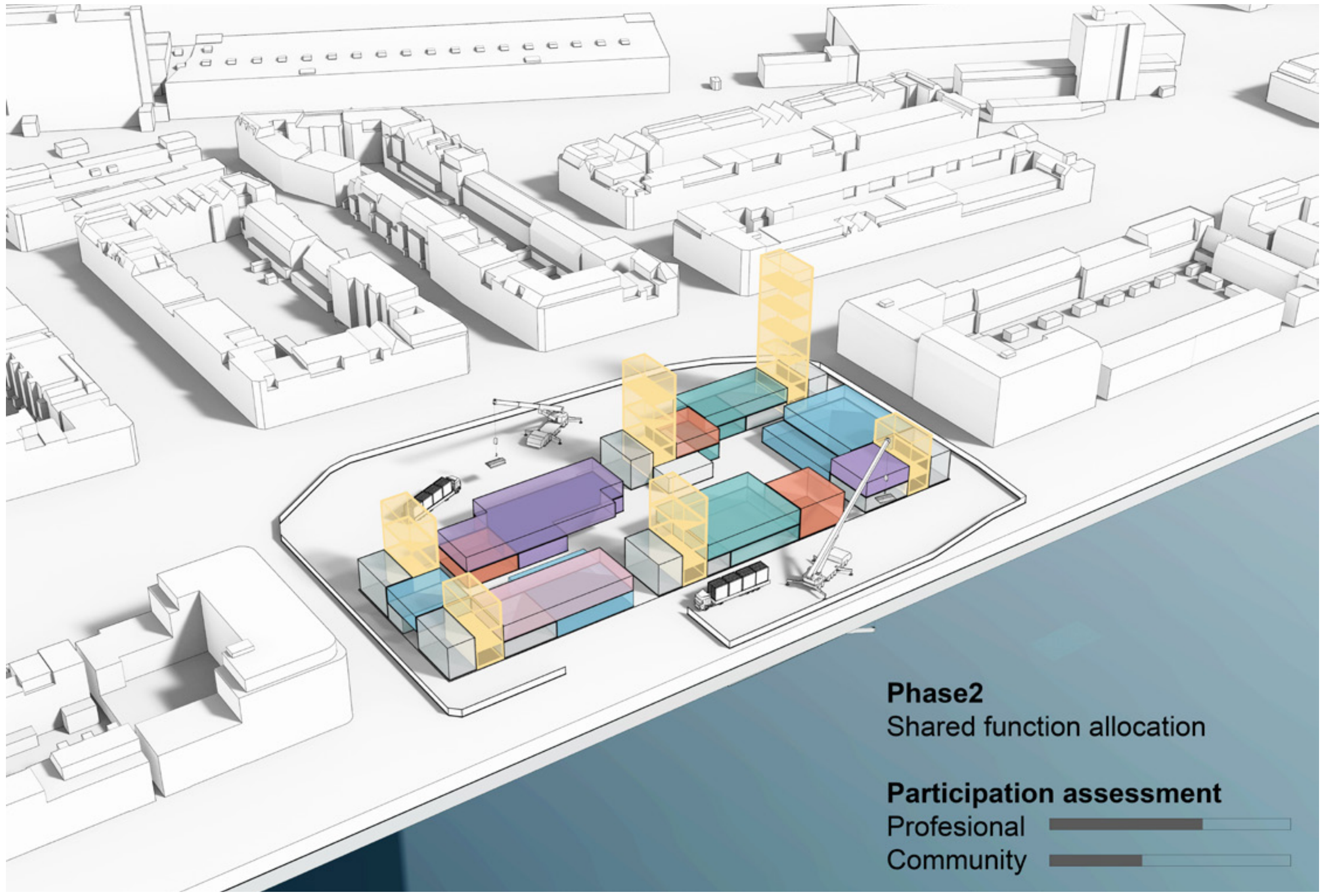
4. Layout configuration by users
   4.1. User selection of components
   4.2. Layout configuration
   4.3. Feedback containing information on the correctness and quality of the created layout (price, light, room orientation, compactness etc.)
   4.4. Reconfiguration - if necessary

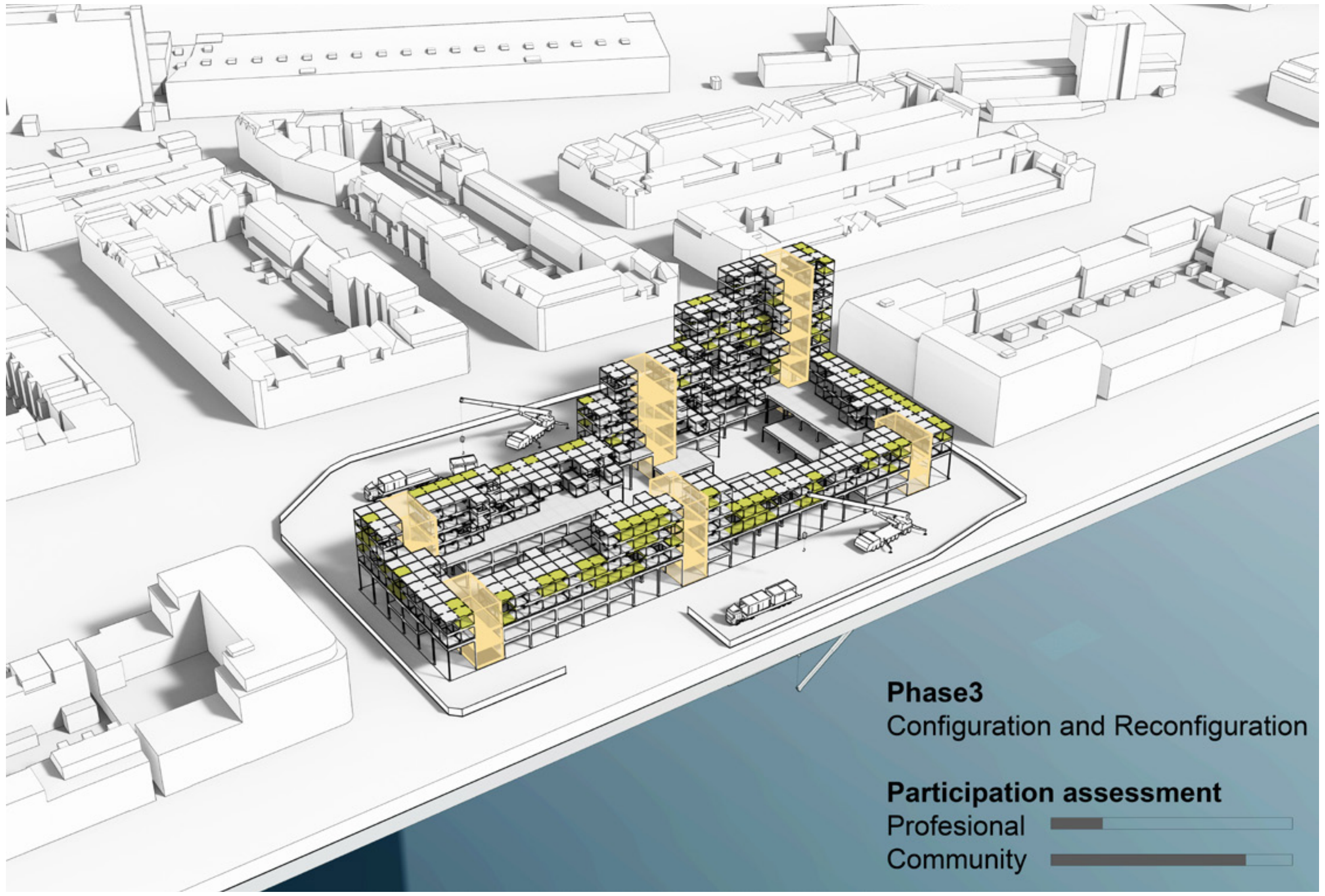
5. Complementing the system with the necessary complementary parts forming shard corridors and adding modules preferred by users to the layout.

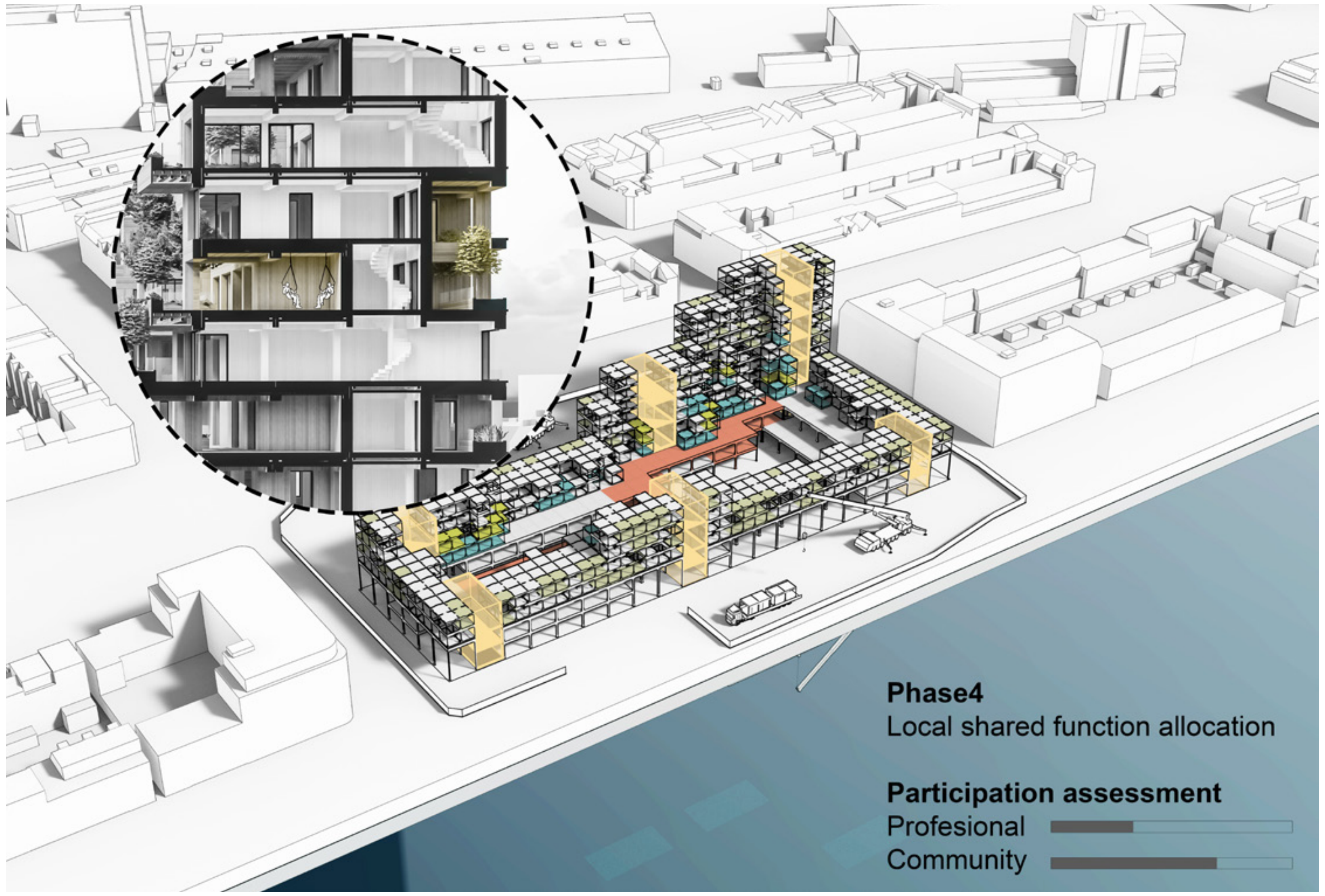
6. Selection of locations and sizes of window and door while maintaining at least the minimal given dimensions

