SPACE META-MORPH-OSIS

PROJECT TITLE
Space Metamorphosis

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ENCLOSED CONTENT:
Common Floor Plan 1:200
Private Floor Plan 1:100

ABSTRACT

This thesis was developed during the 2nd semester of the second year of a Master Degree in MSc. in Architecture and Design, Aalborg University.

The concept behind Space Metamorphosis was born several years ago during an open competition during which the main idea started to grow in our minds. This project's aim is to push further the theoretical approach of the concept but mostly to apply it concretely to a site with its context, users, climate and other constraints. The project being ambitious and experimental, this report contains an important part of research and theory regarding the prior studies and possible physical realization of the concept.

We believe that the development and notion of Space Metamorphosis has the potential to address problems related to urban sprawl and overuse of resources, while creating an attractive platform for working and living spaces. Space Metamorphosis is a cycle of space transformations which occurs as a result of function changes according to a given time interval based on place, people and resources. The sustainable approach of the project highlights the necessity of using resources efficiently. By developing the principle of overlapping functions the project's ambition is to decrease the amount of building's embodied energy and minimize the amount of waste energy, therefore maximizing the potential of both built spaces and used resources while offering great quality of life to its users.

CONTENT

PART II

INTRO

*Fig 1.***Urban sprawl example in Anthem, Henderson, Nevada, USA.**

Fig 2. **Open space working environment. ANZ Centre in Melbourne**

*Fig 3.***Moving walls of "All I Own" appartment in Barcelona**

[1] [2] Mozas, J. Fernandez Per, A. 2006. p. 43

PROBLEM DESCRIPTION

Space and energy consumption are a recurring problem in most countries right now. Every year more and more people move to urban areas and, as our cities expand, urban sprawl (fig 1) is affecting our quality of life and the environment we live in. Therefore the discussion about dispersed city versus compact city is taking place. As a possibility to turn towards a more sustainable living, optimize land use, reduce the need to travel and decrease energy use, people might reconsider their living habits. According to the statistics, the number of person who make up the family unit or cohabit will be divided by two in coming years [1], meaning that in order to maintain the same level of activity in urban areas, it will require to increase the density and optimize the use of the space.

Currently, the basic premises of living are being reformulated and becoming more flexible and indifferent. *"The attachment to the place, where one lives and where one works is decreasing, gradually people are getting away from the rigid system which was shocked from everything foreign."* [2] This statement gives us an opportunity to assume that people are getting prepared for a change in the way they occupy their working and living spaces. Driven by economic and social mechanisms as well as technological innovations people are appearing to be more flexible in the way they travel and the way they adapt to new environment.

In order to follow new trends based on different changes in our understanding of functional cities as well as an increase of mobility and flexibility, the idea of compactness is introduced. Regarding the office spaces, there is a tendency of reducing the square meters per individual mainly because of an increase in collaborative (fig 2) and team-oriented working process and mobility of working methods. Richard Kadzis, CoreNet Global's Vice President of Strategic Communications claims: *"More companies are adopting open floor plans in which employees do not have any permanently designated space at all; rather they use unassigned space when they are in the office, settings that often change daily. This trend is enabled by technology and by cost measures, as they require smaller footprints."* [3] There are many examples of apartments, such as SOHO apartment in New York, "All I Own" apartment in Barcelona (fig 3) or the Gary Chang apartment in Hong Kong, creating virtually gained square meters by introducing built-in transformable furnitures and moving walls.

At the same time most of the current buildings are not used to their full potential. The spaces are not designed according to smaller time intervals, such as day and night. Because of the mono function of the spaces, they can be used only for certain activities at certain times, while leaving them empty volumes and useless the rest of the time. Offices are empty at night for example and the opposite roughly goes for housing units. This waste of space also increases energy consumptions, use of land and resources. It is a paradoxical inconsistency of how people are looking for solutions to decrease the amount of their personal square meters used at home or at work, while our cities are full of unused and wasted spaces during certain time intervals.

OBJECTIVE

These tendencies described above give a foundation for reflections and experimentations within the field of architecture and engineering. In order to explore the possibilities maximizing the potential of use of spaces and resources, this master thesis will suggest a concept where relationship between Space and Time will be explored and connected to the idea of form transformation - Metamorphosis*. The objective of these experimentations will be to find out if the suggested concept can contribute to improve current issues related to social, economic and environmental changes.

To achieve that the thesis will consist of two main parts: theory and practice. It will include theoretical research, analysis and reflections followed by the building design, which will be presented as one possible solutions of space transformation.

The first part will be using research and analysis to identify main architectural and engineering aspects related to the idea of space transformations. These findings will help to establish a definition for Space Metamorphosis and its main components, which later will be implemented in the practical part of the project.

The second part of the thesis will be the design of an experimental building in Copenhagen which will suggest a new urban typology, where spaces will be designed according to local plan requirements combined with Space Metamorphosis principles established in the theoretical part.

***** *Metamorphosis* - **a change of the form or nature of a thing or person into a completely different one, by natural or supernatural means.**

[3] PR Newswire for Journalists, 2012.

PROJECT CHALLENGES

Developing a new urban typology to address social, economic and environmental issues sets a number of architectural and engineering challenges.

The project will focus on finding the ways of maximizing the potential of built spaces and resources while creating architecture with tectonic qualities. In this project we define tectonic as enhanced and expressive. By enhanced, we envision that materials should be honored, used to their full capacity and for what they are made as the famous Louis Kahn quote about the brick states about its desire to be an arch [4] because that is where the brick is performs best. To define expressive, we refer to Sekler who claims that : "Tectonics is a certain expression which could not be described by only structure or construction. Expression could be achieved by order of structure or method of construction. When construction appear to be mutually interdependent-it loses its architectonic qualities." [5] Following that, the construction technique has to deliver its expressive potential and has to assist and be part of the space transformations.

The understanding of tectonics together with considerations about the sustainability will form a framework to deal with main project challenges:

-Relationship between public, common and private.

-Relationship between fixed (static) and movable (dynamic).

-Personalization of the spaces and surfaces.

-Design attractive spaces with atmospheres and changing experiences.

-Servant spaces and their relationship to public and private.

-Balance between heat gain and heat loss.

-Decrease the amount of embodied energy in building construction, operation and maintenance.

The architectural challenges will be addressed using structure, facades, materials and details to create connections or separations between different elements and layers. Structure will also appear as a key tectonic element of space transformation. Meanwhile engineering challenges will focus on using passive strategies and strategic function combinations to ensure good thermal environment and decrease energy demand. Following the experimental nature of the project, the resolutions of the challenges will appear provisional and will be influenced by the specific site and its features.

[4] Kahn, L. 1971. *"Even a Brick wants to be Something"*

-'What do you want, brick?'
-'I like an arch.'
-'Look, I want one, too, but arches are expensive and I can use a concrete lintel. What do you think of that, brick?'
-'I like an arch.'"

[5] Eduard, S. 1965.

METHOD

The method for developing the concept of Space Metamorphosis and a new urban typology will be based on a reformulated version (fig 4) of the Integrated Design Process, where the knowledge from both architectural and engineering realms are equally important and have mutual symbiotic relationships. According to Mary-Ann Knudstrup, the process should focus on integrating knowledge from both fields from early phases of the project, promoting the interaction between each other in order to solve the problems connected to the design of sustainable buildings.[6]

As the concept is visionary, it requires some modification to the original Integrated Design Process model in order to fulfill the objectives set for the project. Formulated in 2004, it originally contains five phases: Initiating problem, Analysis, Sketching, Synthesis and Presentation. In this project there is a big step between the problem definition and sketching phase, therefore there should be more stages in between. As we are aiming to elaborate on a new way of designing transformable spaces it requires to define the mechanism of Space Metamorphosis, which will be based on the analysis of Space and Time, users and their habits, inspirations and function combination. All those studies will establish the main components of the concept which later will be used in sketching and synthesis phases.

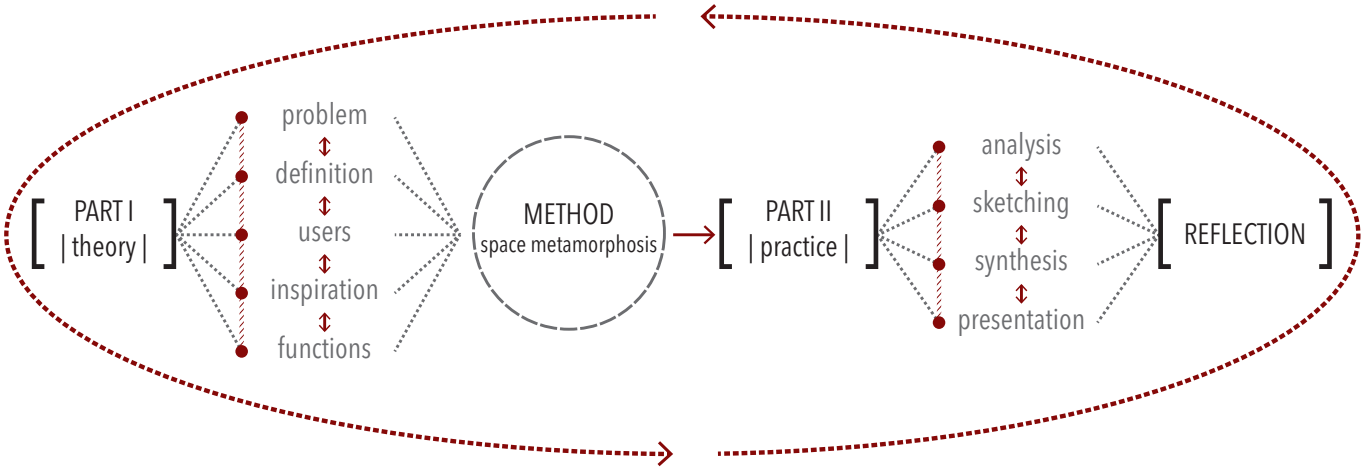


*Fig 4.***Reformulated Integrated Design Process to fit the objectives of the project**

[6] Knudstrup, M. 2004.

PROCESS

PART I: THEORY

PHASE 1 *(problem)*. The process will start with defining the problem related to economic, social and environmental issues occurring in cities.

PHASE 2 *(definition)*. This part will consist of theoretical readings about Time and Space, which will establish a definition of Space Metamorphosis. It will include physical and philosophical discussions of the topic as well as explanation of the Time factor within this concept and reflections on how it can affect the design of space. It will contain observations on how we can create an architecture for an updated model of lifestyle based on our perception of time and flexibility. It will also include a reflection upon the elasticity of public and private spaces for finally draw conclusions and narrow down important aspects of the vision.

PHASE 3 *(users)*. By analyzing statistical data and survey, the second phase will provide information about the target users of the experimental project. It will expose statistic information about living and working conditions in Copenhagen using accessible database "Statistics Denmark" and articles. These finding will be analyzed and discussed in order to get a more critical understanding about the situation in Copenhagen. To reinforce this study, the results from an online survey "Living Habits" * will be evaluated but will not be considered as a main information source as it will provide insights about which living habits citizens of Copenhagen have, if they are ready to change them, if there are any conditions for change and who would be the potential users of the project.

* *Living Habits* **personal survey, with objective to find out users' opinions about their living habits**

PHASE 4 *(inspirations)*. This part will be dedicated to find architectural and engineering references, which will support the concept of Space Metamorphosis and provide inspiration for the project. Those references will be investigated according to the important aspects of the concept. These projects might not be related to the project directly, but will reveal opportunities when dealing with architectural and engineering challenges.

PHASE 5 *(functions)* Space functional analysis will take place in order to find out the possibilities and constraints within the idea of mixing function according to a given time interval. This phase will start with looking at all possibilities and will gradually exclude unfavorable function combinations. The aim of the study will be to suggest intersection points between different functions which are not compromising the expectations of the users and provide attractive qualities to their everyday routines. As a conclusion, the theoretical part will summarize the principles of Space Metamorphosis which will be implemented into the practical part.

PART II: PRACTICE

PHASE 1 *(analysis)* This phase will be responsible of performing the site analysis, which will include urban and climate studies. The results will be evaluated and will serve as a second layer of concept implementation.

PHASE 2 *(sketching)* The focus of the Sketching phase is to arrange different studies in order to elaborate on the established principles of the concept. Using design loops this phase will include both engineering and architectural elements, which will be affecting and adjusting each other to reach unity. It will contain hand sketches, physical and digital models, diagrams. The use of softwares will be selected according to the task.

PHASE 3 *(synthesis)* Based on sketching, the synthesis phase will unite all the components of the building design. This phase will include more detail investigation and therefore will include working on different scales.

PHASE 4 *(presentation)* The last phase of the second part will be devoted to present the produced material, it will focus both on process and final proposal. It will use both written and graphic communication in order to explain the project from different sides and at different scales.

REFLECTIONS

The last part of the thesis will aim to reflect upon the proposed theoretical concept and its implementation in the practical part of the project. Because of the experimental nature of the thesis, the reflection section will discuss advantages and disadvantages of the proposal, its feasibility and how relevant the concept is in relation to defined problem.

PART I

METAMORPHOSIS

The concept of space transformations in this project will take its inspiration from natural means. Metamorphosis is a common phenomenon in biological world, especially among insects, characterized by a change of physical conditions, habitat or behavior. In architecture metamorphosis can be used to describe how a building becomes a space catalyst, for example Santiago Calatrava have arranged an exhibition "The Metamorphosis of Space" (fig 5), where he points out that new, iconic buildings make spaces around to evolve and change.

Another example of metamorphosis in architecture is related to a timely reaction of materials, which became possible by various technological developments. For instance, it is possible to modify the opacity of a window glazing according to the sun using a chemical reaction between liquid and gas. Responsive facade skins can react to their direct thermal environment (fig 6). Both of these transformations are reversible and can be either automated or manually controlled.

However, Space Metamorphosis, characterized by the ability to change and adapt according to different users, uses and time, is an unexplored field in architecture. We believe that the development and notion of Space Metamorphosis concept has a potential to address problems related to urban sprawl and overuse of resources, while creating an attractive platform for working and living spaces. To understand how space metamorphosis can be achieved it is essential to analyze the relationship between Time and Space. Where Space is three dimensional, or at least that is all we perceive, Time can be felt as intervals directly related to the way people distinguish hours, days, weeks, etc. Theorist Paul Virilio named this relationship time-space compression* and claims that it is an essential facet of contemporary life. [7]

Fig 5. **Model of Roma Palasport project for exhibition "The Metamorphosis of Space"**

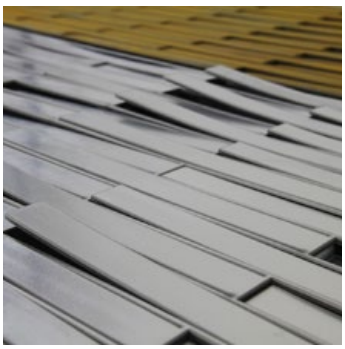


Fig 6. **Responsive facade model by research based architectural studio AREA**

***** *Time–space compression* **(also known as space-time compression and time–space distansiation), first articulated in 1989 by geographer David Harvey in The Condition of Postmodernity, refers to any phenomenon that alters the qualities of and relationship between space and time.**

[7] Decron, C. 2001. p.69-81

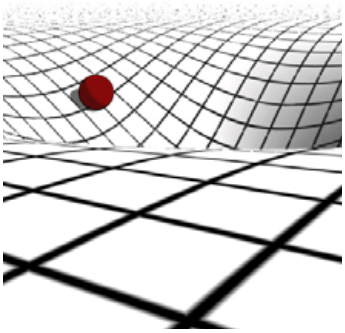


Fig 7. **Four-dimensional description of the universe including height, width, length, and time.**

TIME AND SPACE

As the project is aiming to elaborate upon the relationships between Space and Time and introduce the time factor in the way we design buildings, the research part will start with a discussion on this matter.

To get a better understanding about Space and Time we studied some physical and mathematical theories. We believe that physics and the organization of our universe can give us with some insights to develop the concept of space transformations. For example, Le Corbusier was very interested in mathematical laws and was describing mathematical knowledge as *"flashes of fundamental truth…"*, and compared mathematics to the realm of the gods, the room which holds the key to the great systems [8]. We see physicians as great thinkers, therefore we can learn from their theories and see if their understanding of Time and Space can be applied in architecture.

In the nineteenth century many famous physicists were exploring the relationships between Space and Time. Einstein was the first one to summarize all the research and suggest that space and time can no longer be taken independently. In 1908, Hermann Minkowski argued that space and time could be seen as components of a single four-dimensional spacetime (fig 7) fabric : *"Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality"*.[9] Those discoveries were very important in the scientific world as it allowed to explain and simplify many theories. This tight Space and Time connection in astrophysics and mathematics gives us ground for looking at both parameters as a whole also in architecture.

[8] Peter. C. 1991. p. 48

[9] Einstein's Spacetime

In architecture we often use the term "time" to talk about history, past, present or future. Architecture is described as time based art as it changes according to our perception and experience of the space. We can often hear the expression "architecture of now" and we can clearly imagine, what it is and how it was 20 years ago. Architecture and time have always been close, however, in this project we would like to explore another slightly different definition of time.

Time can be described as intervals or duration, it can be hours, days, weeks, months or seasons, but any given interval will never be perceived the same way. This is why the notion of elasticity is introduced. To better illustrate this time definition, we can consider this situation: on regular days, most people leave their house in the morning and come back in the evening. In contrast to their dynamic lives, the house's status, in their mind, is somehow frozen in time. (fig 8) For them, the house doesn't move and when they return, they expect, quite logically after all, that it will be there, waiting for them, in the exact same state that they left it. Just as if the house's time frame was suspended during their absence, it is as if the house itself ceased to exist the second they left. In scientific words it can associated with time dilation. This term, again, was introduced by Albert Einstein when he suggested that time slows down, stretches out, dilates, in a moving reference frame.[9] Such definition of time, as an interval, which speed depends on a given reference point, was the most revolutionary conclusion of relativity theory. So, if we relate such understanding of Time with the concept of Space Metamorphosis, the principle of the mechanism can be described in such terms: The idea is to take virtually non-existent lapses of time fixed for users and their reference frames and to stretch it in order to introduce more uses. In other words, give it a double identity in a parallel life from their users' perspective. Such use of Time gives a dynamic character to the Space, so that it can respond to a changing environment, therefore approaching closer to a natural process.