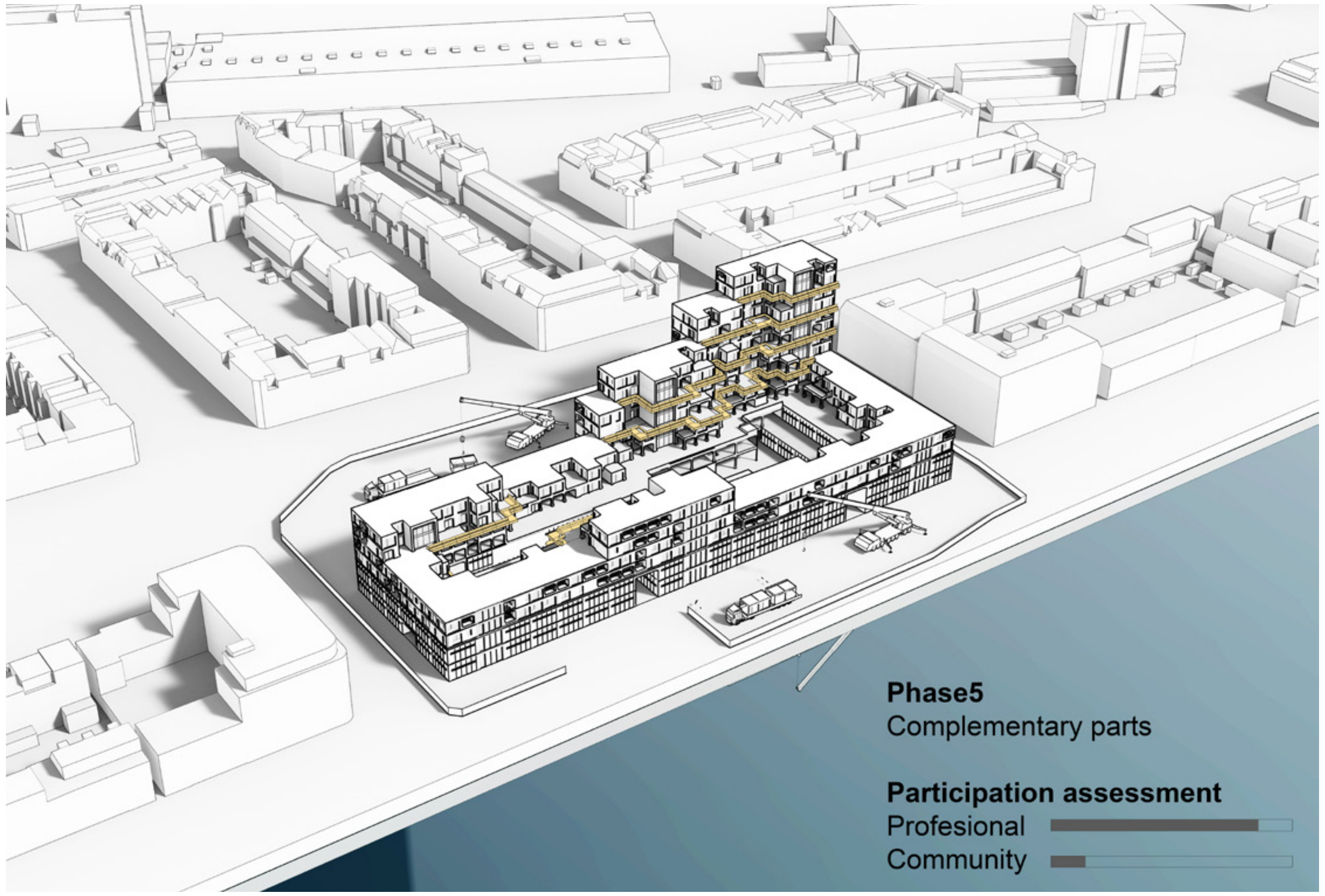
7. Preparation of technical drawings by the architect. Reconfigurations during the life of the building

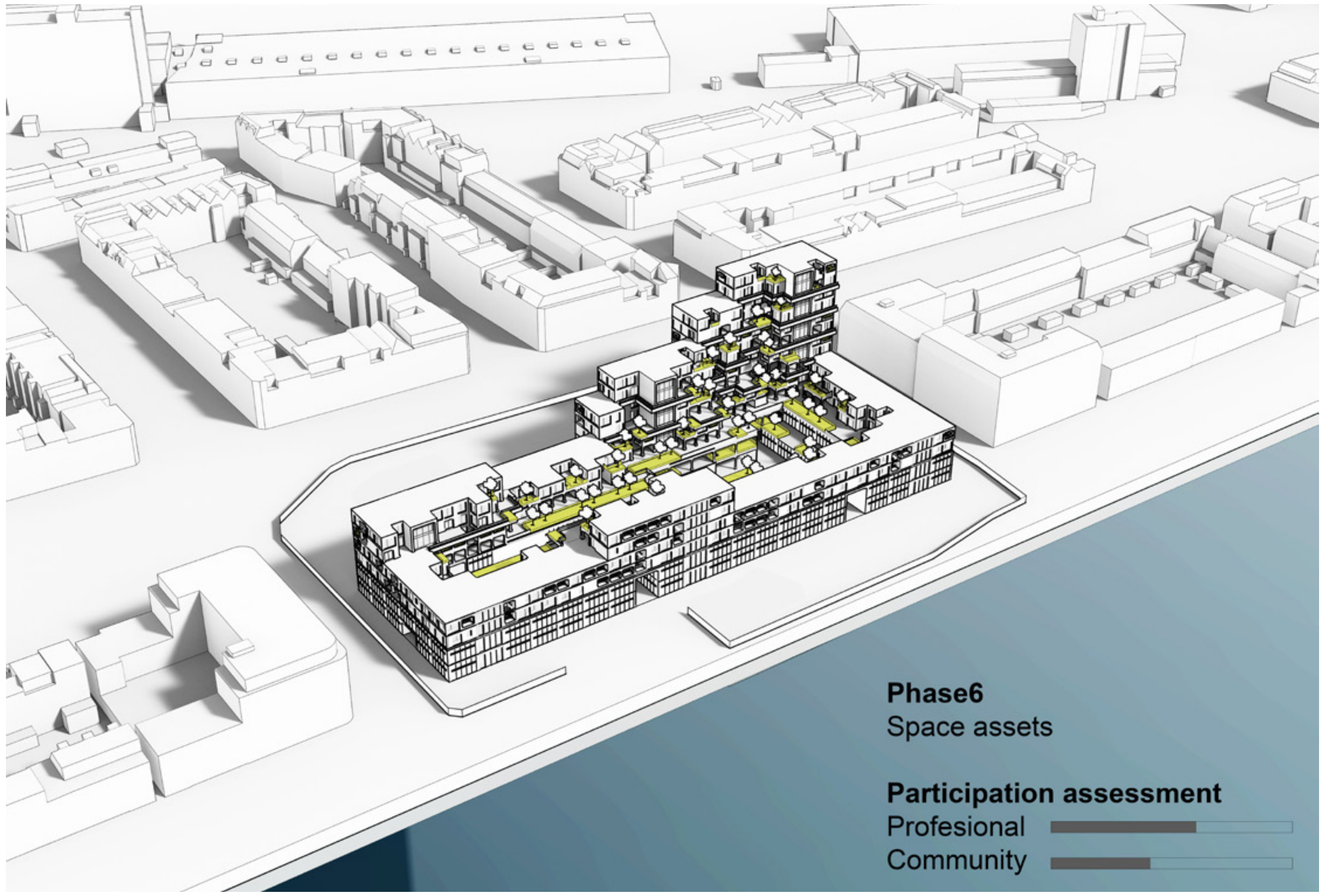

Phase1
Initial Allocation
Participation assessment
Profesional
Community

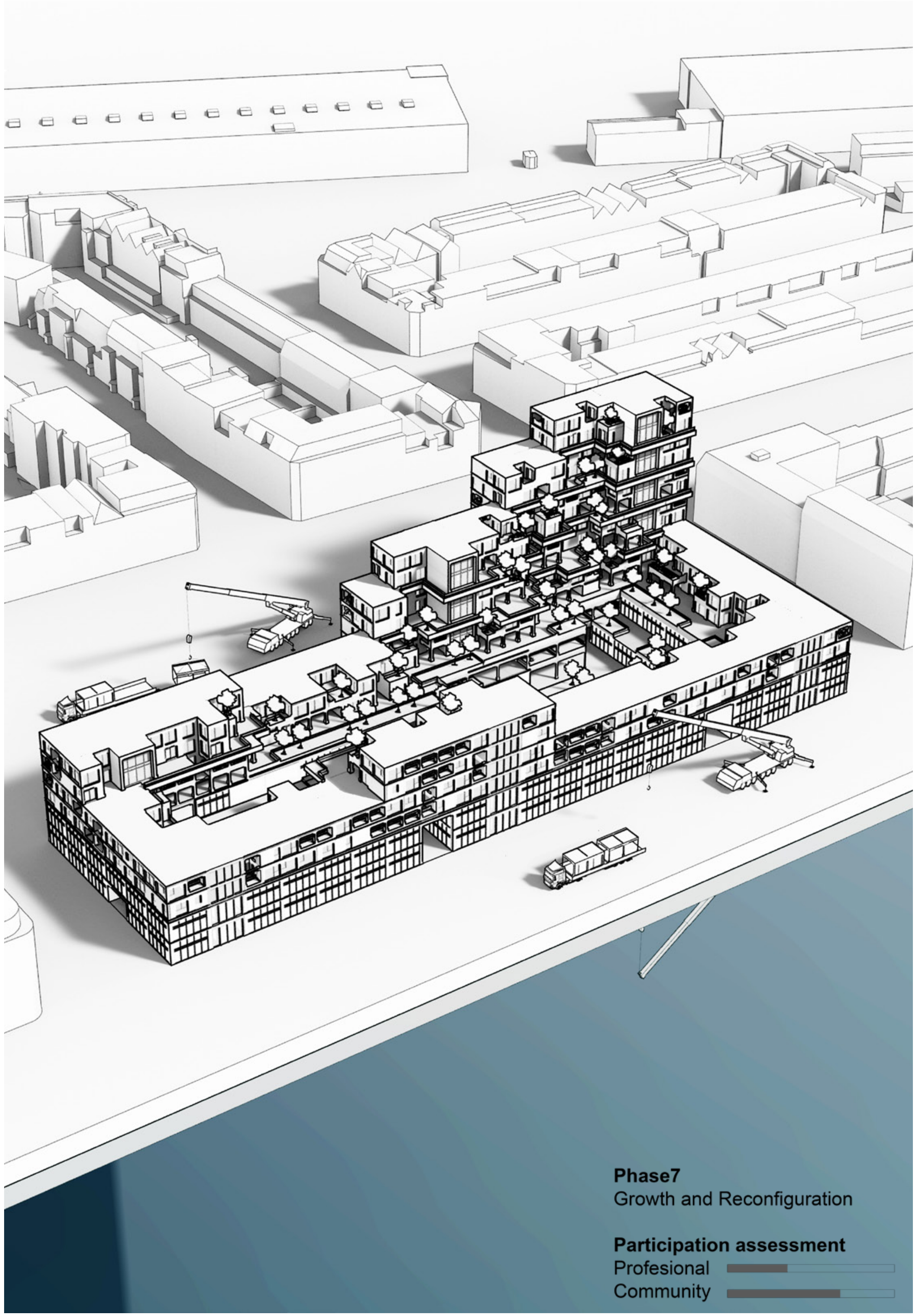

Phase2
Shared function allocation
Participation assessment
Profesional
Community


Phase3
Configuration and Reconfiguration
Participation assessment
Profesional
Community


Phase4
Local shared function allocation
Participation assessment
Profesional
Community

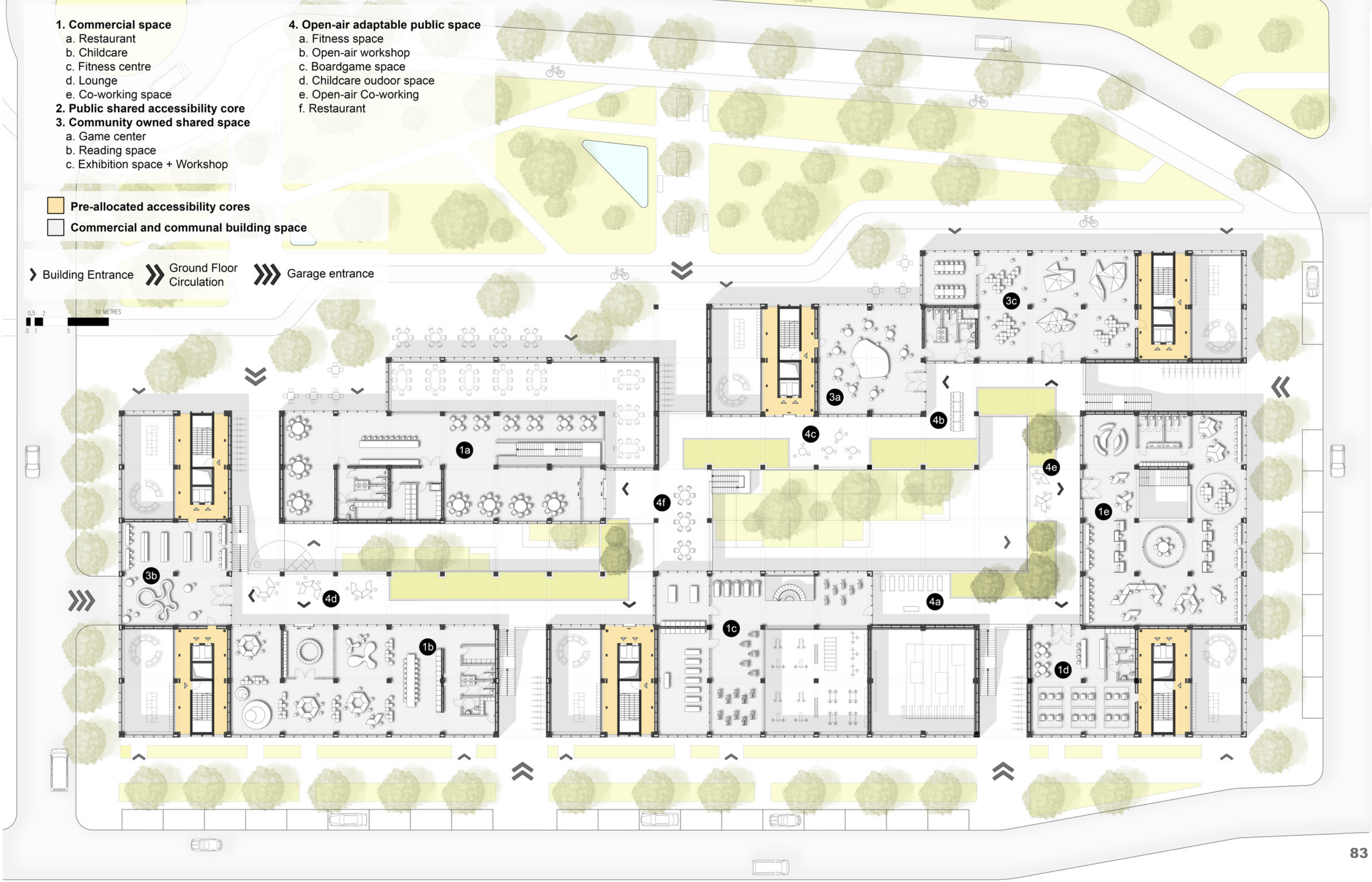

Phase5
Complementary parts
Participation assessment
Profesional
Community


Phase6
Space assets
Participation assessment
Profesional
Community

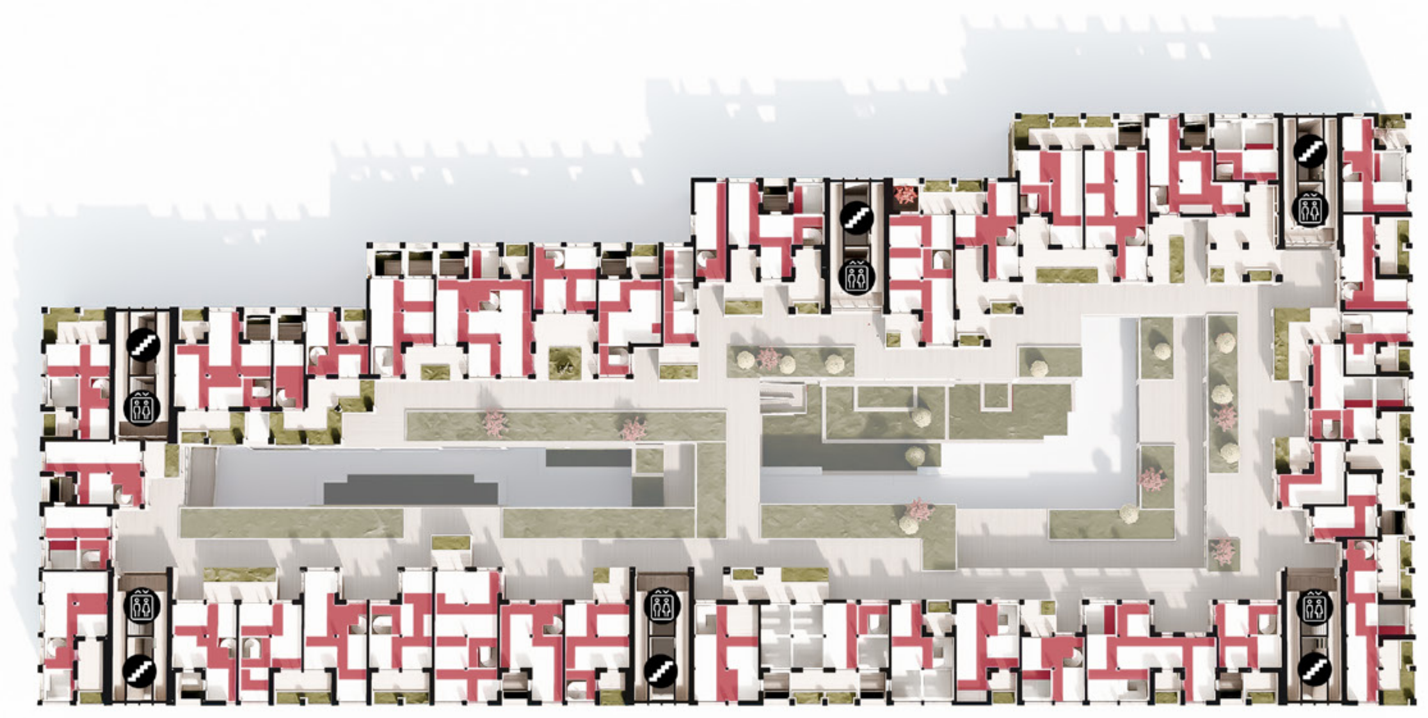

Phase7
Growth and Reconfiguration
Participation assessment
Profesional
Community

Pedestrian Ground Floor Plan
1. Commercial space
a. Restaurant
b. Local store
c. Fitness centre
d. Cafe
e. Co-working space
2. Public shared accessibility core
a. Mailbox
b. Scooter storage
c. Bike storage
d. Technical space
3. Community owned shared space
a. Cinema
b. Meeting point
4. Open-air adaptable public space
a. Playground
b. Open-air cafe
c. Exhibition
d. Relax zone
e. Open-air Co-working
f. Restaurant
Pre-allocated accessibility cores
Commercial and communal building space
Building Entrance
Ground Floor Circulation
Garage entrance
10 METRES