A more philosophical description of Time and Space can be found in the works of cultural theorist and urbanist Paul Virilio, where he talks about time-space compression. This phenomenon occurs as a result of technological innovations, which decrease physical and communication distances. By inventing trains, later cars and planes, people changed their perception of the relation between Time and Space. The same effect occurred when humanity invented telegraph, telephone and, nowadays, Internet. We can also draw a parallel with the building industry, new designing and building tools and methods such as parametric design and 3d printers allow us to accelerate the process of construction. According to Paul Virilio *"Today we are entering a space which is speed-space... This new other time is that of electronic transmission, of high-tech machines, and therefore, man is present in this sort of time, not via his physical presence, but via programming"*.[10] We believe that changes in the way we perceive timeframes, distances, have direct effect on our lifestyle and how adaptable people are in relation to their living and working spaces,giving us opportunities to explore the characteristics of users' flexibility.

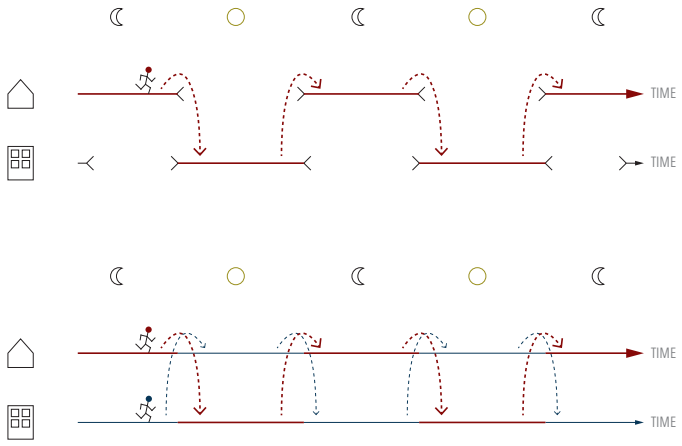


Fig 8. **Graphic representation of time elasticity. First example shows current situation, when the space left is unused. Second example suggests the idea of using the gap for another function.**

[10] Decron, C. 2001. p.69-81

FLEXIBILITY OF THE USER

The era of globalization and "speed space" has an effect on our idea about the place and our attachment to it, therefore the aspect of users' flexibility will be examined for its direct relation to the concept of Space Metamorphosis. According to Richard Sennet :*"There are more and more people who feel the urge to live the life of a nomad, who would live anywhere in the world and who could hardly remember where they lived just ten years ago."* [11] This sort of flexibility gives a certain impression of freedom, when it is possible to pack a bag, leave and quite easily find a new place to call home. The rigid system of attachment to the living or working spaces is decreasing and people are becoming less afraid of the unknown. Moreover, for many people this "unknown" is a source of inspiration and satisfaction as it prevents routine.

Despite the global changes and increased flexibility, we are still facing a lot of the "My house is my castle" philosophy, and this is not necessary about the spaces people live in, it spreads to their cars, goods and everything they own. Many people prefer to be the owners of a very few things, rather than to share many with others. Therefore, the idea of mixing functions, especially sacred ones, such as housing, can raise many questions and upset certain users. The well-being of the individual can be directly connected to the place they live in and how they feel at home. Many would not sacrifice their strong relation to their home, even if they could get other benefits, therefore the project will not seek to change individuals nor to compromise their well-being, but it will rather concentrate on the users who have desire to experiment and cooperate.

The project will aim at exemplifying that there can be different possibilities of the use of Space based on Time intervals and co-existing with strangers can have a positive effect on social sustainability. As Richard Sennett says: *"About the sociability of living with strangers: the mark of the civic realm now is mutual accommodation through dissociation. That means the truce of letting one another alone, the peace of mutual indifference. (...) On the negative side, mutual accommodation through dissociation spells the end of citizenship practices which require understanding of divergent interests, as well as marking a loss of simple human curiosity about The Other."*[11] This peace of mutual indifference in our opinion can not be an appropriate solution. Cooperation between users, where everyone is interested in achieving results and a variety of experiences is an important part of the concept and we agree with the statement of Senneth that there can not be an "end of citizenship". This curiosity about The Other must stay, and be accepted, if our concept wants to be implemented because of the strong need of trust and tolerance required.

The concept will look at the possibility of creating a balance between mutual indifference and curiosity about The Other by looking at relationships between public and private, owned or rented, while providing a flexibility, which is becoming more and more popular, as people prefer to get experiences, rather that own goods.

[11] Richerd Sennett, 2008, p 21

PUBLIC vs PRIVATE

Elasticity of public and private spaces is an essential element when talking about the concept of overlapping functions. Public and private are two extremes, antipodes, and each of them can be described with many elements and qualities. Public space associates with flow, velocity and openness, while private space appears to be enclosed, tranquil and intimate. Public usually has a close relation to exterior, while private represent the interior protected space. Relationships between those two realms varies greatly, and there are possibilities of public space becoming private and vice versa.

The strong character of each realm suggests that in order to overlap them there should be a mediator, which assists in creating a continuous journey. In architecture the term semi-public, or semi-private, is often used to describe the transition spaces, however in our understanding this space becomes not defined and often not used to its full potential. For examples, shared courtyards inside high-rise blocks (fig 9), according to our experience, are empty most of the time because their function is not specified. Only sometimes used for parties or outdoor meals, people tend to prefer either very vibrant public spaces, with many people and noise or their sacred private space. Therefore the project will not aim at reproducing semi-public spaces, it will rather work with common spaces, which have clear functions and usage pattern. If we relate this common layer to the building it will represent the intermediate layer.

As a result the gradient of privacy (fig10) can be organized in three scales: EXTERIOR/*public*, INTERMEDIATE/*common* and INTERIOR/*private*.

Fig 9. **Courtyard atmosphere by BIG, Orestad, Copenhagen**

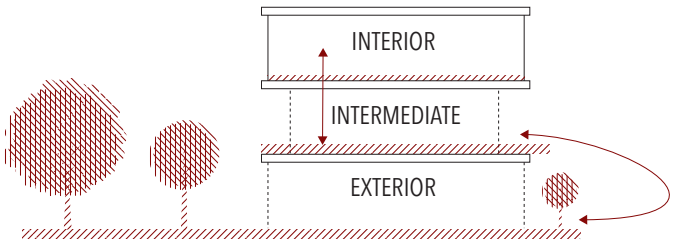


Fig 10. **Gradient of privacy starting with public, transforming to common areas and reaching private units.**

SPACE QUALITIES

While the project is exploring the theme of flexibility and space transformation, it does not suggest that the sense of place should disappear. The idea of Space Metamorphosis will not focus on designing faceless spaces that do not have any character and can be easily occupied by any user or function. Rather, the aim would be to design spaces with tectonic qualities, which in this project are defined as enhanced and expressive.

As the idea of metamorphosis suggests a change of state and character of the spaces caused by external action, such as Time, it was important to define the contrasts of different tectonic qualities and how they affect atmospheres. Those qualities will help to underline the difference of experiences of the spaces before and after metamorphosis.

SCALE. The sense of scale which follows the privacy gradient, where public and circulation spaces will appear grand and open, while private spaces will get more cozy and enclosed. This effect will be assisted by articulated structural elements.

LAYOUT. The contrast between open plan layouts for common uses and corners or pockets for individuals.

LIGHT. Experiences of diffused northern light and direct southern sunlight, which reveals the qualities of chosen materials.

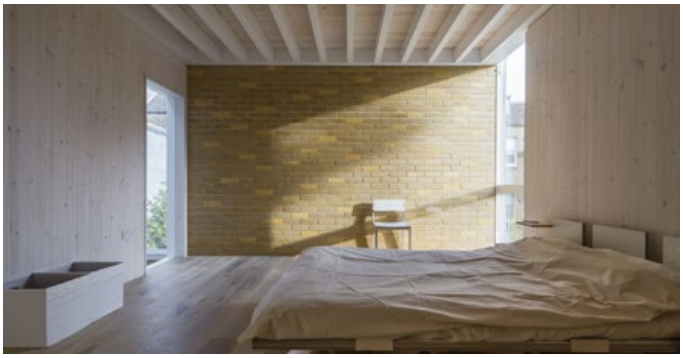
MATERIALS. The use of tactile materials which supports different atmospheres, warm for relaxing and living versus calm for working and thinking.

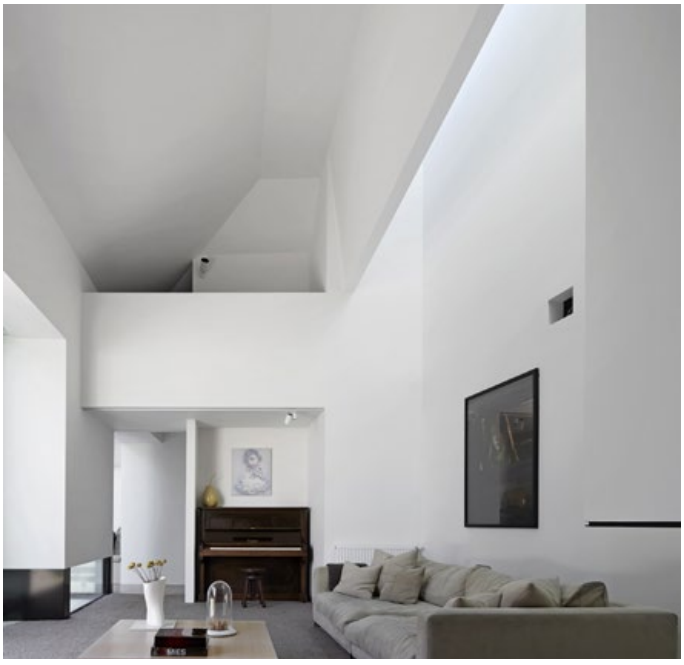
FURNISHING. The design, details and finishings of furniture elements, which will reinforce the attachment to the space.

RELATION TO EXTERIOR. The different character of the facade which reflect the features of the hard urban areas and soft park zones.

CONNECTIONS. Dynamic links between different layers by vertical and horizontal flow elements, which express the characteristics and properties of the structure.

Fig 11 (opposite) **A selection of reference pictures illustrating spacial qualities.**





DEFINITION

Theoretical analysis about Space and Time, flexibility of the users and sense of place, helped to formulate an early definition of Space Metamorphosis and establish important aspects to consider in the process of developing the concept.

Space Metamorphosis is a cycle of space transformations, which occurs resulting a function change according to a given time interval, such as hour, day, week, etc, and is based on time, place, people and resources. The cycle has a direct effect on three main scales: EXTERIOR/public, INTERMEDIATE/common and INTERIOR/private (fig 12).

Reflections about Time revealed an interesting observation: time elasticity, which opens possibilities of exploring the double identity of the space. The importance of the way users perceives the spaces emphasizes the value of designing places with identity and character, bringing a tectonic quality of expressed structure. By focusing on both the well being of an individual and the comfort of the community, the aim of the concept will be to promote cooperation and establish a balance between public and private. People, their everyday routines, their relationships with each others and their motivation to live more sustainably are crucial to allow Space Metamorphosis to take place. The sustainable approach of the project highlights the necessity of preserving resources. By developing the principle of overlapping functions, the project's ambition is to decrease the amount of embodied energy simply by building less, and to minimize the amount of waste energy as it can be directly used by other users, therefore maximizing the potential of both built spaces and used resources.

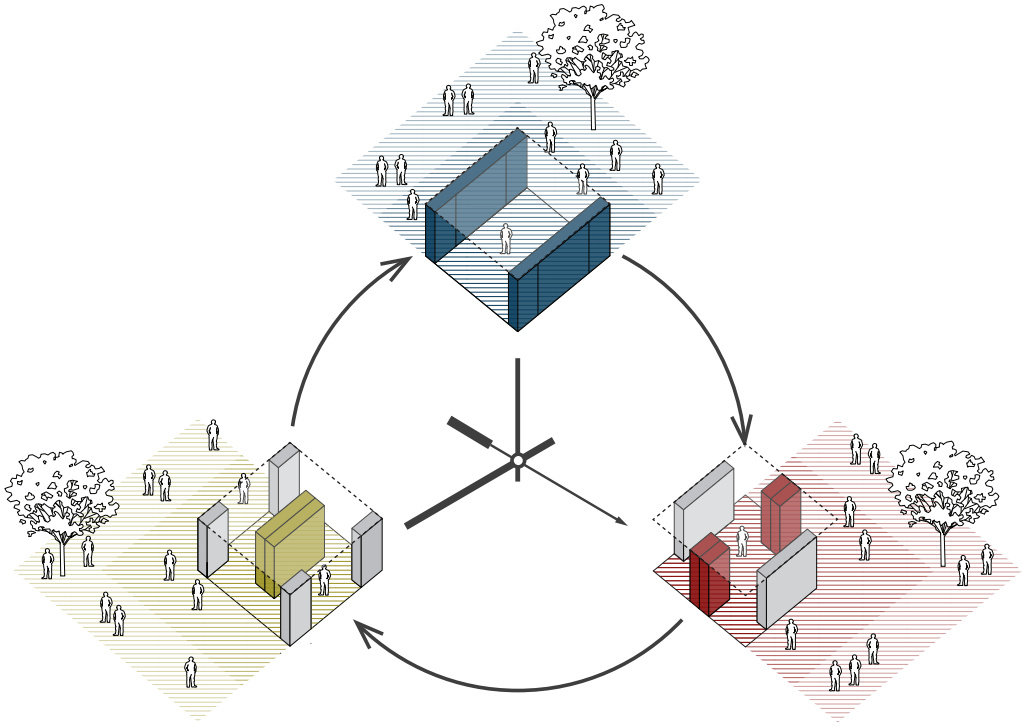


Fig 12 **The diagram illustrates the relationship between the layout and character of the space according to a time interval. It also shows how the interior transformation affects the intermediate and public levels.**

USERS

STATISTICS AND DATA

In Copenhagen housing situation currently has certain issues such as the lack of student housing, the shortage of affordable housing and so on. The project will aim to explore an experimental and ambitious strategy, where more density does not necessarily means less space for oneself, where people will be able to save money and energy while avoiding compromises and improving the quality of space they occupy.

To get a more comprehensive understanding of social and economic situation in Copenhagen, a number of statistics were analyzed together with an online survey. Those studies should provide a better understanding about the flexibility, issues related to living expenses and attitude towards space sharing. It will also be a tool to define a user group for the experimental project.

Fig 13. (opposite top left) **Dwellings by tenure**

Fig 14. (opposite top right) **Dwellings by tenure and use**

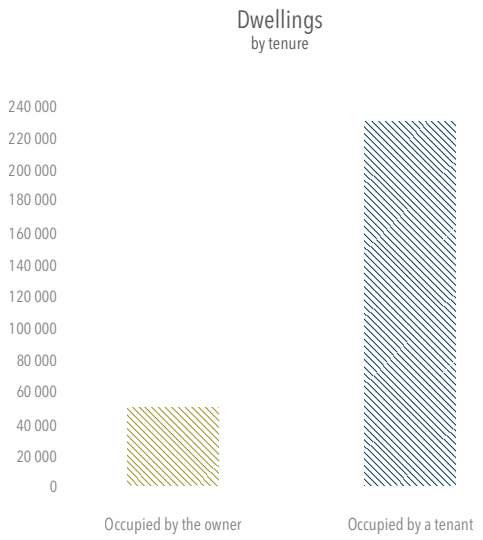
Fig 15. (opposite down left) **Households members by age and finan-**

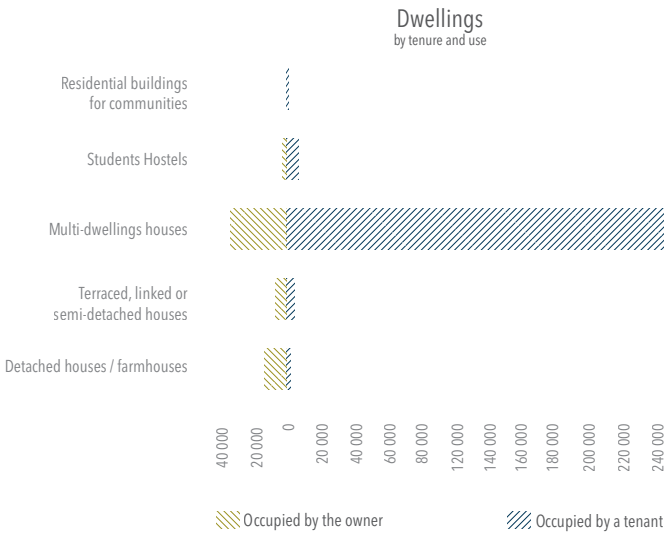
Fig 16. (opposite down right) **Households members by ability to make ends meet**

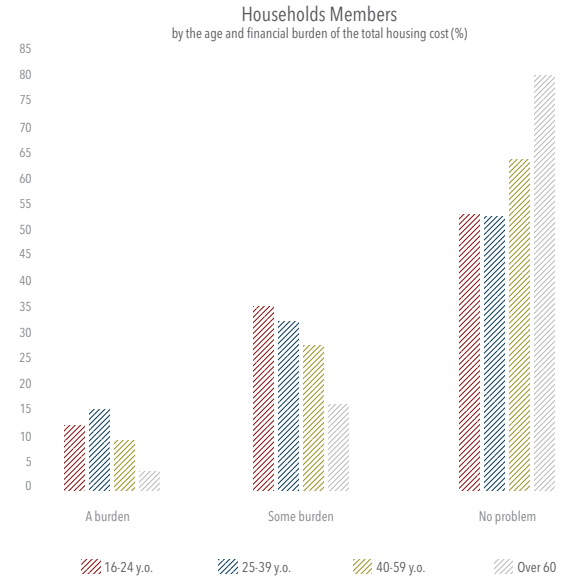
As the project is aiming to promote a sharing philosophy, we will look at the current situation in Copenhagen comparing the amount of tenants and owners, as we believe that this can be a crucial point when talking about flexibility, people tend to be more flexible when they do not own spaces. According to data, in 2014 in Copenhagen the amount of dwellings occupied by tenants was 4.7 times higher than dwellings occupied by owners (fig 13). The biggest amount of tenants and owners live in multi-dwelling houses, however the number of dwellings occupied by tenants is 7 times more (fig 14). There are also many tenants living in student housing, while a big part of owners prefer detached houses. These graphs summarize the situation and suggest that in Copenhagen, the inhabitants prefer to be tenants, because of the high living expenses.

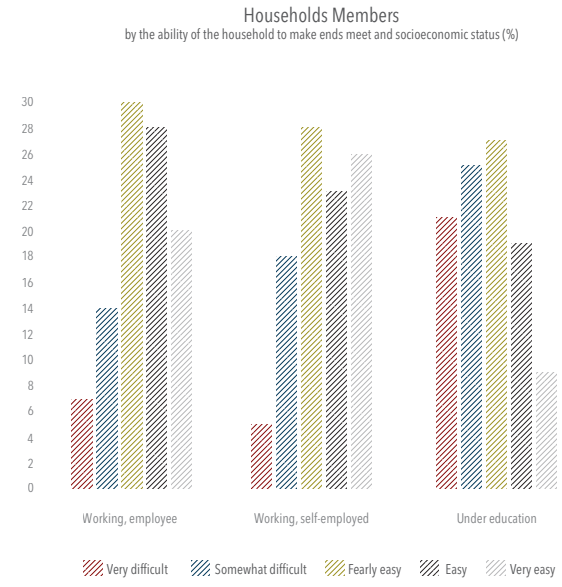
For further analysis we will look at how difficult or easy it is for different age groups and socioeconomic status members to make ends meet. In every age group more than 50% of people does not experience any financial burden on the total housing cost. The most vulnerable age group is 25-39 (fig 15), in which about 15% experience financial burden and 31% have issues with it. Group ages before 40 and after 59 also experience some financial problems, but after 60 years the number is dropping down. Looking at socio economic status we can conclude that households with low education have more chance to have problems at the end of the month (fig 16). It also shows that 5% of self employed households can find very difficult to meet ends. To sum up, this data analysis displays that households are facing financial burden, meaning that they might be open for new solutions addressing this problem.

[13] Statistics Denmark


Dwellings
by tenure
240 000
220 000
200 000
180 000
160 000
140 000
120 000
100 000
80 000
60 000
40 000
20 000
0
Occupied by the owner
Occupied by a tenant


Dwellings
by tenure and use
Residential buildings for communities
Students Hostels
Multi-dwellings houses
Terraced, linked or semi-detached houses
Detached houses / farmhouses
40 000
20 000
0
20 000
40 000
60 000
80 000
120 000
140 000
160 000
180 000
200 000
220 000
240 000
Occupied by the owner
Occupied by a tenant


Households Members
by the age and financial burden of the total housing cost (%)
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
A burden
Some burden
No problem
16-24 y.o.
25-39 y.o.
40-59 y.o.
Over 60


Households Members
by the ability of the household to make ends meet and socioeconomic status (%)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Working, employee
Working, self-employed
Under education
Very difficult
Somewhat difficult
Fearly easy
Easy
Very easy

SURVEY

As a supplement to the statistic analysis, an online survey was launched in order to find out inhabitants opinions about their living status. The aim of the survey was to receive Yes/No answers on two main questions, which are directly linked to the objective of the project:

1. As a tenant, would you like to pay only for the time that you are present in the flat, or as owner would you to like to gain extra money while you are away?
2. Would you accept if the space you rent/own was used for other purposes (e.g. yoga class) while you are away?

Before answering these two questions and explaining their opinions, participants of the survey stated their age, nationality, occupation, if they lived in Copenhagen or outside and if they were tenants or owners. These parameters will help to identify the user group, who answered positively on both questions.

150 people have participated in the study: 78 % aged between 18-30, 80% were not Danish; 74% live in Copenhagen and 80 % are tenants. The overall results of the survey show that around 50% of people answered that they would like to pay only when they are present in their home. And around 33 % would not mind if their place was used for other purposes (fig 17).

The result shows two main tendencies. First, people think that their home expenses are too high, a lot of them would like to save and second some people can imagine their home to be more flexible and be adaptable to any subsequent use. People have expressed very contradictory opinions regarding this issue. Some were very against the proposal, saying that their house is their private space and they can not imagine place being used for other purposes when they are not present : "Because this way I would feel like my privacy is violated.". Another part of the participants had positive attitude towards the idea, but were concerned about its feasibility and were proposing in which conditions they would accept it : "Actually I'd probably consider the option (although I answered no on the question), but only if it would be extremely easy to transform the space for this other purpose and require basically no effort from me." And finally there were one third of the participants who showed their interest in proposed scenario and expressed their desire to use most of the resources we have : "It is the best way of using the space and getting advantages for everyone", "Providing spaces for different activities is nice".

This survey is supporting the opinion of Richard Sennet, who reflected upon the tendency of seeing our attachment to the place less rigid than it was before. The responses are illustrating that the way people see their living space, their home, is appearing to be more flexible and people could experiment with their lifestyles in order to find the best way to live in Virilio's speed time.

USER GROUP

Based on the analysis of statistics and the survey, the user group of the project have been defined. Because this new experimental typology is partly connected to the financial situation of the households as well as their level of flexibility and possibilities to adapt to different models, the project will focus on individuals, couples or young families, who are still undertaking education or starting their career.

We believe that this group of people have regular routine, for example going to university or work at certain times during the week, and they can be flexible in their definition of the home and have desire of saving money and live in a more sustainable way by saving energy and space. We suggest that an advantage would be not to have children, as they might give less predictable schedules and cause complications, the project will however also explore the possibility of integrating young families in the process.

On the other side we expect that it would be small enterprises, self-employed people who would be the best candidates to use the space while households are away. The field of the industry will be defined more carefully in the site analysis part as it will depend a lot on already existing services located next to the site.

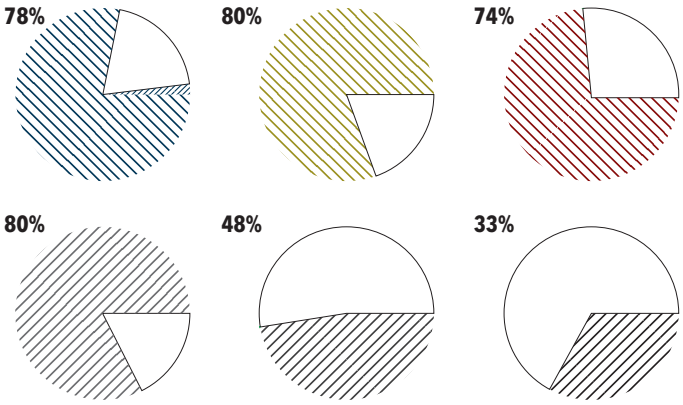


Fig 17. **Results of online survey, the order of the data is described in the text**

INSPIRATION

EXPEREMENTATION

Architecture and design have always been full of innovation and experimentation. During history, architects have been facing different challenges related to aesthetics, function, social aspects, sustainability and so on. They were dealing with these challenges according to the knowledge and tools of that time and not all experimentations led to success, but they were always inspiring to others and were catalyzers for change.

One of the architects who had a chance to change architectural principles was Leon Battisa Alberti. He proposed to exclude time from the making of architecture, which was named "Building-outside-Time". Before his intrusion, the creation of buildings were seen as work of several generations, where buildings were constantly evolving; where people imagined buildings as a work in process, where changes were active tools in the design process. [12]However, in the fifteenth-century, it changed and architects started to think of spaces as perfect and self contained objects. Alberti have changed dramatically the way we perceive buildings in relation to time. This again relates to the Virilio's speed-space mentioned above, the introduction of new visions, technologies and progress has an effect on the way architects and engineers design and create. New tools bring new opportunities and challenges and, in order to deal with them, it is necessary to experiment and by doing that develop new methods and technique which responds to the current and future needs.

In the following pages we will exemplify historic and current experimentation projects related to relationships between different layers of privacy and space transformations.

[12] Trachtenberg, M. 2010

Light and connection to outdoor

Flow pattern

Experimental building Unité d'Habitation by Le Corbusier will also be analyzed to find the relationship between different levels of privacy and exterior-interior connection.

After World War II, architects were facing the great dilemma of designing large scale housing project. According to his concept of "vertical garden city", the Unité d'Habitation was focusing on dense, communal living and proposed a mixed-use building with interior streets, shops, playgrounds, shallow pool and so on. It was, and still is in a way, a radical and challenging idea and he had to work a lot on spatial organization of the apartments as well as the relations between private and public spaces.

By analyzing the section of the building (fig 19) we can make a parallel with the earlier defined three scales of Space Metamorphosis: exterior, intermediate and interior. As the building is lifted from the ground by pilotis, it is not interfering with the public space and nature flow. Interior streets, rather than corridors, between apartments and common activities located on the rooftop are illustrating the intermediate layer. The privacy is more restricted, yet the spaces each have a clear function: street, pool, kindergarten. In between these public and common layers, the private units are located. For the building to operate fully, both horizontal and vertical circulation are needed, they allow users to have a continuous yet changing journey. His efficient system of interlocking volumes allowed to fit more units while providing quality living spaces by working with flow patterns and light.

The organization principle of the unit has many innovative solutions for the time. For example, narrowing the units and allowing for a double height space, while placing a balcony at each end (fig 18) of the units protected by a brise-soleil, that allowed to have cross ventilation flowing through the narrow bedrooms into the high living room emphasizing an open volume rather than an open plan.[14] Those design solutions brought quality to the living spaces which are appreciated by the building inhabitants. The building's layout suggests a specific lifestyle which on the one hand can not satisfy every user, but can bring a lot of value for those who shape their life around the building and explore all opportunities it has to give.

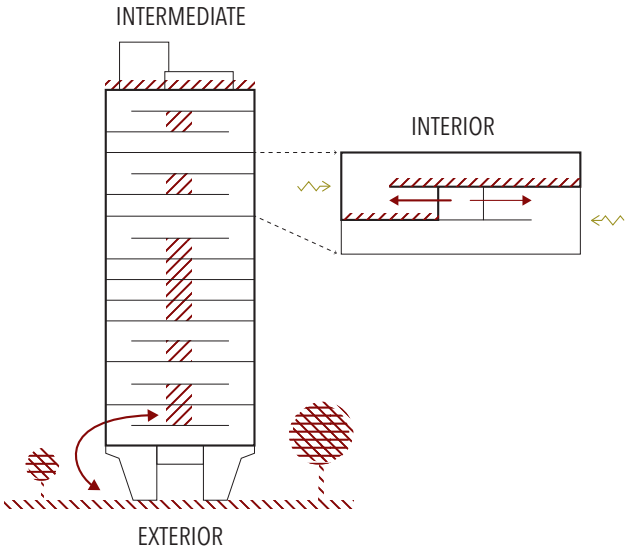


Fig 18 (top). **Repetitive facade of Unité d'Habitation showing how interlocking volumes are affecting the exterior expression**

Fig 19 (bottom). **Section of the building analyzing the relationship between different privacy levels**

[14] Kroll, A. 2010

FLOW AND LIGHT

Following the analysis of the interrelations between three privacy scales, it is interesting to look more closely at Interior/private units and analyze the layouts in terms of flow and light, as in our eyes these are the parameters, which determines the way users occupy and use the spaces. Later in the process these parameters will be implemented, when designing a unit.

The case studies have been selected because of their experimental and transformable nature. The first example is the Schröder House, where the architect Gerrit Rietveld has implemented an innovating concept of moving walls. In 1924, movable walls, which are separating living room and bedrooms were certainly considered as something bizarre. The flexibility of his layout is intriguing and in our mind affect the way users inhabit the space and define their flow patterns.

There is a great difference between the open plan layout (fig 21) and when the main volume is divided into individual bedrooms. The main circulation core is still in the center, however, in the open plan version the flow appears to be much more fluid and has a visual connection to all functional corners and views towards all directions. When the layout transforms into individual rooms, the access becomes more direct and strict and the relationship with outdoor occurs only in one direction.

Multi-functionality of the space was not the only feature he designed in the house, he worked a lot with asymmetrical compositions, primary colours and corner windows which blurs the boundary between inside and outside.

The second case study is a study project of Abalos & Herreros for the contest housing & city that was organized in 1988 by the magazine "Quaderns d'architecture i urbanisme". The architects are proposing a series of changing unit layouts depending on the user, as they see uses as an active participant of the architectural process.[15]

The strategy for the building itself is the maximization of the thickness of the slabs to allow the horizontal deviation of water supply and disposal, enabling to connect the bathrooms and the kitchens in every point of the house, giving a decisive role to the user. The concept explores various space scenarios (fig 22) and also includes a design of special furniture elements (fig x), which is facilitated with technological solutions to allow desired transformations.

By looking at the plan in terms of habitancy and light, the flow pattern and the amount of light entering the rooms is depending on the chosen layout configuration. The relationship to the exterior follows one main direction and the special furniture elements are placed perpendicular to the opening.

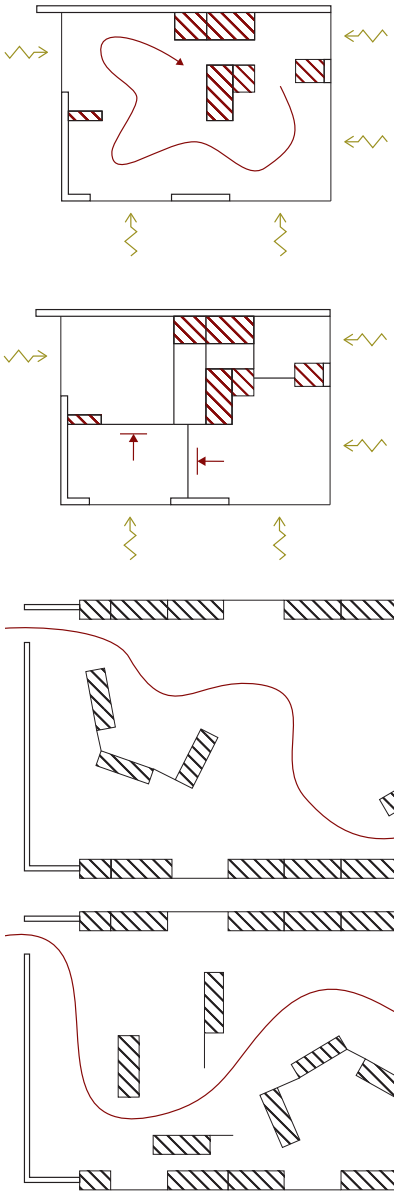
[15] Hacedor de Trampas, 2011

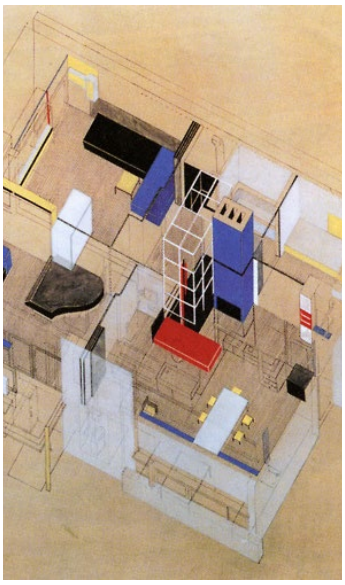
Light/ connection to outdoor

Flow pattern

Fixed space

Movable module/furniture





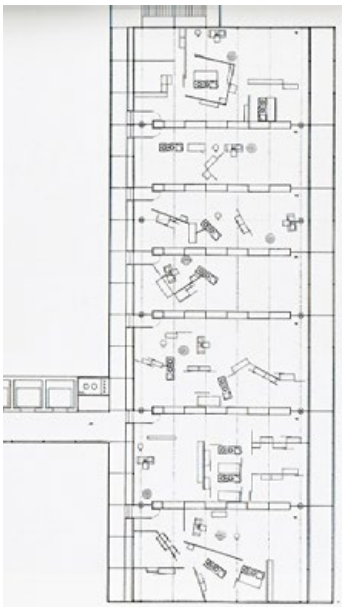


Fig 21 (top). **Schröder house, comparing two plan variations in terms of flow and light**

Fig 22 (bottom). **Variations of the plan according to users with different requirements**

COMPACT LIVING

The two following project are more recent examples of compact living layouts. The idea is to occupy the smallest space possible without loosing the amount of rooms users would normally need. Currently there are many examples of small living units, which are based on the idea of an open plan organization with functional and movable walls and furniture. Most of them are based on the same principle of creating virtual space by introducing smart systems of arrangement and storing allowing to unfold temporary zones for different activities yet restraining most of the time the number of coexisting functions to one or two.

A tiny apartment in Hong Kong by Gary Chang has certain similarities in plan with the visionary project of Abalos & Herreros. The rectangular plan (fig 22) has one main opening and functional walls with built-in transformable furniture elements are located perpendicular to it. In this example the flow pattern is depending on the functions which are in active mode. As the space can easily transform according to the changing needs of the user, the appearance of their living space is changing according to the time of the day or situation. Changing position of the furniture affect the flow pattern of the user which can, in some cases, become quite narrow and squeezed.

By contrast, "All I Own" apartment in Barcelona has a slightly different approach of layout organization. Here the architect has distinguished open plan room from compact functional zones. This project also establishes clear borders between movable and fixed, (fig 23) the kitchen and bathroom are located on two opposite ends of the room and can be hidden by movable furniture elements. In this project the flow is facilitated by the big open room, however the use of fixed spaces can be compromised, as every time you need an access the utilities, it is necessary to move a 500kg functional walls.