Pedestrian First Floor Plan



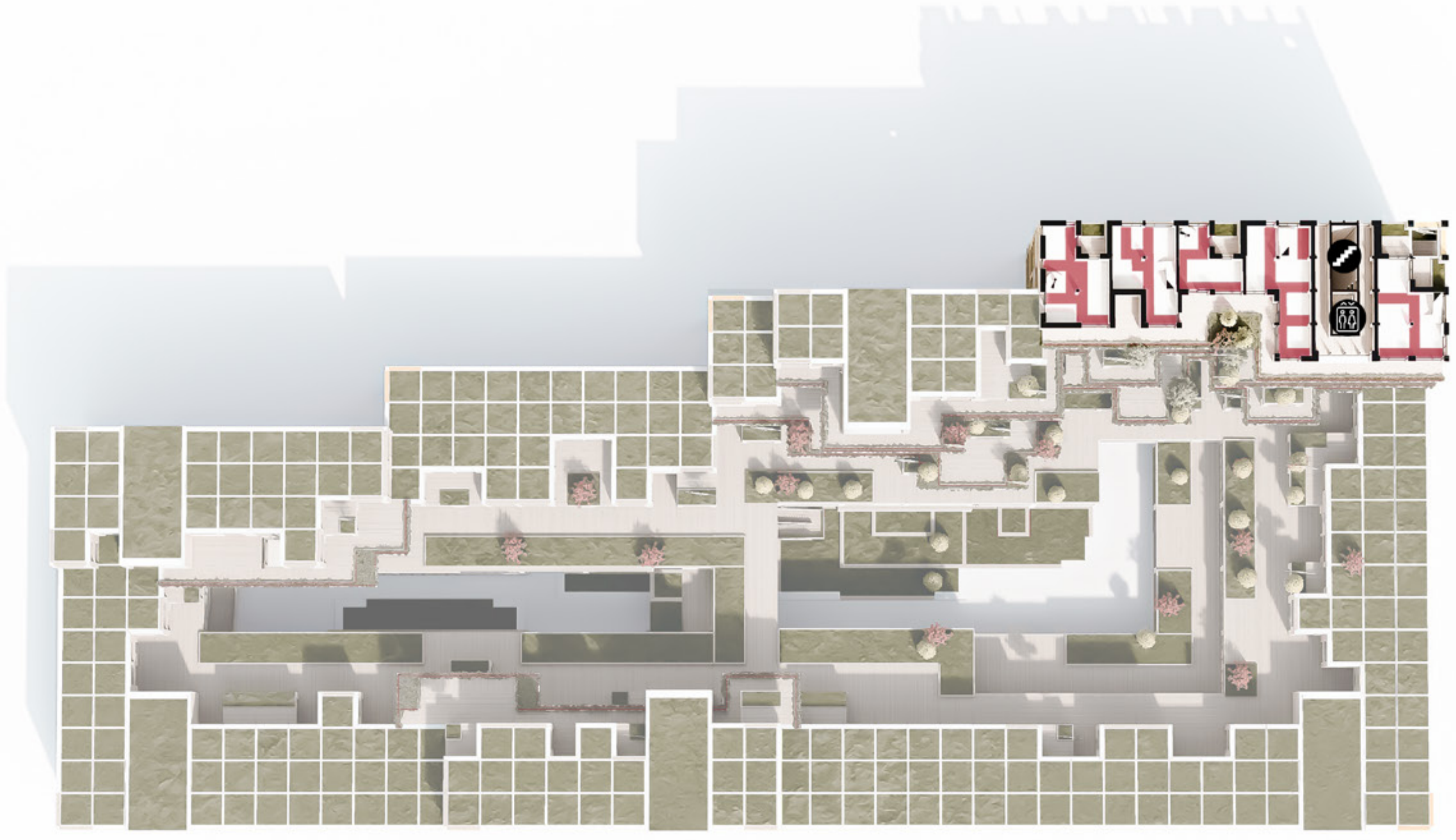
Residential Floor Plan #2 1:200 | Ownership structure



Floor Plan #4

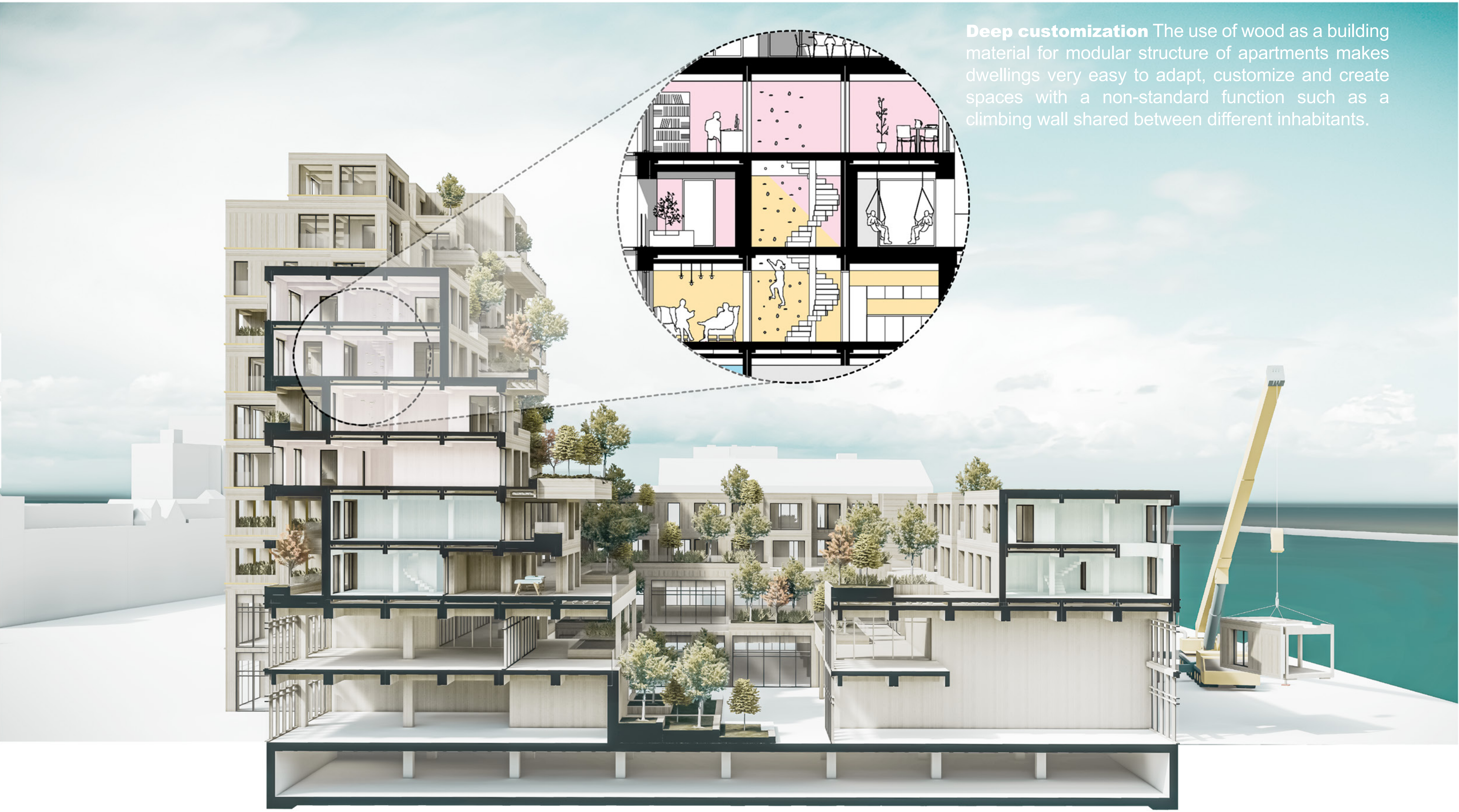
Floor Plan #5

Floor Plan #8



Floor Plan #9

Section 1:200



Deep customization The use of wood as a building material for modular structure of apartments makes dwellings very easy to adapt, customize and create spaces with a non-standard function such as a climbing wall shared between different inhabitants.

Section 1:200 | Deep castomization

Environment

Identification The building is divided into neighbourhoods defined by accessibility cores. Each neighbourhood was given its own colour code visible on the external staircases and blinds integrated into the façade. This allows for easier identification and orientation in space.

239
214
231

193
212
238

173
169
200

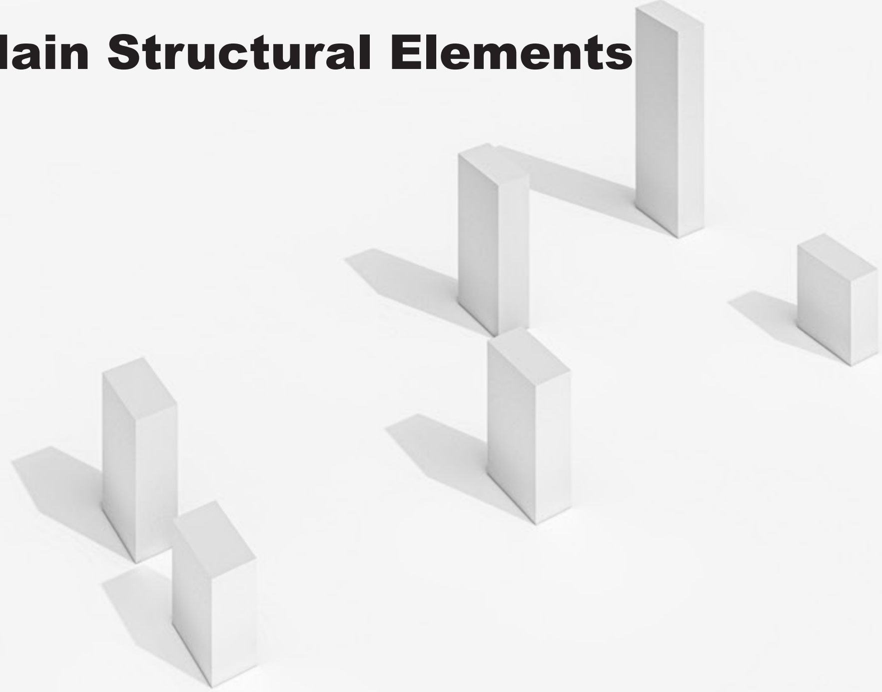
193
212
238

232
212
185

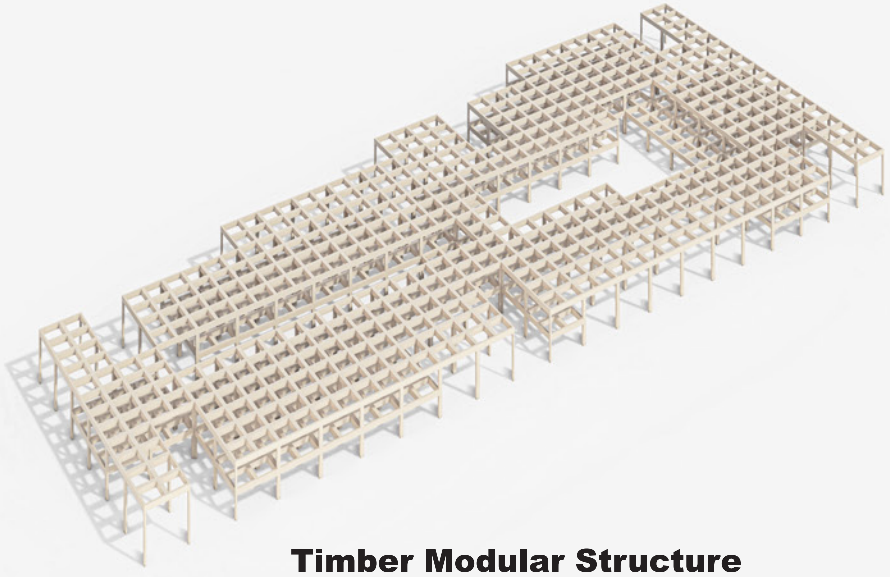
179
212
212

211
166
190

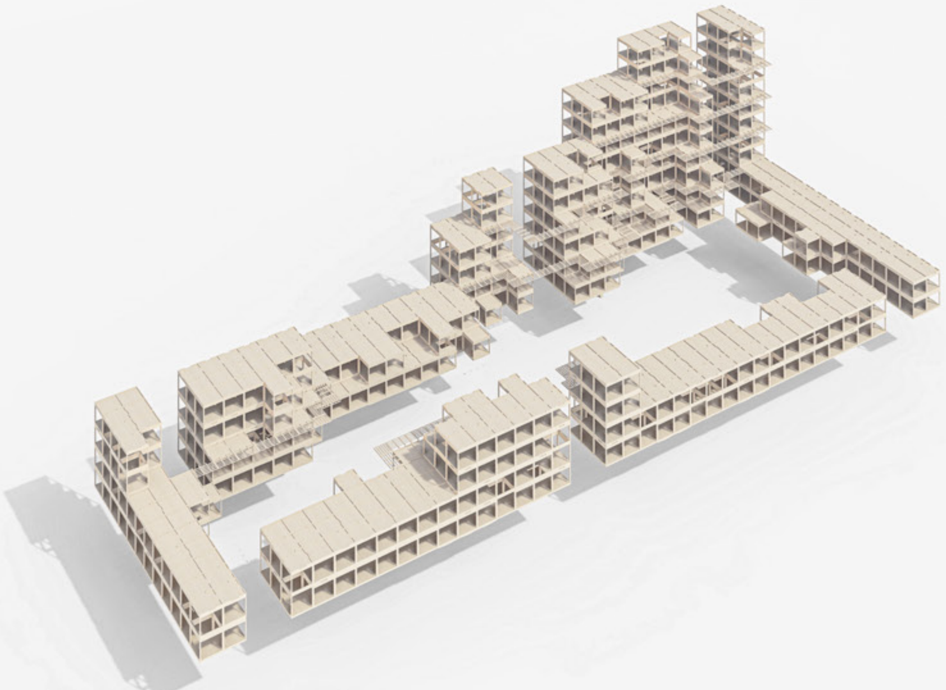
Main Structural Elements



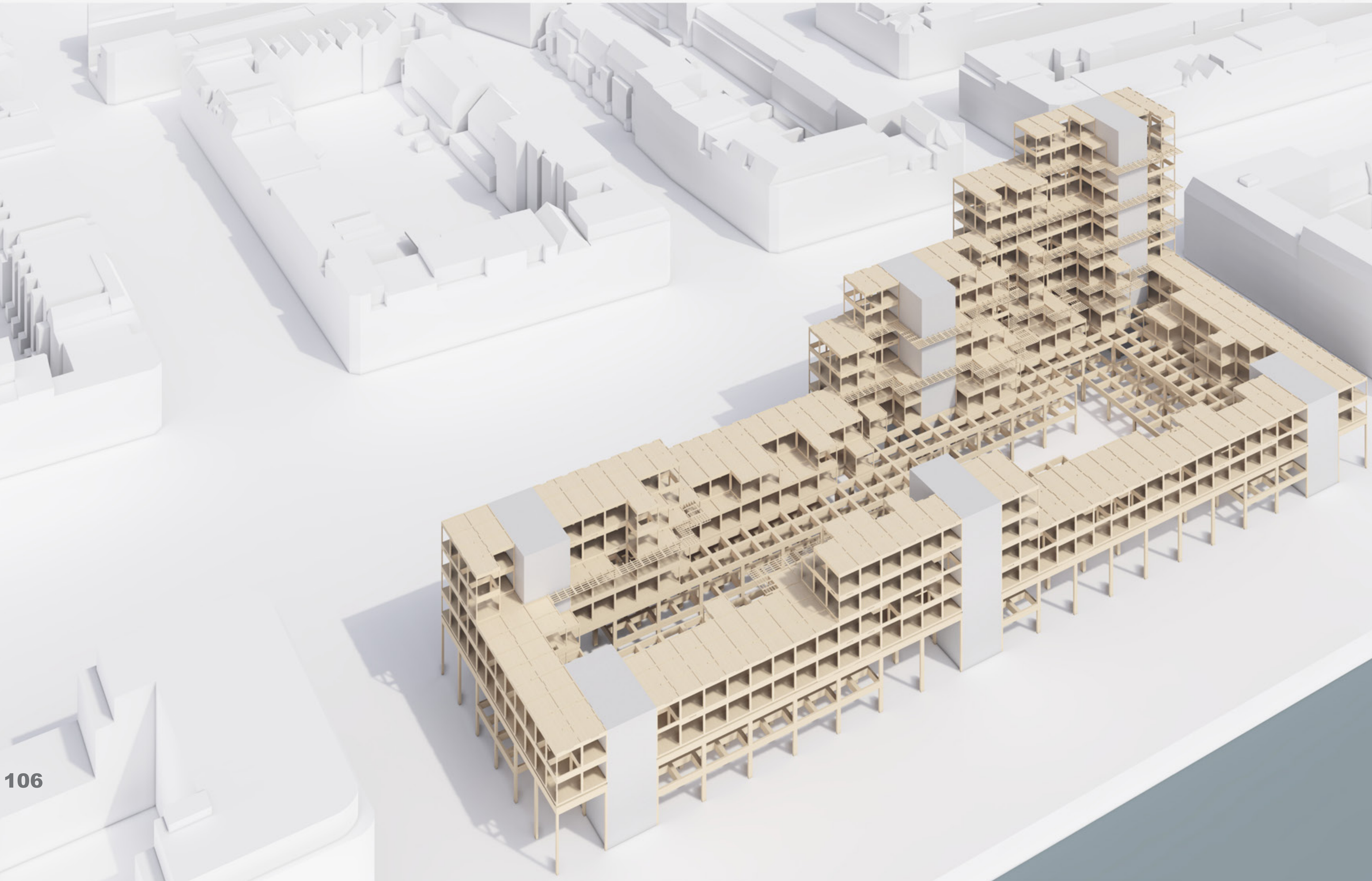
Concrete Circulation Cores



Timber Modular Structure



Timber Living Modules



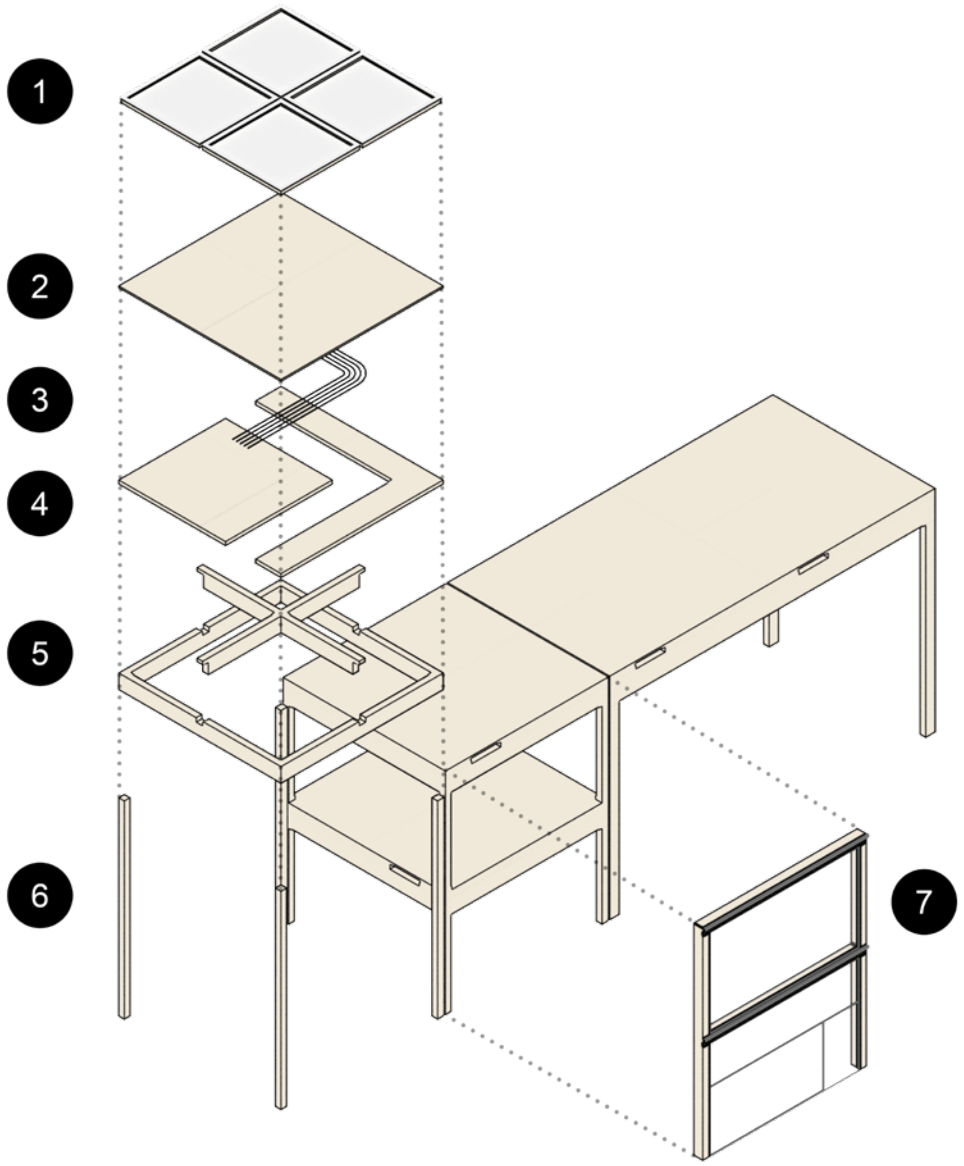
Structural Composition Plinth structure of shared spaces is a skeletal framework based on a square grid which is twice a size of modules grid. The structure is equipped with prefabricated external wall panels and external ceiling finishes. The system has been designed in such a way that it is possible to form the space freely.