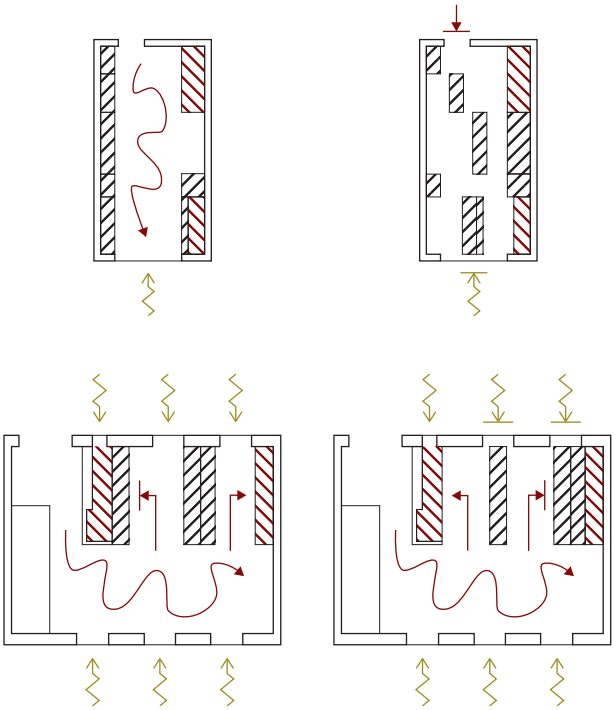
In our understanding, this concept has certain advantages and disadvantages. The positive side of the tendency is that we can observe how people are reconsidering their needs of space, how they shift from owning many "volume" square meters to living in a compact environment. However, in our opinion, their compromises are quite dramatic and that even though they might be able to squeeze many different spaces according to different functions and time, the space gain remains virtual and none of their "rooms" can coexist at the same time.

Light and connection to outdoor

Flow pattern

Fixed space

Movable module/furniture



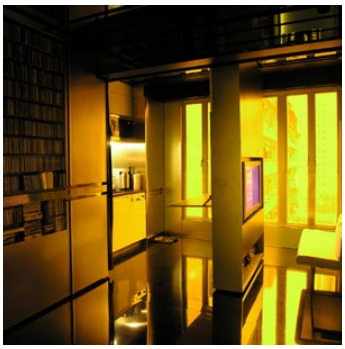


Fig 22 (top). **Compact apartment in Hong Kong with functional walls**

Fig 23 (bottom). **Transformation principle of "All I Own" apartment**

HYBRID SPACES

As our last case study we looked at a project where architects actually have combined two functions in the same space. Zecc Architects have recently designed a flexible office space in Haarlem (fig 24), which helps accommodate and diversify round-the-clock studio life.

The idea is based on the very simple principle that the space can transform when office hours are over and provide open space for other activities such as yoga class, communal eating area or dance floor. In this example such concept can be achieved by introducing deep ceiling, which can accommodate working tables with computers or other necessary equipment.

In this example the transformation of space between working and leisure is quite dramatic, from a flow pattern which is constrained by working tables to a complete open space, which then can be occupied by other functions.

To justify the concept, Studio Heldergroen claims that most offices are only used for 40 hours a week on average, and that this dynamic way of transforming ordinary offices means they can now be used for a range of evening and weekend activities as well without compromising the structure of the workspace. If offices are only occupied for eight or nine hours a day, landlords are missing out on over half of the potential time that their spaces can be rented for. By providing the space for nighttime events as well, the renting potential of these spaces could more than double. [15] We support this statement and see a potential in this way of thinking about Space in relation with Time. In our opinion such relations between functions might limit burglary risks, reduce costs, energy, etc. Such relationship between Space and Time might propose some idea about dealing with current social, economic and environmental issues

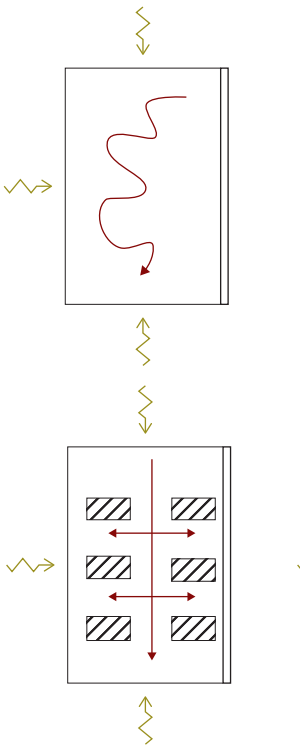
[16] Steeds, L. 2014.

Light/ connection to outdoor

Flow pattern

Fixed space

Movable module/furniture



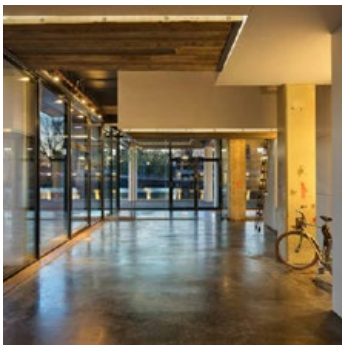


Fig 24. **Illustration of space transformation which changes the function and affects the flow**

FUNCTIONS

FUNCTIONS AND TIME

After defining Space Metamorphosis according to Time and Space, reflecting about users flexibility, and studying architectural examples in relation to flow and light the next step of the analysis will be to investigate the needs and character of different functions. The first part of the function analysis will focus on space occupancy related to different time scales. In order to perform this analysis, a representative functional list was compiled itemizing the different interior spaces that can be encountered in an urban environment.

Starting with the smaller scale, an hourly study of each space occupation ratio was done on a 24h scheme (fig 25). It is there that we found the biggest difference and complementarities. All analyzed cases resulted in only 55% of overall space tenancy. The next two bigger scale were less significant and decreased as the time lapse grew bigger. With an approximating average result of 19% of free space in a week and 2% in a year these two scale were shown to be less interesting in the case of our study and had a minor influence on the resulting ratio of 45% occupancy for all functions combined over a year period, if we assume that the functions have the same coefficient. The ratio were estimated only with fixed and reliable data such as academic holidays but we acknowledge the fact that some ratio as the housing function might be more diverse over a weekly or yearly basis.

The next step will focus on trying to combine the spaces regardless of their function and their moral or social constraints but solely focusing on their availability in time. Doing so, we will explore all possible option we might have and already sort the impossible combinations out.

As displayed on page 38, the spaces were systematically combined in all best ways possible. A certain degree of tolerance and flexibility over some overlapping occurrences was set in order to maximize their potential. Some of these intersections are minor and solvable due to the function's flexibility, some are solvable with specific design interventions, others might be more intrusive in people's habits and require more participation and understanding at the user's level. These inter-relations were summarized with a matrix diagram (fig 27page 39) in which largely combinable spaces can be distinguished from those which are not. Their color vary depending on their combination's level of occupancy and their number of connection that can be made.

After concentrating only on time intervals, the fig 27 on pages 40-41 illustrates the following study made focusing on the spaces' technical and aesthetic requirements. The different parameters were chosen according to their possible relevance for the upcoming need to be combined. Whereas time was the only filter earlier, in this table most of them are focusing on the spatial dimension with insights on their respective energetic performances and demands.

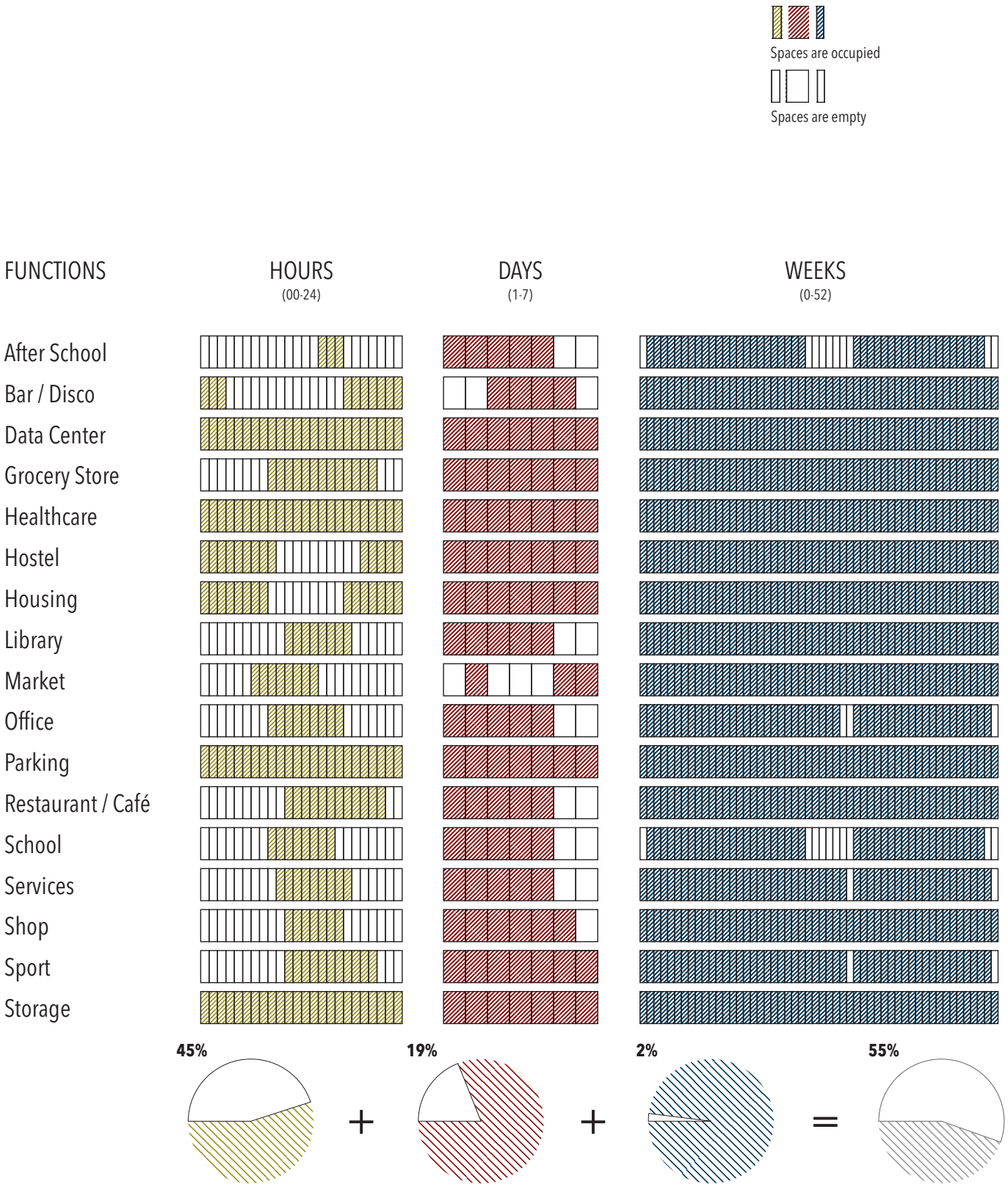


Fig 25. **Table representing space occupancy of different functions according to day hours, weekdays and weeks of the year**

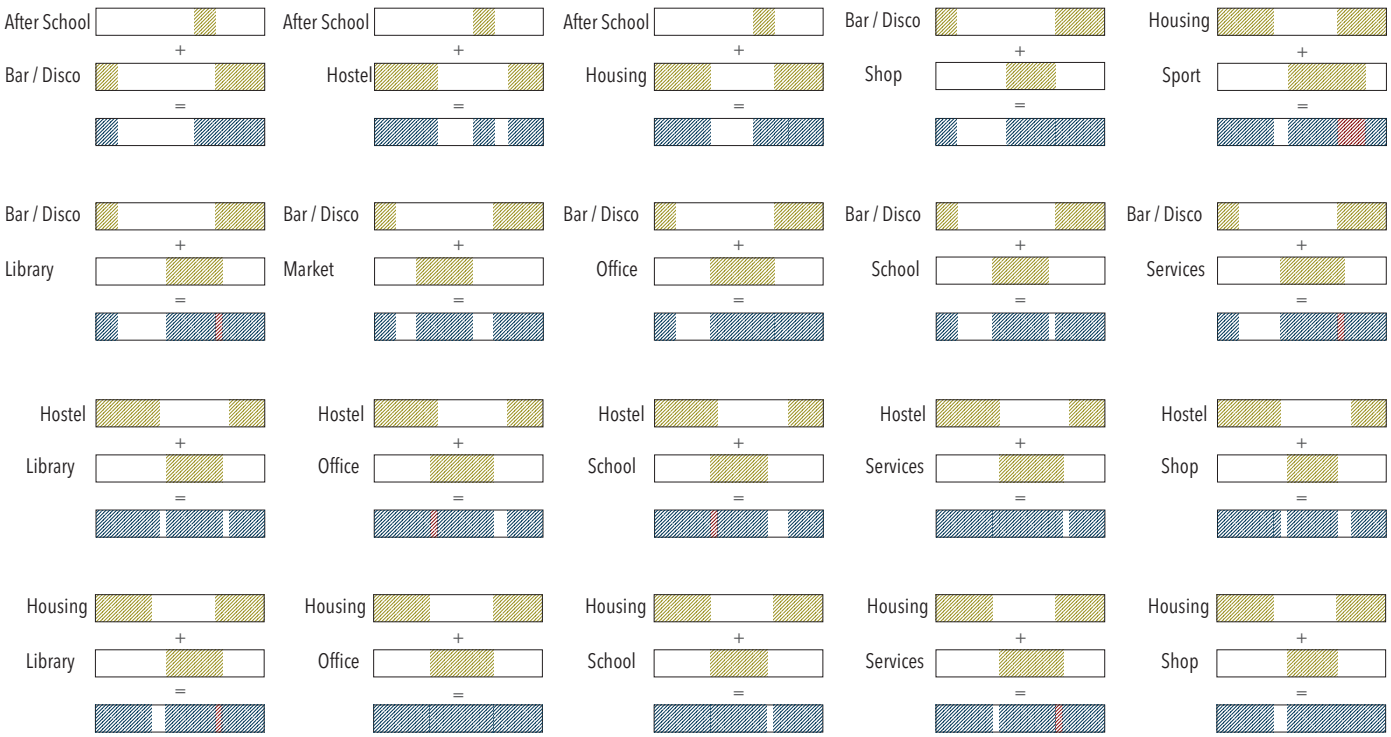


Fig 26. **Successful combinations of functions focusing only on the time factor as a criteria for mixing**