Modules are made from CLT. It is a material with good structural properties and at the same time, subject to great flexibility and ease of change. The basic modules could be created as perpendiculars with the possibility of cutting out holes based on users' preferences. Additionally, the floor would be raised, and the resulting void would be used to provide all the necessary services such as HVAC, plumbing etc. for the proper functioning of the building.

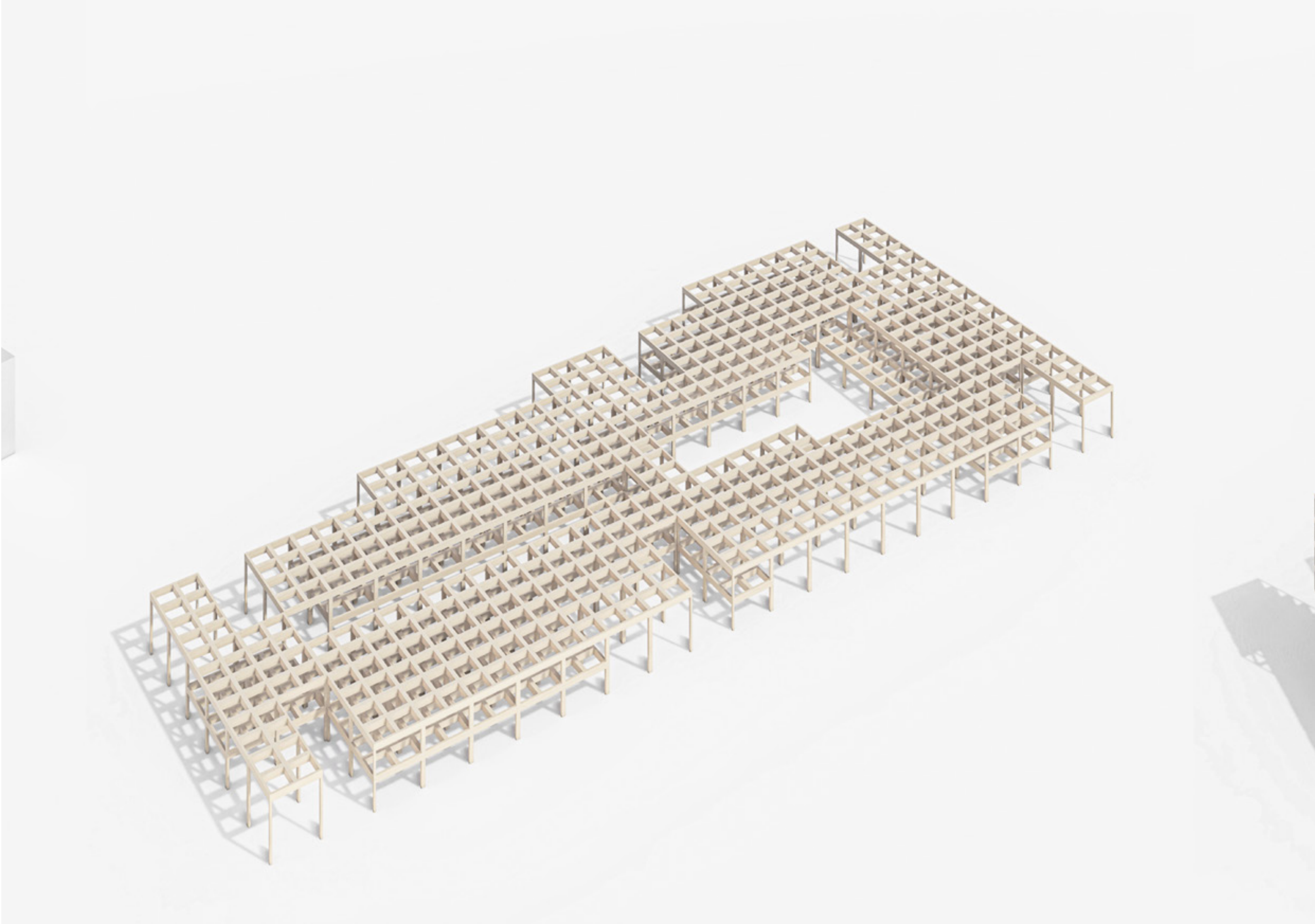
Components are connected through easily disassembled connections, to ensure the possibility of reconfiguration of the systems.

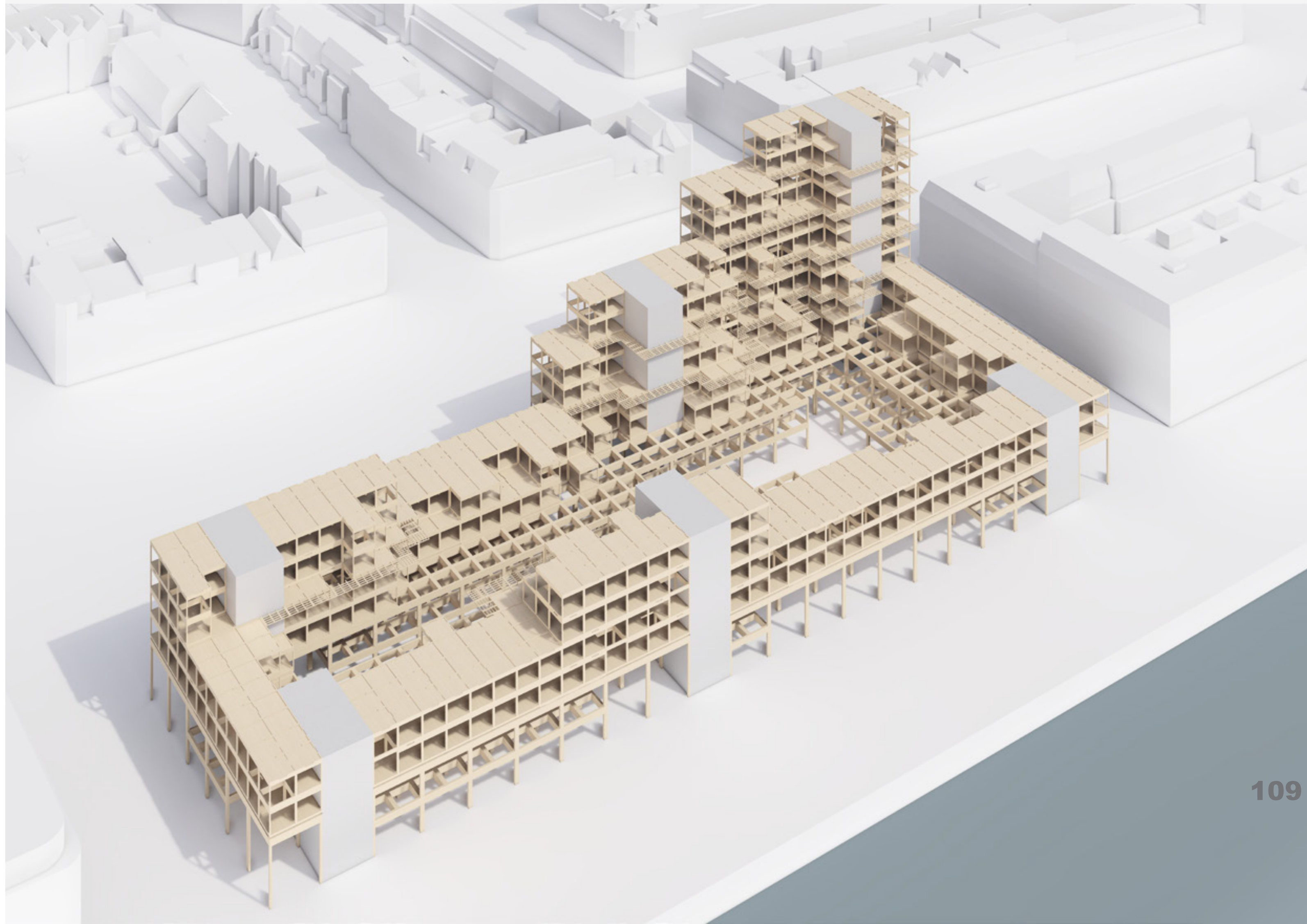
The modules would be finished with prefabricated panels both outside and inside. Panels are made from CLT. The size of windows and doors has been unified. The decision on the location and type of panels would be up to the residents so that the residents would have a large influence on the external appearance of the building and their living units would be tailor made.