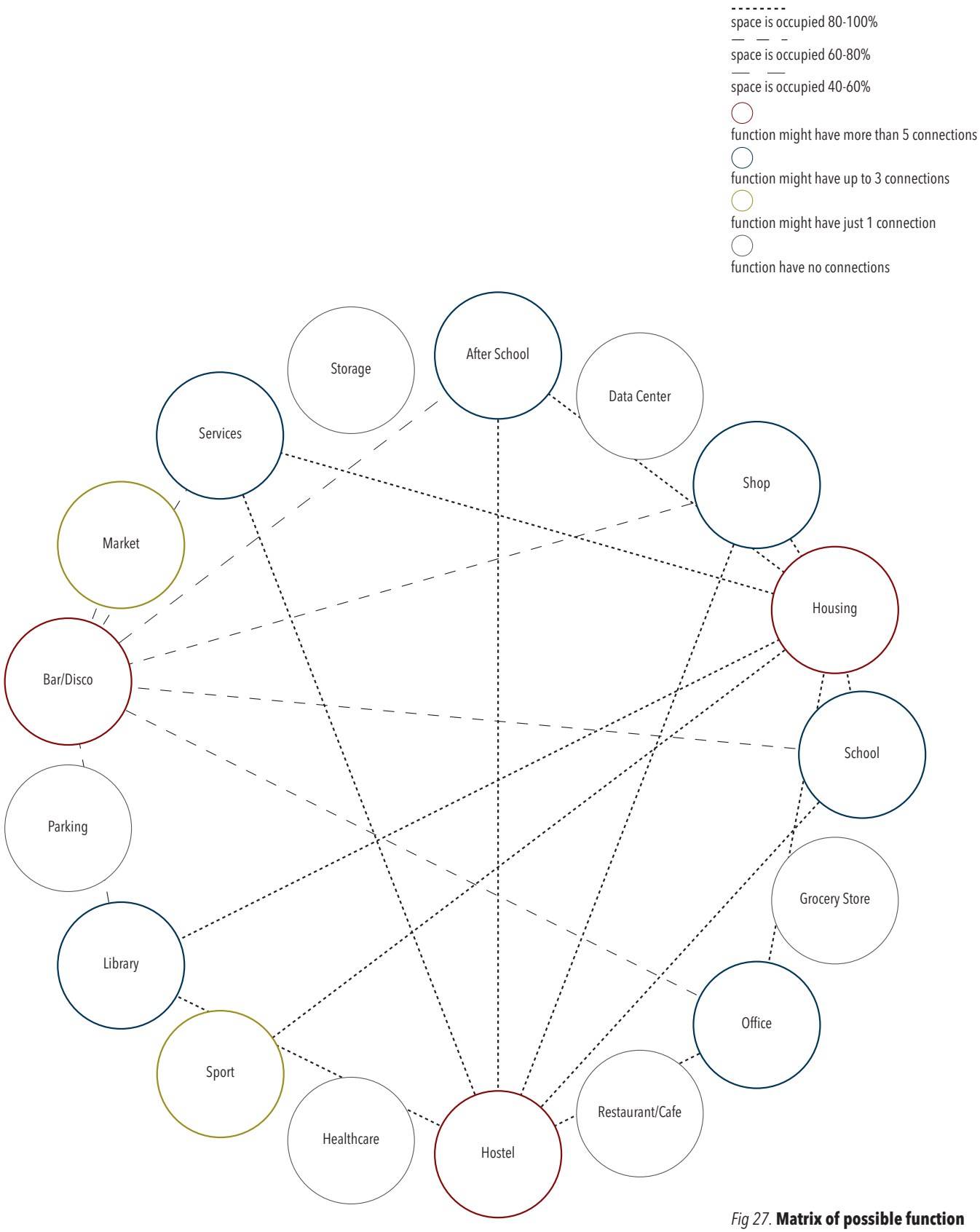
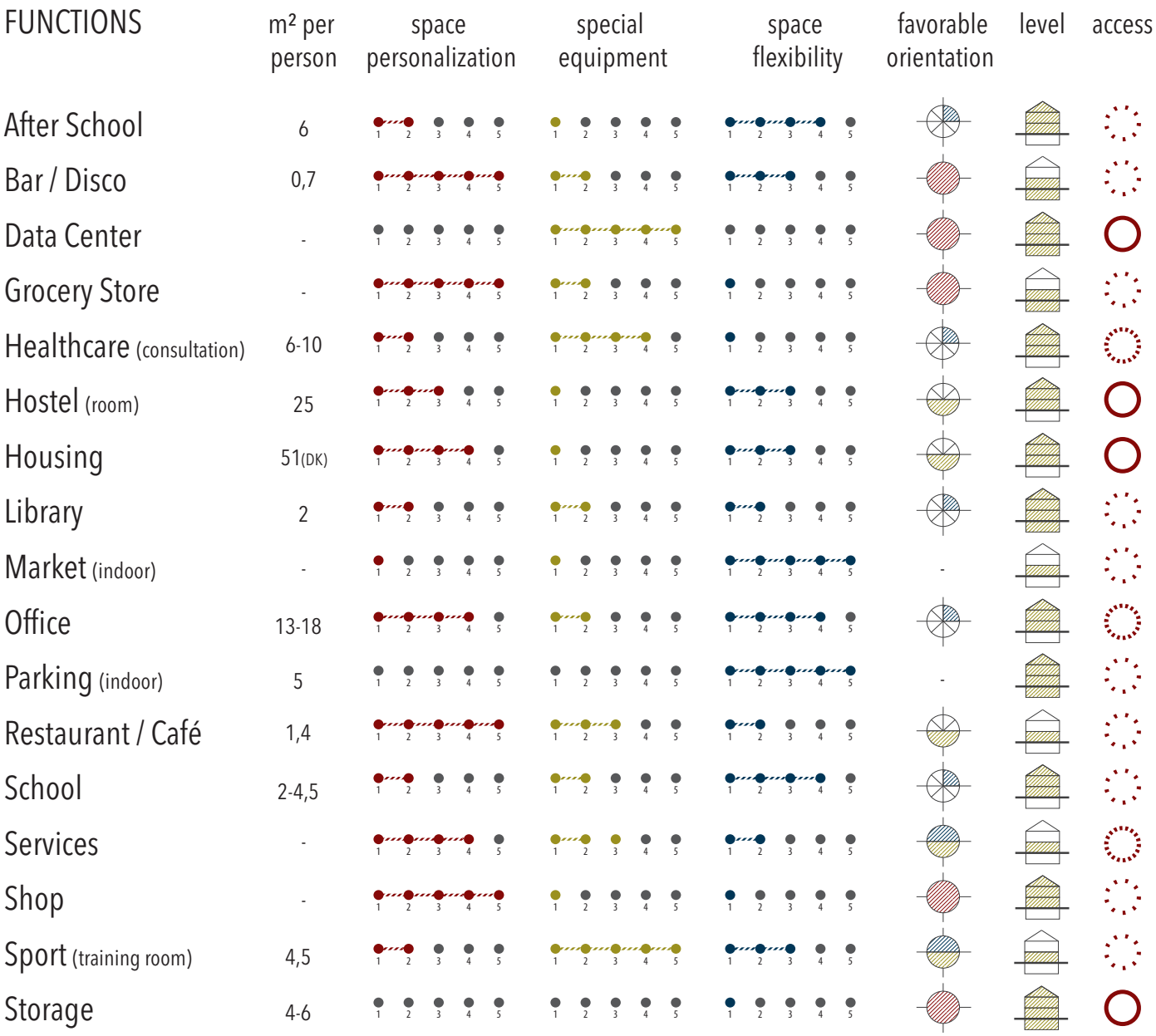
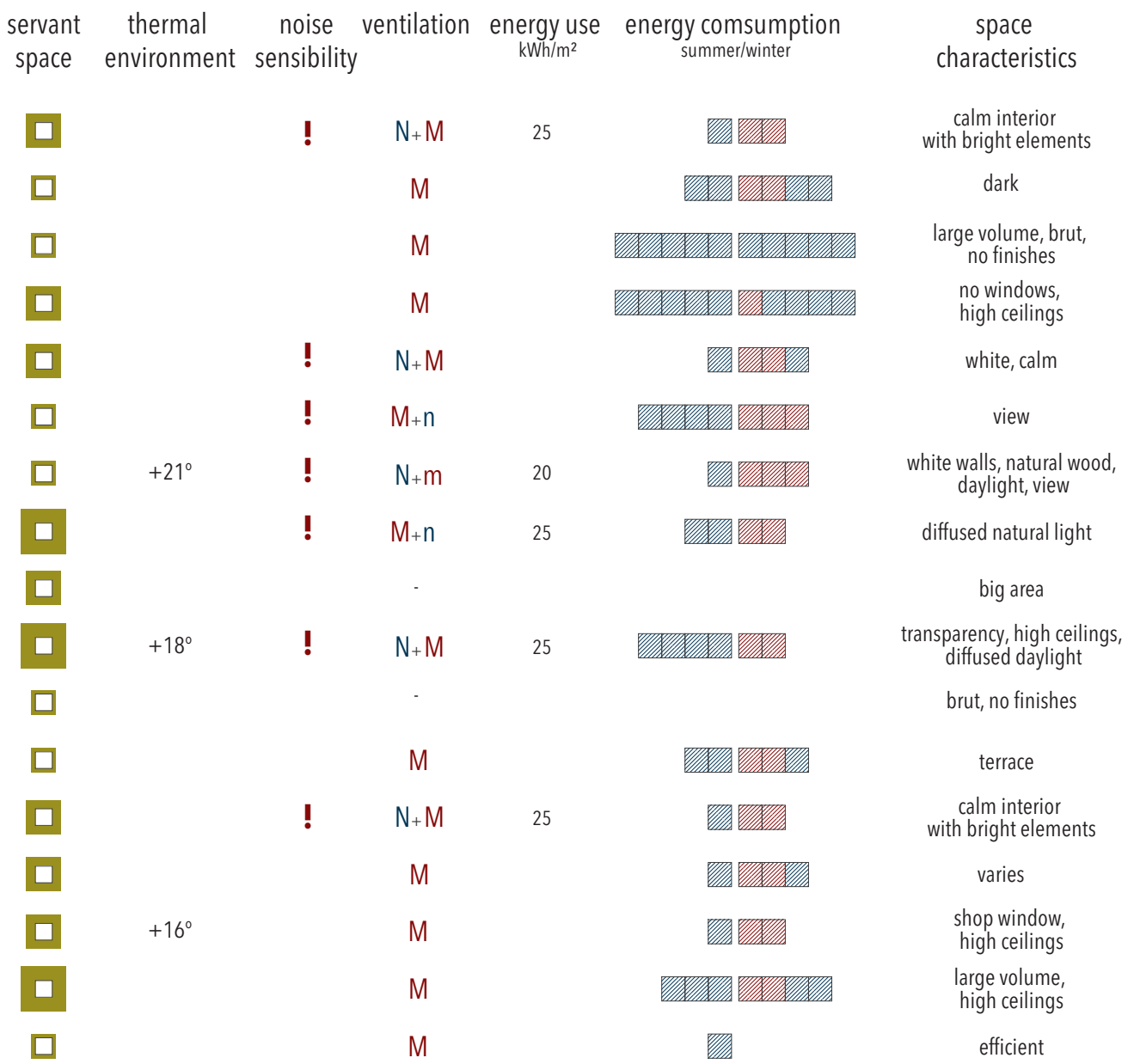


Fig 27. **Matrix of possible function combinations, showing functions with the most and the least possible connections and the % of space occupancy if mixing**



Conclusion 1: Spaces with high personalization needs should be paired with low ones or the two spaces should both require low personalization attention.

Conclusion 2: the spaces should have low special equipment needs, as specific equipment requires a lot of space and might not be movable.



Conclusion 3: Both spaces should be preferably located at the same level, thus guaranteeing similar degrees of privacy towards the street.

Conclusion 4: It is favorable to mix functions with similar thermal environment and ventilation requirements.

Fig 28. **Comparison of functions by different architectural and engineering parameters**

SPACE SCENARIOS

Having investigated the building scale with different time intervals, spatial and functional criterias, this stage's aim will be to look at the very generic level, how any two functions from the previous list can be mixed, joined and interrelated, having in mind the notions about flow and light gained from case studies.

The diagrams illustrate the possibilities lying within the space organization of a unit, where function A and function B are operating at different time intervals. The two basic layout forms of rectangle and circle (fig 30) were selected to easily illustrate possibilities, however it does not suggest that the layout is the most optimized. Some section studies (fig 29) were also performed at this stage, which revealed the opportunities of using the third dimension as ceiling or walls between two units to introduce the concept of Space Metamorphosis.

In order to satisfy storage and service needs common to all functions, a special element was introduced in all the plan organizations. Sometimes mobile, sometimes static, this unit can act as a function divider, main space divider or subspace divider depending on the units' configuration, place and orientation.

Some of the sketched solutions appears to perform better in relation to light and connection to exterior, others are more optimized for convenient flow pattern. For example, in sketch number one, both functions will get the same amount of light, while in number 4 each of the functions has a specific orientation, meaning A will get a northern light while B will get the southern one. In terms of flow, diagrams 1, 2, 4 and 6 suggest more fluid connections in between zones, while in layouts 3, 5 and 9 the movement is more fragmented (fig 30).

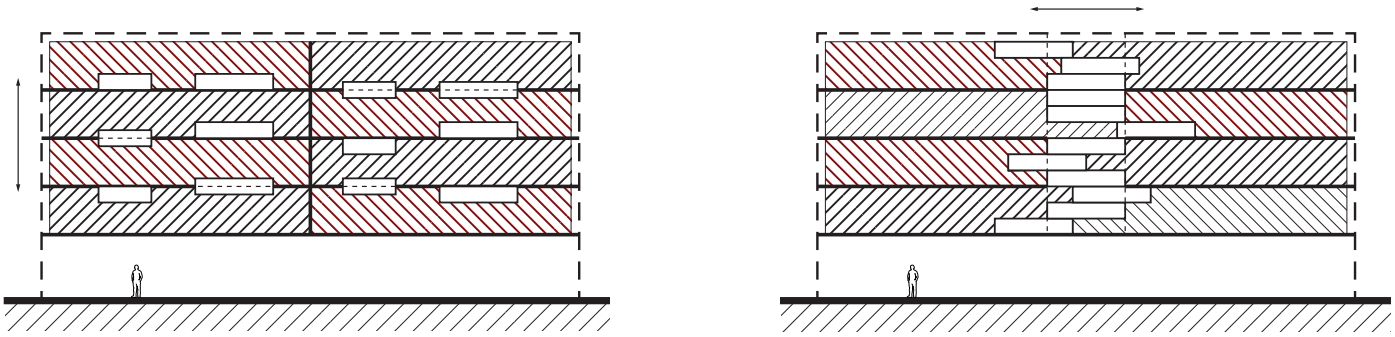


Fig 29. **Space transformations caused by special elements in the ceiling and partition walls of the units**

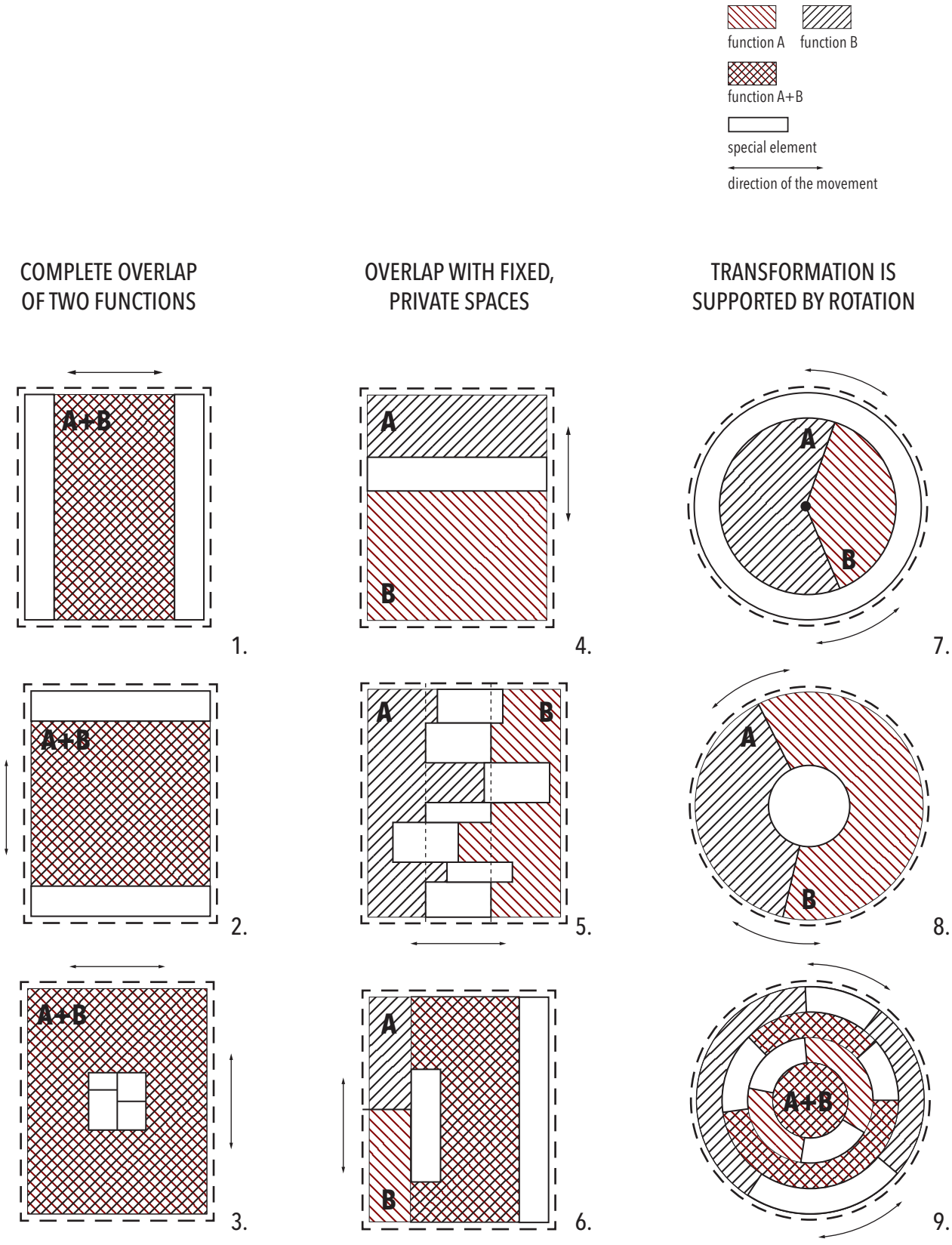


Fig 30. **Possible plan organizations showing relationships between two functions and special elements**

SUMMARY

After examining theoretical readings, statistical data, architectural references, and function analysis, we have underlined important conclusions, which will help in developing the new urban typology based on Space Metamorphosis concept.

Readings about Time and Space and our changing perception of these aspects, suggest that in our era of globalization and "speed space" the society is getting more open for changes. As the attachment to the place where we live or work is decreasing because of the desire to get new experiences, people can start exploring different ways of being flexible, therefore finding new possibilities for sustainable living. Statistical data supported by an online survey have highlighted two main tendencies: first, people think that their home expenses are too high, a lot of them would like to save and second, some people can imagine their home to be more flexible and be adaptable to any subsequent use. The philosophy of sharing has a potential to be explored in Copenhagen, where the population have a high level of awareness about sustainability. Moreover, some people are already exploring different ways of using spaces efficiently, such as Airbnb where living spaces becomes hostels, giving extra income to the households and affecting social and economic trends.

Reflections about relationships between private and public have revealed some important considerations, suggesting that in order to create successful public, shared areas there should be corners for privacy. It is important to maintain this balance so that the curiosity about The Other will not disappear and the well-being of individuals can be respected. While overlapping functions, it is necessary to work with transition areas between public and private, so the users' journey and experiences are continuous and fluid. This suggests that the project's will explore three main scales of privacy: EXTERIOR/ public, INTERMEDIATE/common and INTERIOR/private.

The analysis about experimentation in architecture, with examples of Le Corbusier, Gheritt Schroder, Abalos & Herreros and current examples of compact living layouts suggests that experimentation and innovation is an inevitable part of the architectural progress, which might not always bring the right solutions, but raise many discussions in the field of architecture and engineering, which activates the mechanism of innovations. Those case studies demonstrated some important points in relationships between different scales of privacy and brought to our attention the importance of light and flow.

Analysis of relationships between functions and time have revealed some interesting patterns in the way activities can be combined. According to this study our main focus in the practical part of the project will be to overlap Living and Working functions, which according to the collected data will have some architectural and engineering challenges. Those challenges will be addressed using a tectonic approach, where structure will become an important and expressive element of Space Metamorphosis.

PRINCIPLES

Following the established method and process, the information gathered in the theoretical part will be used to summarize the concept of Space Metamorphosis and will suggest some guidelines regarding architectural and engineering aspects which should be considered when implementing the theory into practice.

The key phrase of the concept is maximizing the potential of built spaces and resources. This efficiency of design solutions should be present at all building scales, starting from master plan all the way to detailing.

In order to design transformable spaces, a careful consideration of relationship between private and public which can be arranged in three scales: EXTERIOR/ public, INTERMEDIATE/common and INTERIOR/private has to be considered. To ensure a balance, there should be a ratio of fixed and transformable spaces as well as corners for "breaks", which provide a high degree of privacy in the continuous flow.

While testing function overlap, we draw the conclusion, that there always has to be a fixed, emergency space, especially when talking about housing, that is also important to give a sense of security and belonging to users (fig 31). When two function are present in the same space it risks to lose its identity and personalization, therefore the design solutions should focus on opportunities to personalize and at the same time to simplify the process of transformation.

Storage should be considered as an important element of the design, as in order to allow function to co-exist there should be enough space for needed equipment and it should be easy accessible.

The concept suggests few specific architectural elements, such as deep ceilings and movable, capacious modules. Those two elements, the way the are designed and connected to the building structure are crucial for a fruitful Space Metamorphosis, as they facilitate the transformations. The placement and operation of these mobile elements will also have to be optimized and carefully implemented to maximize access to natural light while improving flow patterns and space hierarchy.

Final parameter is related to complexity and diversity of the program. In order to conduct this experimental building, it will be necessary to work with many different functions in order to maintain the round the clock approach.