Timber Modular Structure - Plinth

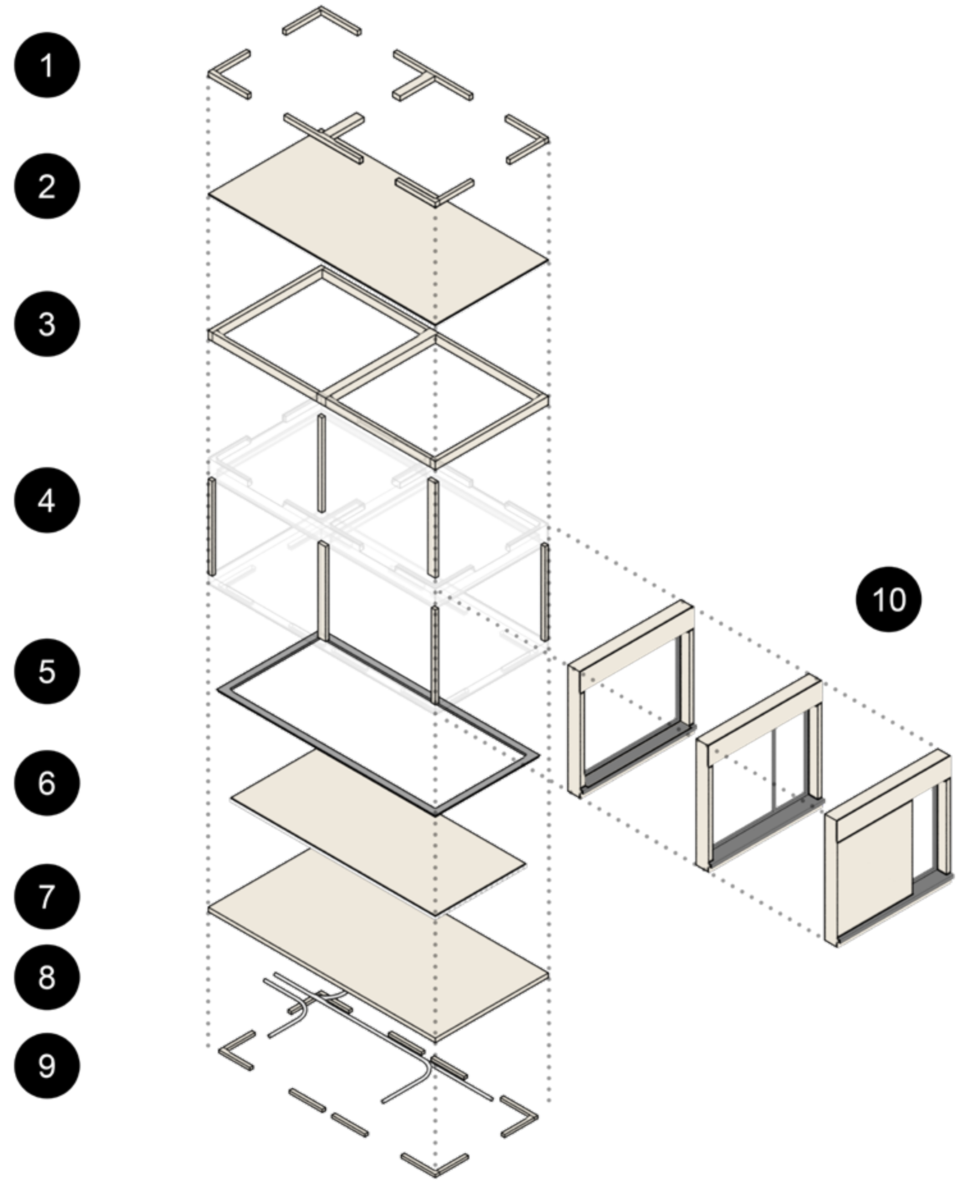


1. **Installation space:**
   wood plank 200/120 mm
   Sound insulation, fibreglass panel 70 mm
2. **Floor slab:**
   Cross laminated timber, three layers 99 mm
3. **Installation space - piping**
4. **Ceiling slab:**
   Cross laminated timber, five layers 169 mm
5. **Beams:**
   Glued laminated timber 400/600 mm
6. **Columns:**
   Glued laminated timber 225x225 mm
7. **Curtain wall panel:**
   Triple - glazed window
   Wooden Structure