The practical part of the project will be based on these guidelines and will keep exploring other parameters of the concept, as we believe that the site location and character will add another layer of considerations and will enrich the principle of Space Metamorphosis. The connection between urban environment and the building should appear as a strong, recognizable link, which will create a distinctive label for the whole project.

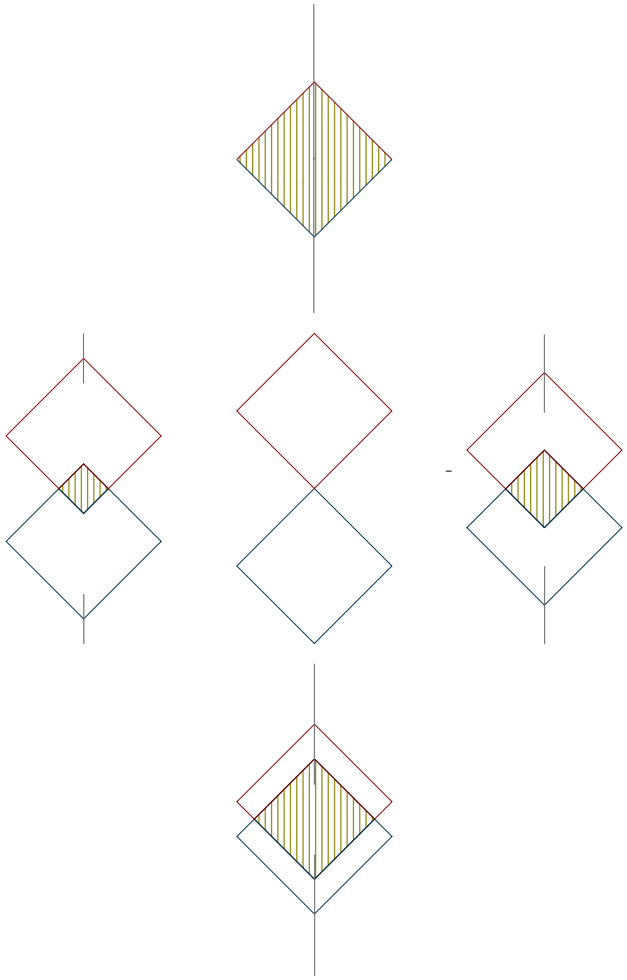


Fig 31. **Two space-overlapping principles, where the area of overlapping varies from 10 % to 100%. The rest of the spaces are considered to be fixed and the spaces in between of two volumes to be used for storage**

SITE

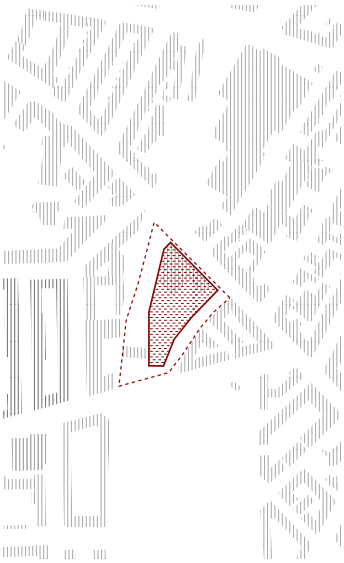


Fig 32. **Zoom of the location map. Site according to the local plan is marked with continuous red and the area which could be used for a landscape project is marked with a dashed line.**

GENERAL

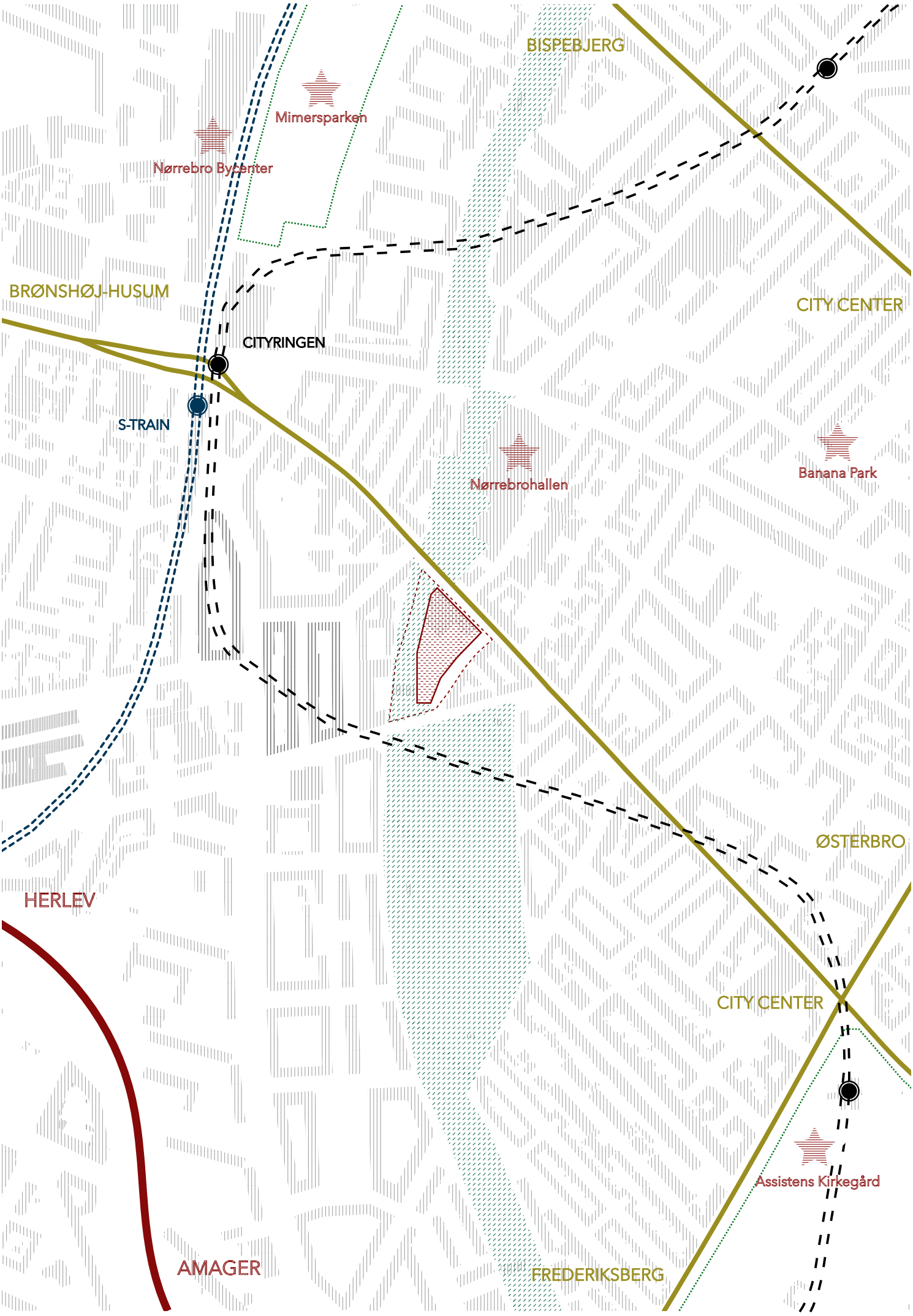
The site analysis has been conducted at different scales and on four dimensions. X and Y axis represent planar surfaces of the site, Z stands for heights, volumes and their relations, the fourth dimension is Time. This stage of the analysis is to identify, highlight and differentiate what make the urban fabric of the surrounding neighborhood.

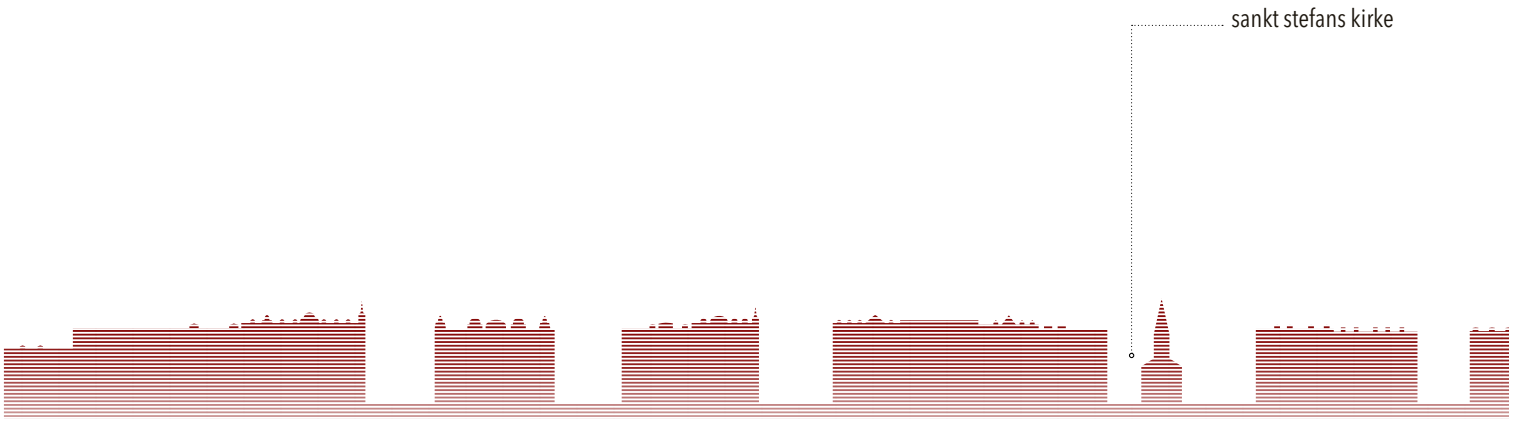
With Nørrebrogade to the northeast, Farumgade to the southeast, Hillerødgade to the south, a park area along the green bicycle route "Nørrebroruten" to the west and Aksel Larsen's square to the northwest, the chosen plot is situated almost at the edge of the Nørrebro district, close to the Frederiksberg's and Bispebjerg's border it places it into a very well connected environment with numerous access to cultural activities, services and commerces. Its very diverse urban infrastructure provides the area with a wide range of transport facilities.

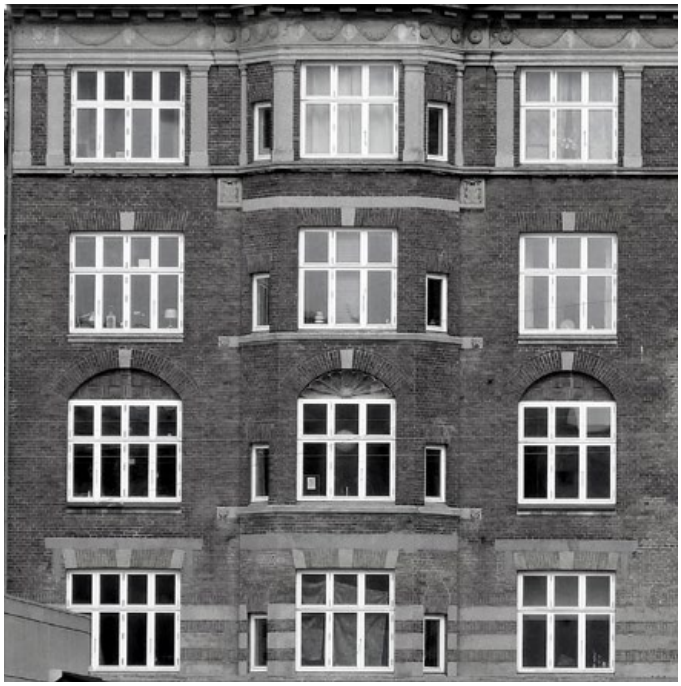
The neighborhood is mainly composed of 5-6 storey blocks of apartments from late 1800s and early 1900s with building percentages typically between 250 and 350 with exception going up until 415. Situated on former railway tracks from the North Line linking Copenhagen and Klampengorg between 1863 and 1930, the area has since then been converted and re-purposed as cultural and activity centered spaces with a transversal green spatial sequence with the Superkilen and Nørrebroparken as main elements. The reconversion of the old railway warehouses as the Nørrebrohallen is also a strong actor in the dynamism of the neighborhood. On the other side of the Green Route stand a major commercial building from the 1960s which, with its large scale, constitutes the dominant element of the area.

Situated in the Nørrebro district of Copenhagen, the plot is skirted by Nørrebrogade, a collector road linking Brønshøj-Husum and the city center. The future metro line Cityringen, the S-Train line and the Nørrebroruten, a green bicycle path linking the Bispebjerg district with Fredericksburg are the main connection axis accessible from the site. It is also surrounded by different points of attraction such as the Superkilen, the Nørrebrohallen, the Nørrebro Bycenter, Mimersparken, Banana Park, Nørrebroparken or the Assistens Kirkegård. Furthermore, it has a close connection with the highway 16 running all the way up to the northern part of Zealand and going south until Amager (fig 33).

Fig 33. **Site map showing main connections and relationships to the Green Route and highlighting the landmarks of the area**


BISPEBJERG
Mimersparken
Nørrebro Bycenter
BRØNSHØJ-HUSUM
CITY CENTER
CITYRINGEN
S-TRAIN
Nørrebrohallen
Banana Park
ØSTERBRO
HERLEV
CITY CENTER
Assistens Kirkegård
AMAGER
FREDERIKSBERG





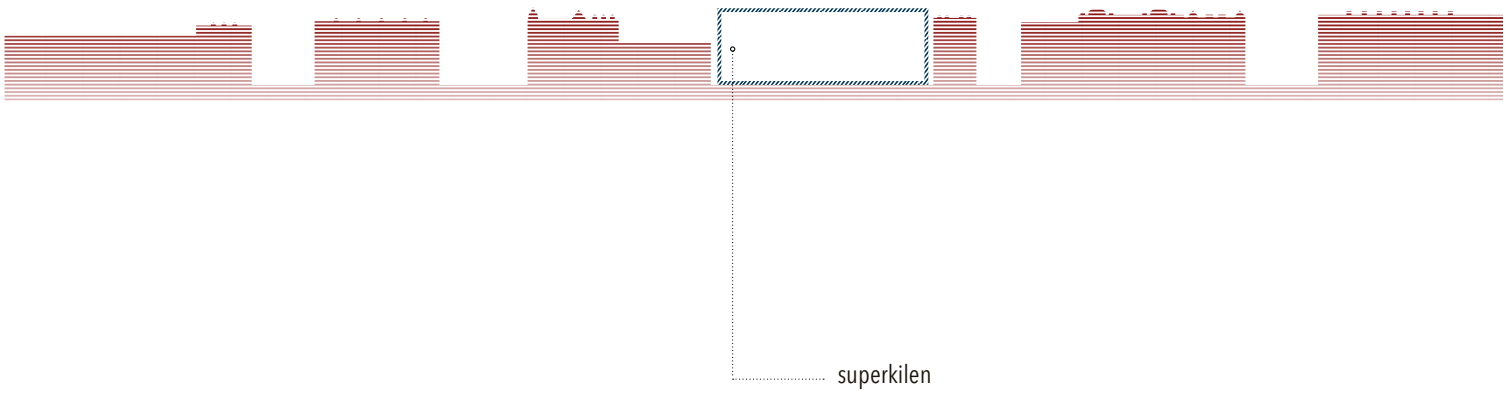
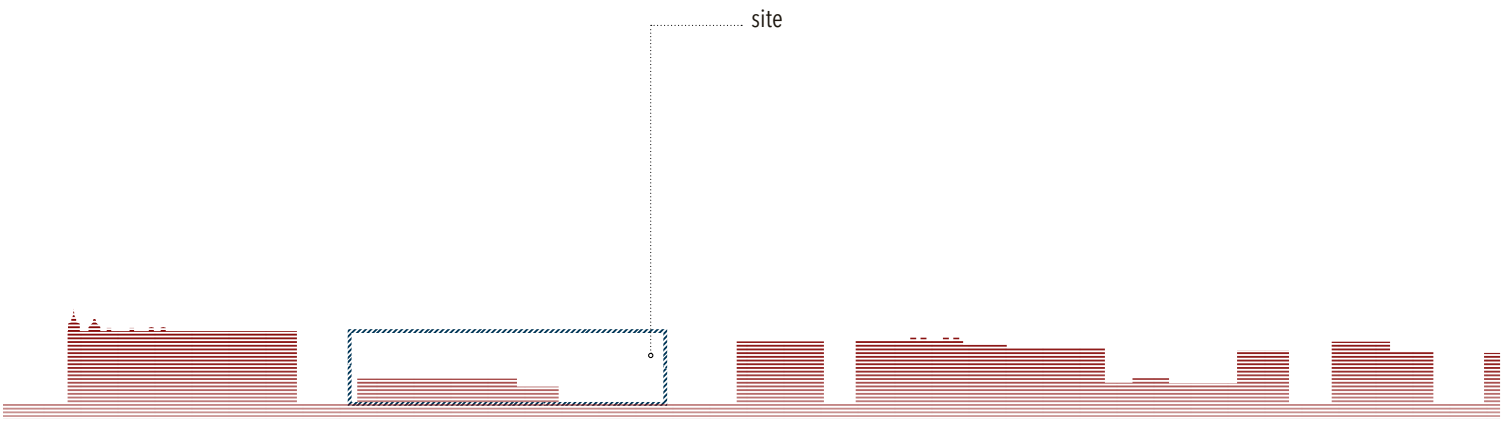


Fig 34. (top, bottom) **Graphic representation of the Nørrebrogade skyline looking towards and from the site**



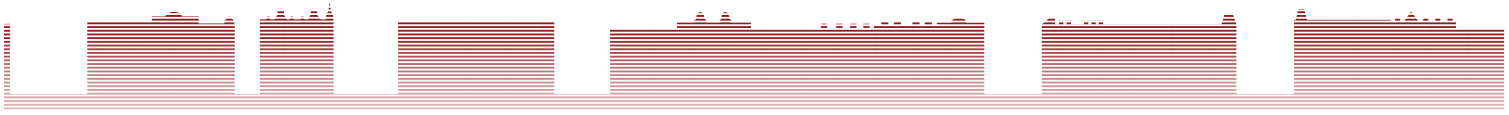


Fig 35. (middle) **Photos showing patterns and materiality of Nørrebrogade facades**

URBAN ENVIRONMENT

Looking closer at the city fabric and the different typologies present around the site, a couple of different environments can be observed. Ranging from high dense small city blocks, separated residential long building, low industrial to large city blocks or more recent thick office buildings, the site is in the middle of a large spectrum of different identities (fig 36).

A long facade analysis of Nørrebrogade was performed in order to study its heights profile and the balance of its volume versus voids. Clearly, the rhythm of the street and the surrounding block structure are broken (fig 34) and the most recent introduction (1999) of the recessed low commercial building is not an appropriate answer giving the place a blurred character.

Fig 36.(opposite) **Map showing the zones of different urban typologies**


industrial area
small city blocks
office blocks from 60's
long residential bars
large city blocks

MAPPINGS

The urban analysis was intended to study the space in four dimensions, where X and Y axis represent planar surfaces of the site, Z stands for heights, volumes and their relations and fourth dimension is Time.

Two dimensional parameters represent the street level of the area and mainly focus on the flows of cars, public transports, bikes, pedestrians as well as the differences between passing-by and resting spaces. Diverse urban infrastructures provide a good amount of roads and paths around the plot (fig 37). Nørrebrogade, as an arterial road, has a traffic load of approximately 14,500 cars and 15,000 bikes a day, making it a very busy road emitting approximately 70 dB of noise (fig 41). This route also accommodates several buses' routes, one of the stops is directly facing the site. Regional train and the closest metro station, which can be easily accessed by foot, are located 4000 away from the site (fig 38). They all create a direct connection to the city centre, while providing diverse activities at the street level with shops, cafes, bars, grocery stores and services. The street becomes a lively public space, which sometimes extends to small squares and becomes more than for transit purposes only. By contrast, Hillerødgade is a residential road with about 10,500 cars commuting daily connecting the site with the western part of Copenhagen. This path is less dynamic than the main road and is less likely to be a place to stay. Farumgade is a secondary one-way road which links Nørrebrogade with Hillerødgade.

By looking at the relationship between built and empty spaces, we can conclude that the site is located on an important axis of open space. This area is creating a break in a rigid urban fabric by interrupting the building edge of the street (fig 39), while the rest of the area can be described as defined and strict. Urban blocks are creating isolated courtyards and bring verticality to the street. The uniformity of the building heights, being on average 5 storeys (fig 42), of Norrebrogade is interrupted by the north-south axis, which at the moment accommodates public spaces with squares, parks and recreational areas. Moreover, this axis has a fluid character, as it accommodates the green route and a large amount of trees bringing more life and biodiversity to the area.

Such particular position - being part of the Green Route as well as its edge on Nørrebrogade - gives the site both built-in evident qualities like its immediate proximity with green spaces and strong constraints like the need to maintain the street hard edge and vibrant atmosphere while shielding the most vulnerable spaces from noise.

Fig 37. (opposite top) **Public transportation and greenery**

Fig 38. (opposite bottom) **Cycling roads, pedestrian flows and parking**


metro
train
bus
pedestrian
bicycles
bike parkings
car parking

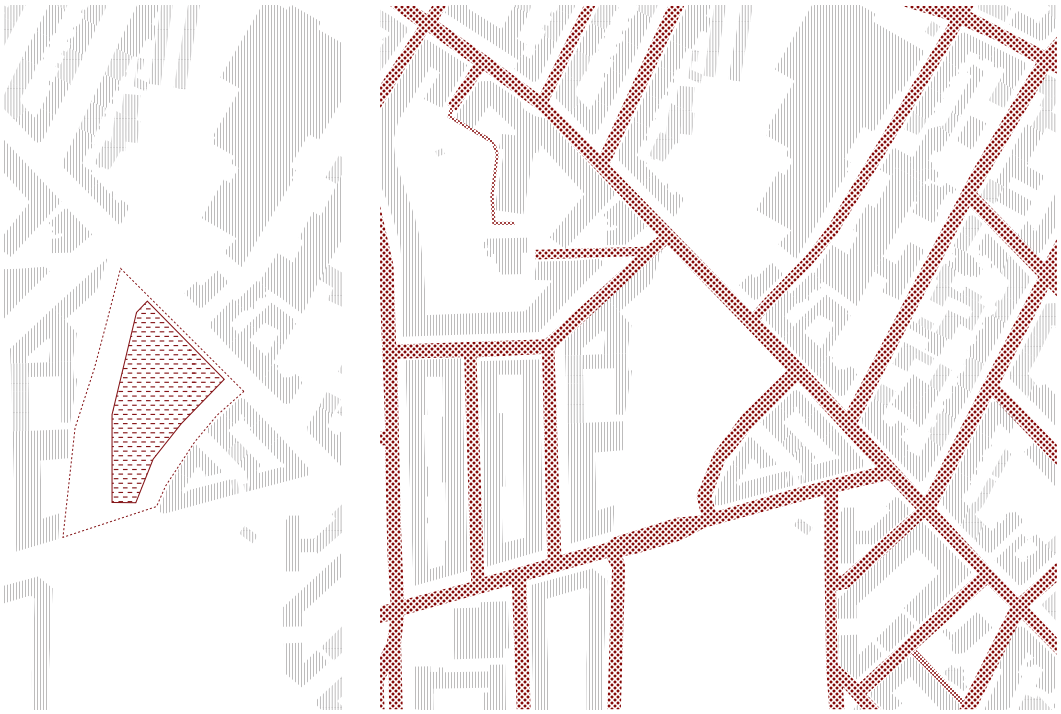
Fig 39. (top left) **Relationship between built and unbuilt**

Fig 40. (top right) **Roads**

Fig 41. (bottom) **Noise**

Fig 42. (opposite top) **Heights**

Fig 43. (opposite bottom) **Private and public spaces and edges**



one floor
two floors
three floors
four floors
five floors
six floors

edges

FUNCTIONS AND TIME

Because of the specific nature of the project, an analysis of the typologies around the chosen site will be more versatile and will include not only functions, but also will show when spaces are not in use during the day. (fig 44)

As the objective of the project is to design a new typology where spaces can accommodate different functions, it is important to establish what kind of activities are present in the area and see which buildings have the most of "waste space". In order to illustrate this, the buildings will be analyzed in two levels: street level, as it contains both public and private areas and first floor as it will mainly represent all other upper floors and usually indicate more private zone. All the buildings will be divided in 10 categories: housing, offices, commercial, educational, cultural, health-care, services, sport facilities, catering and nightlife.

Then, in order to get an impression about how much space is misused in the area, all buildings will be divided into two categories. The first category will represent buildings mainly functioning during the day, such as offices, schools, shops, hairdressers and the second one will focus on buildings primarily operating in the evening and at night, such as housing, restaurants or some sport activities. What we can see from the map is that most of the square meters of the upper floors are not in use during the day as they only contain housing (fig 45). At the same time there are many unused spaces on the street level at night (fig 44).

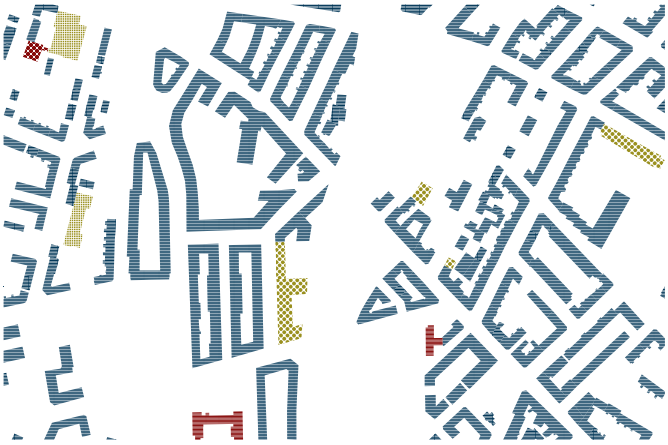
Fig 44. (opposite left) **Functions on the ground level followed with day and night usage of the spaces**

Fig 45. (opposite right) **Functions on the first and upper floors followed with day and night usage of the spaces**

religion
catering
industrial
nightlife
healthcare
cultural
housing
commercial
parking
offices
sport
occupied
educational
services
empty

GROUNDFLOOR

UPPER FLOORS



day

day

night

night

LOCAL PLAN

The municipality of Copenhagen has decided to think "environmentally friendly"[17] in connection with new construction, major renovations and construction work, the following is a summary of the local plan introduced in 2006 with "The Thinking City". Their four area of action are: the sustainable city, the city for all, the city on the water, the dynamic city. These "Sustainability in Building and Construction" guidelines of February 2006 focus on environmentally friendly design, energy consumption, materials, water and drainage, urban and nature, waste, noise, indoor air quality and the construction site.

The local plan relates multiple objectives such as mixed-used with high bicycle accessibility, more pedestrian friendly, accessible and beautiful with better seating areas and supporting a vibrant and diverse urban life by introducing new city apartments with a sustainable architecture.
These are the most relevant principal points more detailed:

-The maximum level of traffic noise at the facade of residential areas according to the Environment Agency guidance no.3/1984 must not exceed 55 dB. The requirement is to ensure that living and sleeping functions can be reasonably well accomplished in periods when there is a need to have the windows open.

-The noise impact on the primary outdoor living areas should not exceed 55 dB and in special situations, the noise level at at least one of the facade should not exceed 55 dB.

-It is allowed to design a building that fills almost the entire area of the site keeping in mind that the ground floor should be used for audience-oriented services.

[17] Local Plan

-The handling of rainwater is very important to avoid flooding. The roof can not be discharged into the sewer system, the rainwater should be handled locally.

-The totality parking should be located underground and its entrance should be made by the southern end of the building as close as possible on Hillerødgade in order to relieve Farumgade from traffic. The parking coverage should be one parking space fzor every 100m² of floor area.

-The area of each grocery store and food retail outlet must not exceed 3,000m² with maximum 1,500m² of gross floor area.

-The average size of dwellings should be 95m² and no less than 75m².

-There may be collective facilities and institutions as well as other social, educational, cultural and environmental services but they, as well as businesses, are not to be placed above the residential floors.

-Shared laundry, resident rooms or workshops are encouraged.

-The maximum building height should not exceed 20m.

-The FAR (floor area ratio) should not exceed 2.85.

-The building must be designed with a high architectural quality, reflecting and highlighting the specificity of the location in a contemporary spirit. The facades should appear with a distinct urban expression towards the adjacent streets and with a "green"character towards the park. The facades should be brightly colored with a surface treatment such as masonry or plaster.

-Solar collector and solar cells are encouraged.

-Housing should be provided with seating balconies.

-Windows and doors frames should be in wood and/or aluminum with colors that harmonizes with the building's facade.

-The windows glass should be clear and tinted or with a mirror effect.

The totality of the local plan might be found online and some of it is reproduced in the appendix in Danish language.
These points were taken from a review of the local plan made after a feasibility study. Most of these points will be followed such as the noise, water or parking regulation but some like the FAR, facade treatment or maximum height, might be slightly altered in order to comply with our metamorphosis concept idea and its new typology.

PROGRAM

Even though this thesis' main characteristic is its experimental nature, the underlying aim is to implement it into an existing context in order to test its feasibility in a given environment. Having this in mind, the local plan was examined and restructured according to our site analysis and their requirements (fig 46).

The project proposed will include a new mixed-use development following the guidelines of the local plan with mainly housing as well as other different functions. The exact nature of the program as well as its quantities and proportions will mainly be devised during the early sketching phases in which a more precise idea of the balanced proportions of function will be determined.

By overlapping functions, the aim is to develop a program with around 50% more usable surfaces than a traditional one would with the same built floor area ratio. Taking this approach in relation to the local plan is resulting in building less square meters, which allows us to devote more space for outdoor public spaces or increase density by around 1,5 times.

To sum up, the Space Metamorphosis concept would allow us to build less while satisfying the usable space need of the local plan. Housing being the predominant function, shops and services will have to be implemented in order to meet Nørrebrogade needs in terms of social activity and interaction, and office spaces will be the third main component of the program. Green spaces and possibly cultivated gardens are also an important part of the project and will occupy a significant place in the design process.

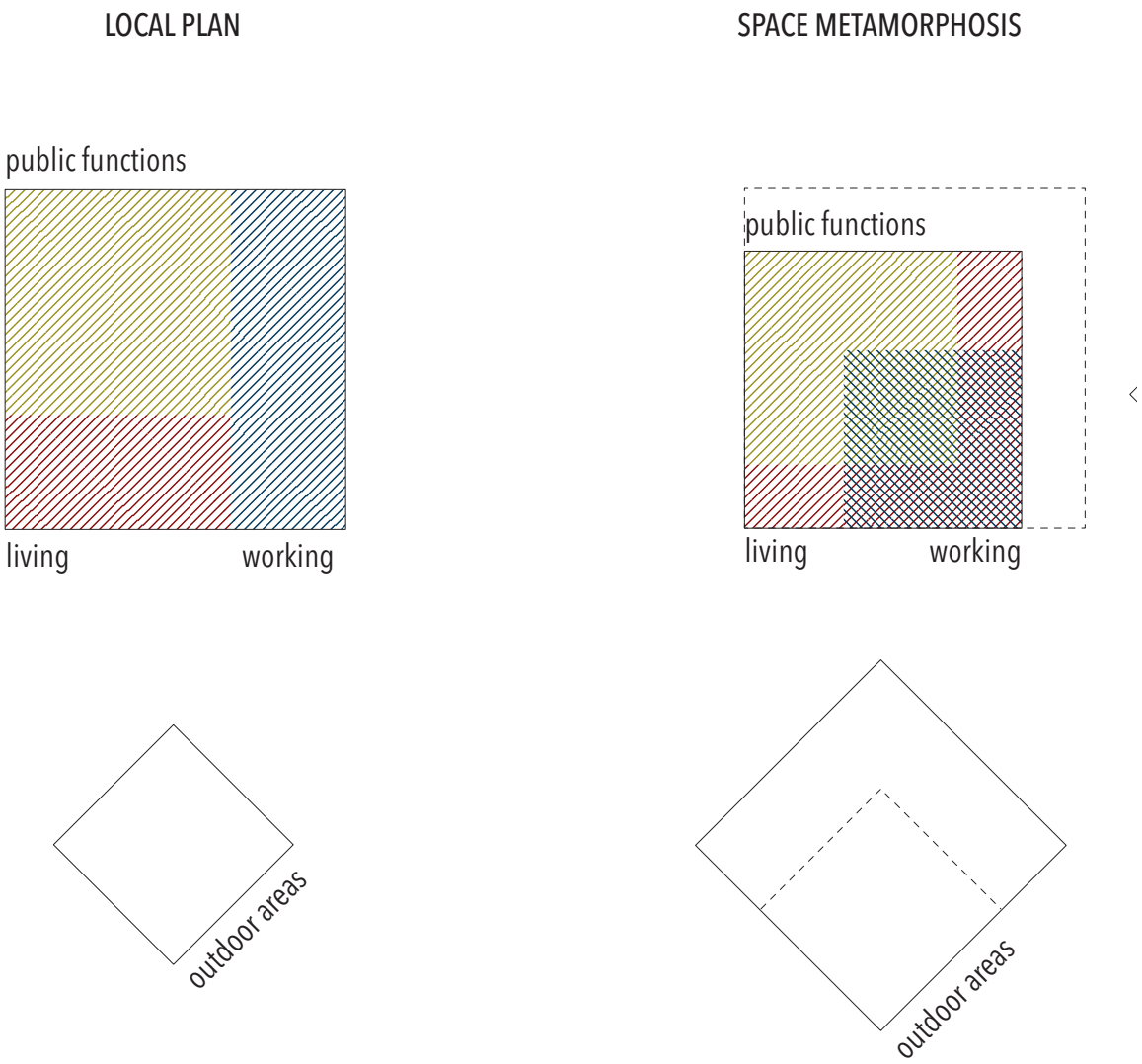


Fig 25. **Comparison between the built square meters of the local plan and Space Metamorphosis, where, by overlapping, more space can be devoted to outdoor areas**

SUN

Sun exposure is an important factor, as it will affect the building's orientation, form, height and materiality. Therefore, careful sun analysis was done as part of the investigation.

In Denmark there is a great difference between the length of the day throughout the year. The shortest day is December 21, with 7:02 hours of daylight while the longest day is June 20, with 17:32 hours of daytime. Daylight does not mean direct sunlight and even if the cloud coverage is high (91% in winter and 63% in summer), [18] a sun analysis was performed.

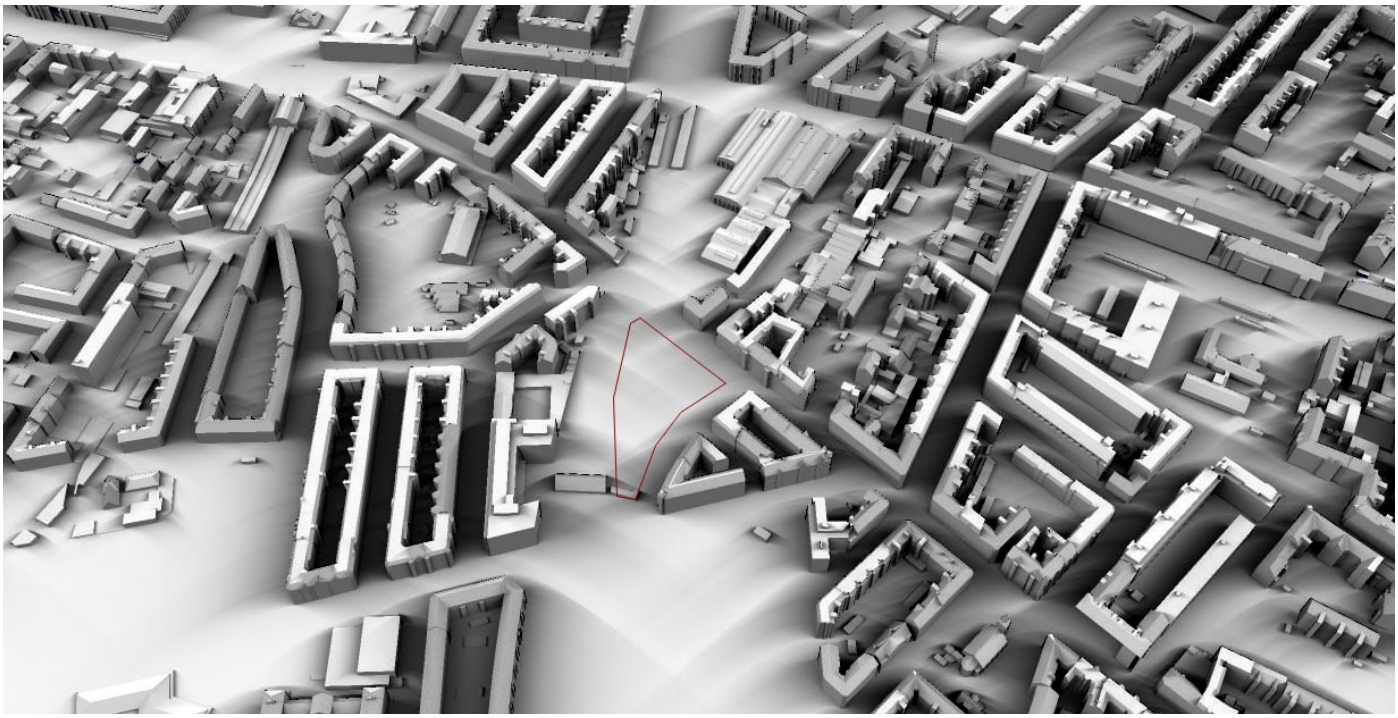
Using SketchUp's sun and the geo location of the model, approximately one image every five minutes was created to show the amount of direct light reaching the ground level of the plot during summer and winter solstices.