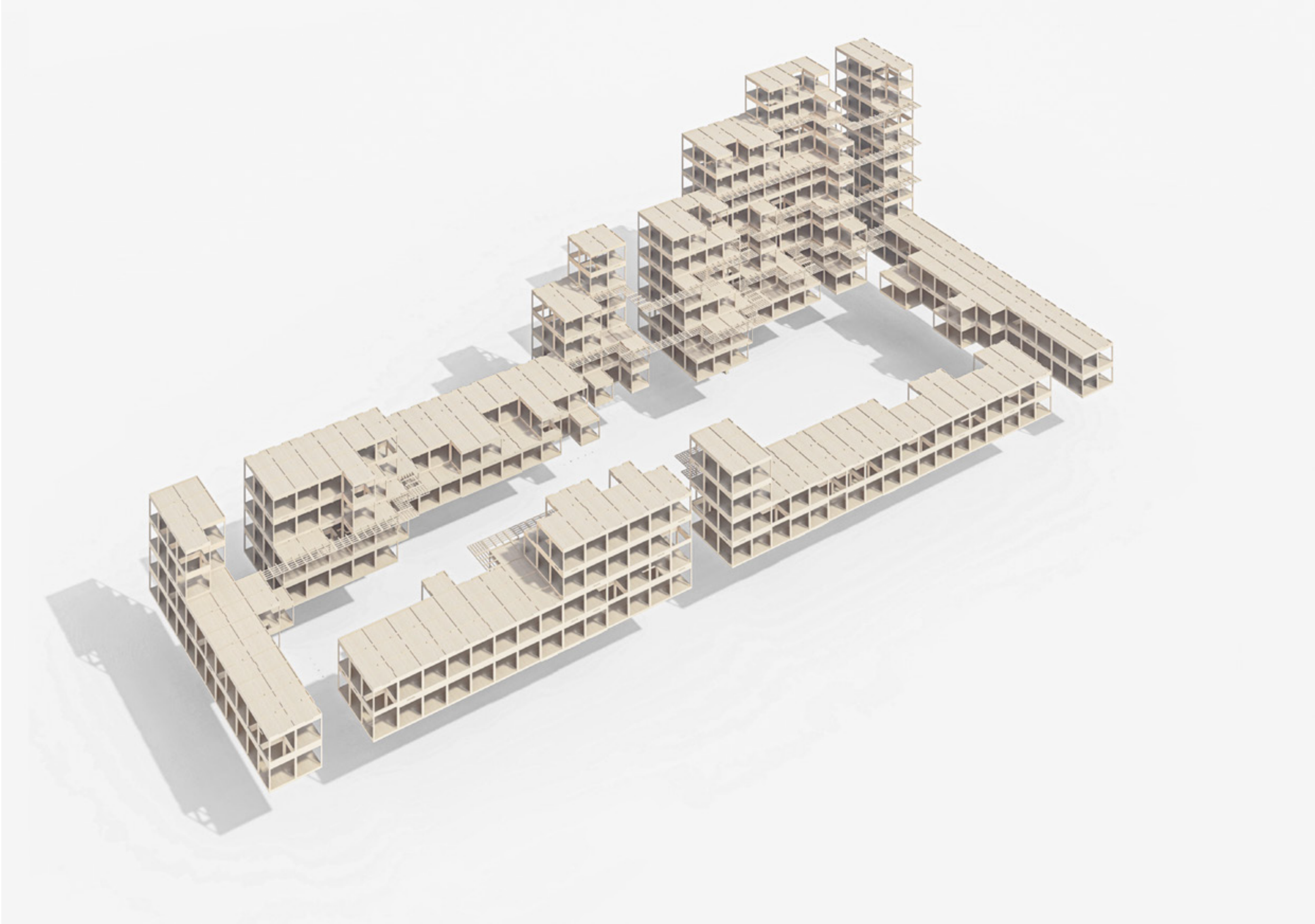


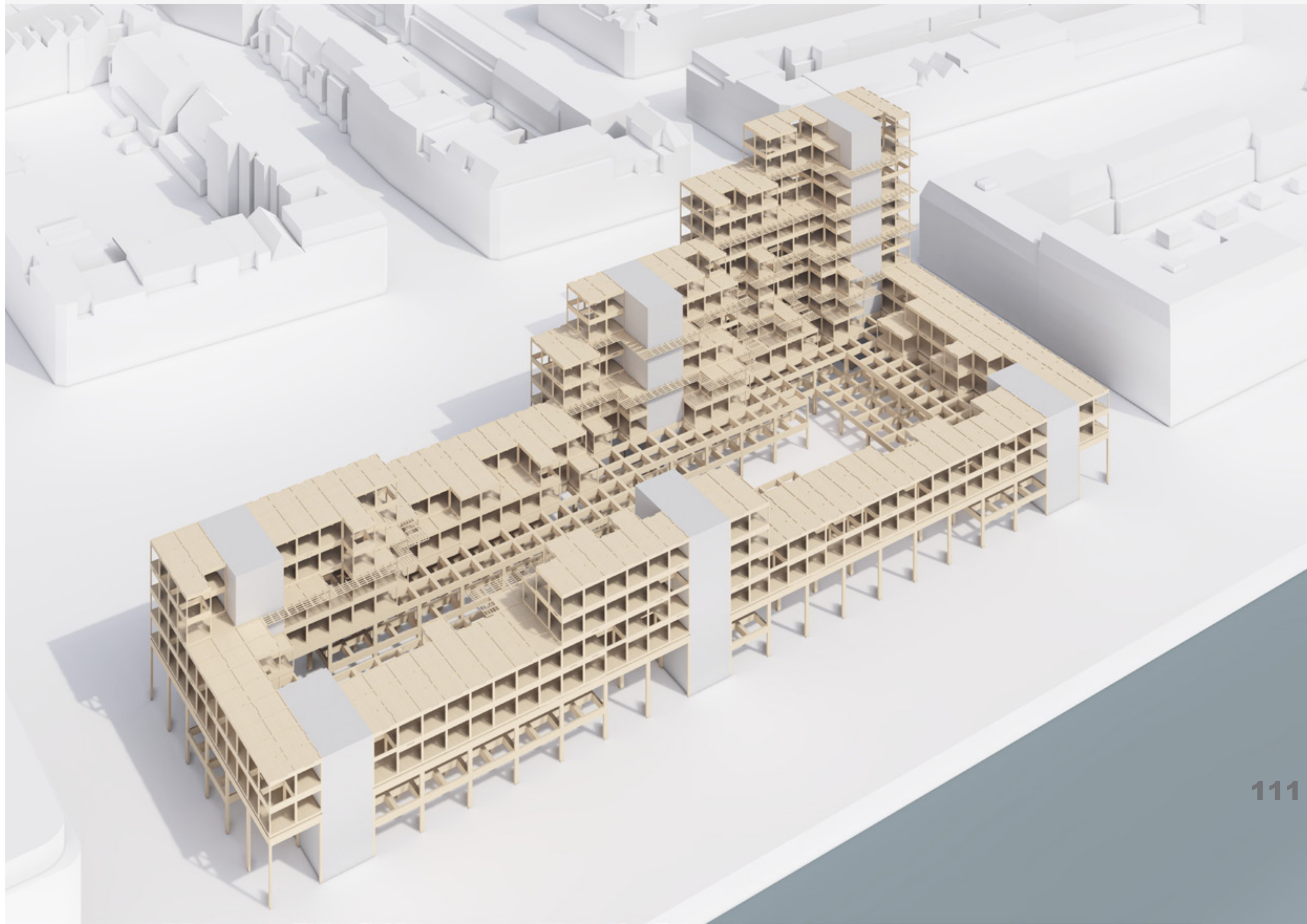


Timber Living Modules



1. **Installation space:**
   wood plank 200/100 mm
   Sound insulation, fibreglass panel 70 mm
2. **Ceiling slab:**
   Cross laminated timber, three layers 60 mm
3. **Beams:**
   Glued laminated timber 95x210 mm
4. **Columns:**
   Glued laminated timber 140/280 mm
5. **Installation conduits:**
   floor duct with steel plate 80 ≈ 150 mm,
   screwed into gypsum fibreboard
6. **Flooring:**
   parquet 10 mm
   cement screed with underfloor heating 70 mm
   separating layer, PE foil
   thermal and impact sound insulation,
   mineral wool 30 mm
7. **Floor slab:**
   Cross laminated timber, five layers 140 mm
8. **Piping**
9. **Installation space and piping:**
   wood plank 120x140 mm
10. **Wall panels**





Detail - Plinth

Detail To anable proper functioning of the building ventilation is decentrally controlled, with a single room fan integrated in the windows (including heat recovery). This made it possible to almost completely dispense with ventilation ducts. The whole building has been designed to make maximum use of the material it is made of.

1. **Ventilation unit with heat recovery**

2. **Installation space:**
   wood plank 89/40 mm
   Hollow metal rail, spring-mounted
   Plasterboard 2x 12.5 mm
   Sound insulation, fibreglass panel 50 mm
   Acoustic mat
   Sound insulation 24 mm
   Battens with intermediate space 19/40 mm

3. **Beams:**
   Glued laminated timber 400/600 mm

4. **Floor slab:**
   Flooring 9 mm
   Sound impact insulation 15 mm
   Thermal insulation with honeycomb structure 30 mm
   Cross laminated timber, three layers 99 mm
   Cross laminated timber, five layers 169 mm

5. **Glare protection:**
   Timber slats (horizontal)

6. **Curtain wall:**
   Triple - glazed window
   Wooden Structure

7. **Installation space:**
   Plywood board 2x 13 mm
   Installation conduits
   Sound insulation, fibreglass panel 2x 25 mm






Imagine, you could grow plants and chat with you neighbours,

or take care of your body with your favorite friend,

create art in a very inspiring environment,

or practice yoga with a bunch of your favorite people,

start a band and meet love of your live,

or just relax and enjoy the sun, living all the troubles behind.

FINAL REFLECTION
ON SOCIAL AND THEORETICAL RELEVANCE

The objective of the thesis is a formulation of a method for the structuring of modules, which usage is intended to enable users, without architectural background, to configure spatial layouts of their dwellings freely. The presented approach to the development of this system is an early design phase. It is therefore difficult to determine its significance. There are a great many aspects that should be investigated further. Such as the influence of component characteristics on the formation of layouts aggregations or the efficiency of constructing buildings in this way. Interest and resources are needed to further develop the system. Therefore, the main focus of this work is to identify the advantages that can arise from the use of modular systems in the residential environment and promote further research.

The work specifies a residential building system modularity construct by defining modules structure as formed from activity requirements, relating interface of modules to the way human movement and by proposing a methodology to operationalise a dimensional system.

Adapting modularity can contribute to the development of end-user cooperation. The main theoretical contribution of this work is the investigation of adaptation of human activities as a factor for creating primary functions defining the modules.

Regardless of this study adaptation of the grid describing the construction environment could provide a basis for further integration of computer techniques in the context of architectural design.

I believe that this project proves that modularity does not have to be limited to the minimums and that it can become the basis for creating very interesting and great places to live with value overcoming standard solutions. A living environment filled with aesthetics as well as special qualities.

The system presented could have a significant impact on changing the perception of where people live and contribute to improving their living conditions and raising public awareness of housing in general. However, it is hard to determine because the performance of the presented system was not tested in real life conditions with people without architectural experience The system also focuses on caring for the environment and its resources, making it possible to create housing with reduced negative impacts.

One of the aspects related to modularity is the possibility to reconfigure the space. This aspect should be subject to further investigation.

The proposed methodology framework was used to create a prototype of a dimensional system for the representation of large scale objects. The concept is based on the assumption that modules are built as separate entities that can function independently.

Regarding future studies, at least three topics can be explored. First, this research has focused on a proximate representation of space-based mainly on pure spatial requirements of performed activities. Therefore there is still a need to explore how to include various physical elements in the creation of modules. Secondly, future studies should also explore the details of interconnections and how they affect performance. Lastly, future studies should investigate the calibration of performance at both the component and the system level.

References

[1] T. T. Lo, M. A. Schnabel, and S. Aydın, ‘Modrule: A Gamified Design Communication Platform’, p. 10, 2016.

[2] T. T. Lo, M. A. Schnabel, and Y. Gao, ‘ModRule: A User-Centric Mass Housing Design Platform’, in Computer-Aided Architectural Design Futures. The Next City - New Technologies and the Future of the Built Environment, vol. 527, G. Celani, D. M. Sperling, and J. M. S. Franco, Eds. Berlin, Heidelberg: Springer Berlin Heidelberg, 2015, pp. 236–254.

[3] L. Madrazo, Á. Sicilia, M. González, and A. M. Cojo, ‘Barcode Housing System: Integrating floor plan layout generation processes within an open and collaborative system to design and build customised housing’, p. 16.

[4] R. Reubens, Holistic Sustainability Through Craft-Design Collaboration, 1st ed. Abingdon, Oxon ; New York, NY : Routledge, 2019. | Series: Routledge studies in sustainability: Routledge, 2019.

[5] J. Iivari and J. R. Venable, ‘Action research and design science research - Seemingly similar but decisively dissimilar’, p. 13.

[6] I. Horváth, ‘COMPARISON OF THREE METHODOLOGICAL APPROACHES OF DESIGN RESEARCH’, p. 12.

[7] C. Rocha, C. Formoso, and P. Tzortzopoulos, ‘Adopting Product Modularity in House Building to Support Mass Customisation’, Sustainability, vol. 7, no. 5, pp. 4919–4937, Apr. 2015, doi: 10.3390/su7054919.

[8] H. Voordijk, ‘Construction management and economics: the epistemology of a multidisciplinary design science’, Constr. Manag. Econ., vol. 27, no. 8, pp. 713–720, Aug. 2009, doi: 10.1080/01446190903117777.

[9] M. L. Maher, S. J. Simoff, and J. Mitchell, ‘Formalising building requirements using an Activity/Space Model’, Autom. Constr., vol. 6, no. 2, pp. 77–95, May 1997, doi: 10.1016/S0926-5805(96)00171-9.

[10] T. M. Press, ‘The Structure of the Ordinary | The MIT Press’. https://mitpress.mit.edu/books/structure-ordinary (accessed Mar. 21, 2020).

[11] Y. Cuperus, ‘AN INTRODUCTION TO OPEN BUILDING’, p. 10.

[12] S. KENDALL, ‘Open Building Concepts’. http://open-building.org/ob/concepts.html (accessed Mar. 21, 2020).

[13] K. Patelia, J. Pitroda, and J. J. Bhavsar, ‘APPLICATION OF MODULAR COORDINATION CONCEPT IN CONSTRUCTION INDUSTRY’, p. 9, 2013.

[14] K. T. Ulrich, ‘The role of product architecture in the manufacturing firm’, p. 38, 1992.

[15] J. B. Dahmus, J. P. Gonzalez-Zugasti, and K. N. Otto, ‘Modular product architecture’, Des. Stud., vol. 22, no. 5, pp. 409–424, Sep. 2001, doi: 10.1016/S0142-694X(01)00004-7.

[16] F. Salvador, C. Forza, and M. Rungtusanatham, ‘Modularity, product variety, production volume, and component sourcing: theorising beyond generic prescriptions’, J. Oper. Manag., vol. 20, no. 5, pp. 549–575, Sep. 2002, doi: 10.1016/S0272-6963(02)00027-X.

[17] F. Salvador, ‘Toward a Product System Modularity Construct: Literature Review and Reconceptualization’, IEEE Trans. Eng. Manag., vol. 54, no. 2, pp. 219–240, May 2007, doi: 10.1109/TEM.2007.893996.

[18] M. J. Ostwald, ‘Le Corbusier (Charles Edouard Jeanneret), The Modulor and Modulor 2 – 2 volumes. Basel: Birkhäuser, 2000.: Reviewed by Michael J. Ostwald’, Nexus Netw. J., vol. 3, no. 1, pp. 145–148, Apr. 2001, doi: 10.1007/s00004-000-0015-0.

[19] R. Itham Mahajan, ‘THE INEVITABLE ORDER: Revisiting the Calibrated Biomimetics of Le Corbusier’s Modulor’, presented at the LC2015 - Le Corbusier, 50 years later, Nov. 2015, doi: 10.4995/LC2015.2015.895.

[20] L. Corbusier, The Modulor and Modulor 2. Springer Science & Business Media, 2004.

[21] M. Zawidzki, Discrete Optimization in Architecture. Singapore: Springer Singapore, 2016.

[22] L. Madrazo, O. Rivera, G. Costa, and Á. Sicilia, ‘BARCODE HOUSING SYSTEM: ENABLING USER PARTICIPATION IN HOUSING DESIGN AND CONSTRUCTION’, p. 15.

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