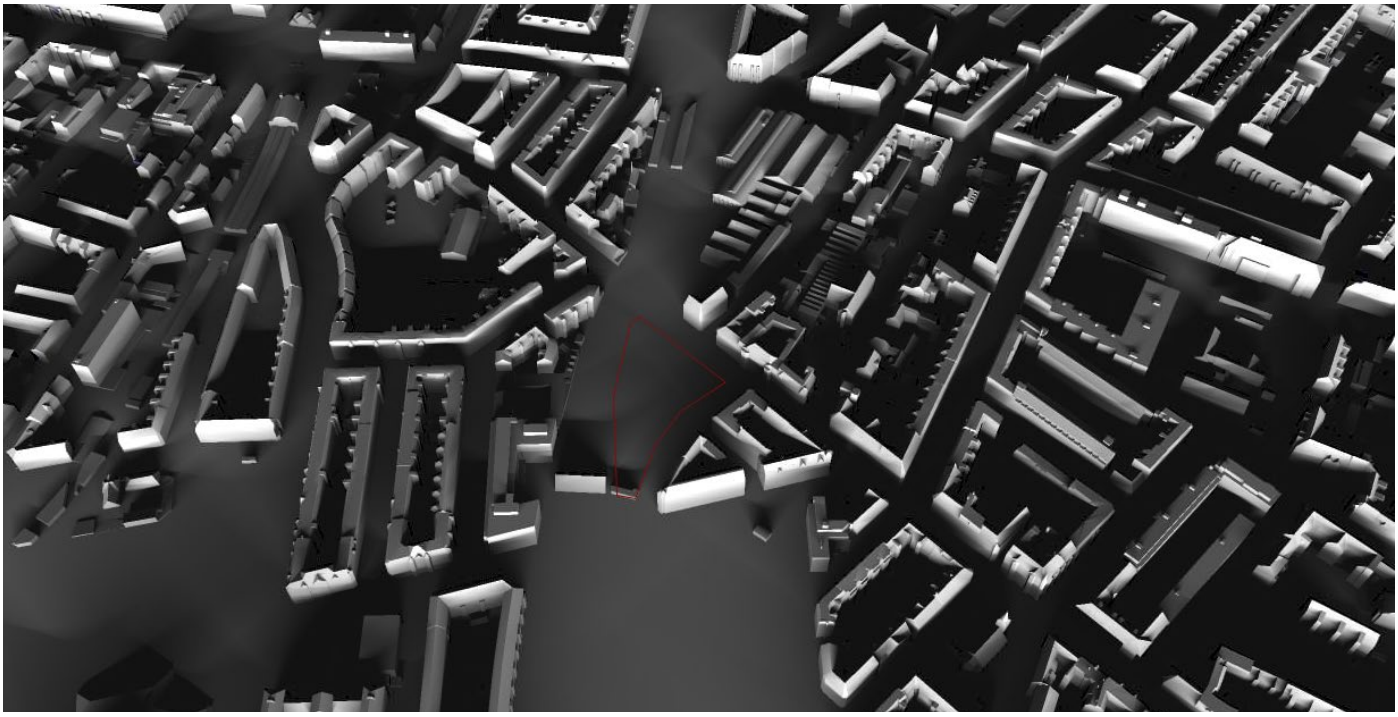
The generated images illustrate that the site has very good sun exposure in summer time (fig 47), therefore building should be design in the way to take the advantage of its position. In winter there the plot appears much lighter that courtyards between surrounding buildings (fig 48), meaning that it will be possible to get some sunlight on the ground level. Moreover, adding more floors will insure direct sunlight on the facade, which can be seen as convenience for developing the project.

Fig 47. (opposite top) **21st of June, direct sunlight at ground level**

Fig 48. (opposite bottom) **21st of December, direct sunlight at ground level**

[18] Weather Spark





WEATHER

Copenhagen has a humid continental climate with warm summers and no dry season. The area within 40 km of Copenhagen Airopr Weather Station, is covered oceans and seas (47%), croplands (41%), built-up areas (10%), and grasslands (3%).

Over the entire year, the most common forms of precipitation are moderate rain, moderate snow, and light rain. During the warm season (June to September), there is a 55% chance of precipitation. During the cold season (November to March), there is a 69% chance of precipitation. Even though the average rainfall days are quite constant with around 15 days per months, the volume of precipitation is much higher starting from July till January with a maximum of 70mm (fig 49).

Despite the high chance of precipitation, the chance of snowfall is quite small. The snowfall season spans from November to April with its peak in January, occurring in 37% of the days with a median depth of 8.8 cm. The relative humidity typically ranges from 53% to 97% over the course of the year. The air is driest around May (below 63%) and it is most humid around December (exceeding 93%). [18]

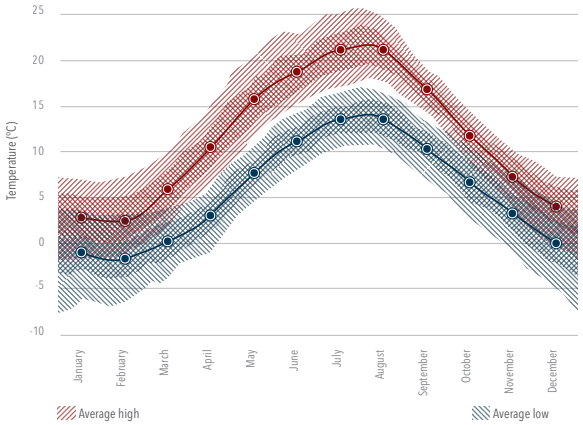
Over the course of the year, typical wind speeds vary from 2 m/s to 9 m/s, rarely exceeding 13 m/s. The highest average wind speed of 6 m/s occurs around January, at which time the average daily maximum wind speed is 8 m/s. The lowest average wind speed of 4 m/s occurs around August, at which time the average daily maximum wind speed is 7 m/s. The wind is mainly coming from the south in summer and from the south west in winter (Fig. 50).

These parameters will influence the project in terms of protection against the strong winter winds and in terms of optimization of the weaker summer western winds to promote natural ventilation.

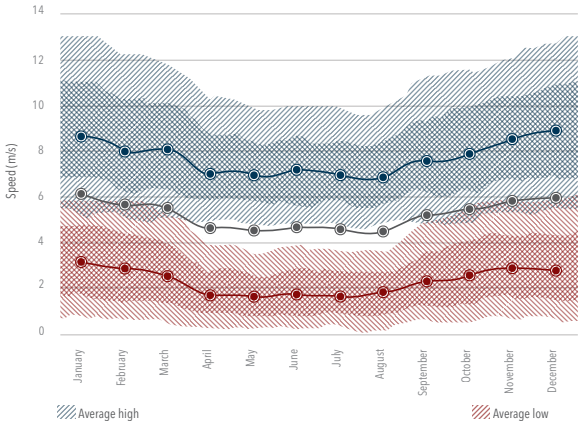
Fig 49. (opposite left) **Temperature, Sun, Cloud coverage and Rainfall**

Fig 50. (opposite right) **Wind speed and directions**

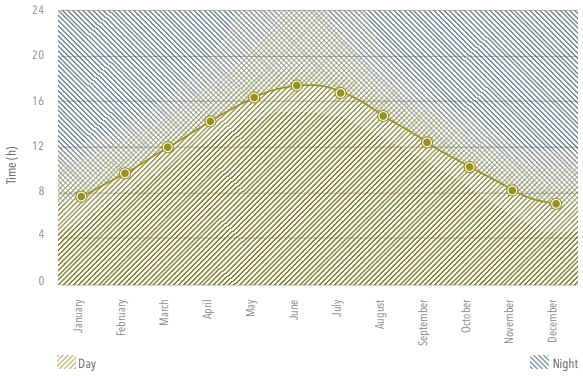
Average Temperature

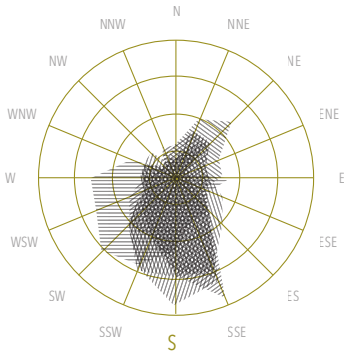


Wind Speed

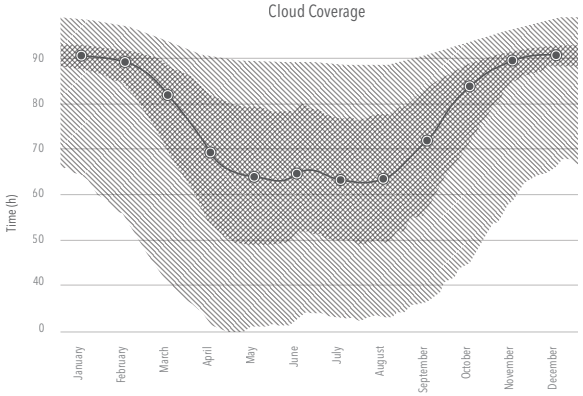


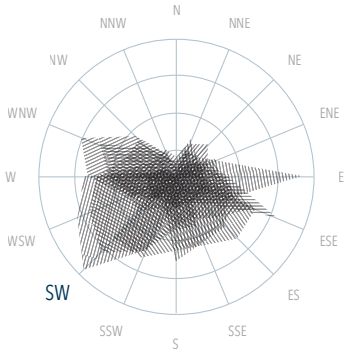
Daily Hours of Daylight



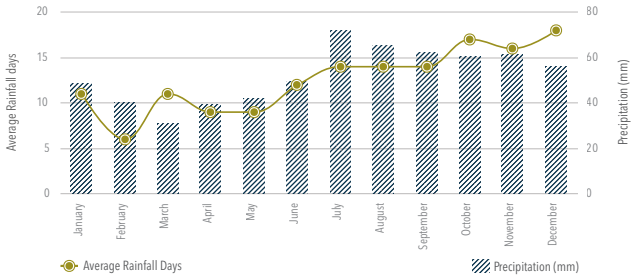


Cloud Coverage





Average Rainfall



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Insolation (kWh/m²/day)	0.49	1.16	2.34	3.85	5.19	***5.43***	5.31	4.41	2.86	1.47	0.75	***0.39***
Clearness (0-1)	***0.33***	0.39	0.44	0.48	***0.50***	0.48	0.49	***0.49***	0.45	0.38	0.39	0.35
Temperature (°C)	***-0.75***	-0.43	2.02	6.35	10.87	15.27	***17.57***	17.32	12.77	8.49	3.05	0.09
Wind speed (m/s)	***5.18***	4.53	4.51	4.10	3.83	***3.72***	3.78	3.77	4.41	4.61	4.42	4.63
Precipitation (mm)	51	***32***	41	41	43	54	***70***	62	62	57	63	59
Wet days (d)	16.7	12.8	14.5	12.6	11.3	***11.1***	13.1	13.1	14.0	14.8	***17.5***	16.7

SUMMARY

Site itself has many advantages, its particular position between the Green Route as well as its edge on Nørrebrogade gives it both built-in evident qualities and will be a strong feature of the project.

Produced maps and tables, gives an idea about which functions could be mixed according to time intervals. It also provides graphical representation of the stated issue of not using built spaces to their full capacity. The analysis of the climate conditions opens opportunities of implementing passive and active strategies in order to decrease energy use and provide good indoor environment and thermal comfort.

The ambitions of the local plan encourage to explore new, daring concepts in order to find better solution for sustainable living in Copenhagen. Currently , the surrounding area has many examples of architectural interventions which enriched the experience of the public spaces, therefore the experimental nature of Space Metamorphosis concept can find its place.

To sum up, the urban analysis shows that the selected area could support the experimental and ambitious project of Space Metamorphosis. Specific character of the area and local plan requirements will transform theoretical knowledge of the concept into a design, which will provide various outdoor and indoor spaces for selected user group.

VISION AND STATEMENT

This thesis project is a possibility to explore a new architectural typology by introducing time factor as a design tool to craft the spaces. It is an ambitious experiment, but we believe that nowadays, when architecture is facing a challenge of sustainability we, as young architects, should address this issue and be open to undertake risks while looking for innovative solutions.

We believe that people are dynamic, the environment is dynamic, so if we want Spaces to be related to the Time and be a part of the great system they should not remain static. By overcoming architectural and engineering challenges through specific to its location design solutions, we suppose that Space Metamorhosis concept can conduct positive improvements in social, environmental and economic aspects.

Space Metamorphosis concept aims to maximize the aesthetic and technical potential of spaces while minimizing the use of resources. By encompassing all scales: EXTERIOR/public, INTERMEDIATE/common and INTERIOR/private, it aims to create a diverse and vibrant environment for its users.

PART II

OVERVIEW

The presentation of the project will consist of three main parts : Outline, Storyboards, Specifications & Process which will be followed by Reflections and accompanied by Sketches & Numbers, which represents the appendix. Because of the complexity of the project, the parts are organized according to the importance of their content.

The Outline part will illustrate the prime principle of the concept, the relationship between DAY and NIGHT configurations according to the project's three main scales : EXTERIOR/*Public*, INTERMEDIATE/*Common* and INTERIOR/*Private*. This part gives a general understanding about the project's technical and aesthetic aspects and its main components.

It will be followed by three Flows which will illustrate different journeys taken by different users within the project and establish relationships between them and the spaces. There, the accent will be made on the lifestyles of the users, their everyday routine and their experiences. It will highlight the tectonic qualities of the spaces and provide insights about the structural features and detailing.

The next part of the presentation will be focused on explaining the Process and Specifications of topics such as: movable modules, facades, design and calculation of the structure, sustainable strategies and details.

The report will be followed with the Reflection part, which will focus on discussing how the end result of the project relates to the aim set in the theoretical part of the project, what are advantages and disadvantages of certain solutions and how successful solutions can be implemented in further projects.

Other elements of the projects which are considered to be complementary, will be presented in Sketches&Numbers. This part will add another layer of design solutions which were developed within the project, but are not crucial to make Space Metamorphosis possible.

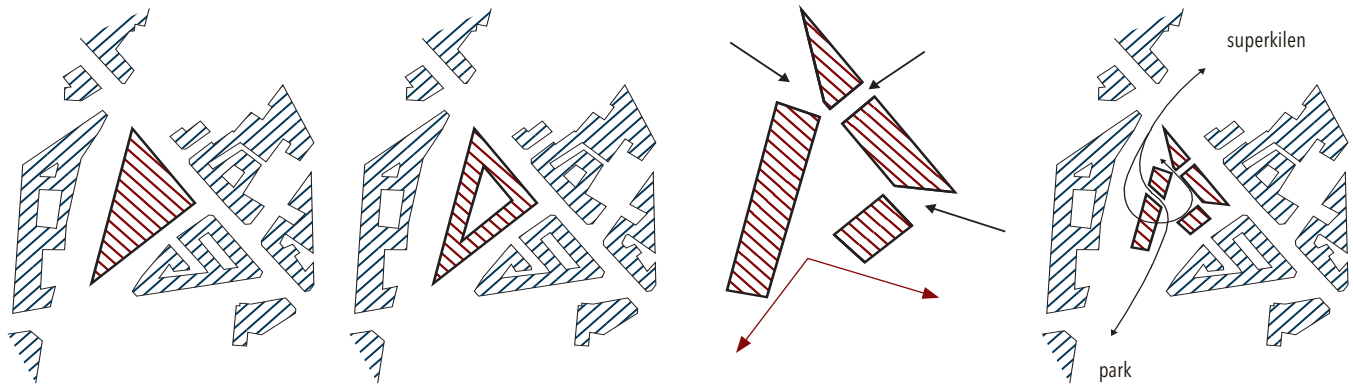
MASTER PLAN

Before looking at the three main scales of the project, it is important to understand its relation to the existing urban fabric. The way in which Space Metamorphosis is blended into its surroundings is drawn from the urban analysis, local plan directions and climate considerations.

The site's immediate surrounding urban typology is dominated by the presence of blocks covering the entire area of the site and sheltering a courtyard in its center. A more chaotic organization is also present in the north close to the Nørrebrohallen.

Following our intention to integrate the project within the existing fabric, the first stage is to introduce a block taking the primitive shape of a triangle following roughly the perimeter of the site (fig 51). Knowing that the most constraining function in term of slab width would be the Living one, the block is simply carved out leaving a peripheral 12 meters wide band. This band is then sliced in order to allow people's flow inside the central courtyard mainly from the main axis Nørrebrogade. The creation of these very clear and sharp cuts were accentuated and placed strategically to make a parallel with the area's identity. Following that, the southern angle opens up towards the natural green area of Nørrebroparken increasing the possibilities of having an efficient natural ventilation strategy from south-western summer winds. The last stage is to re-establish the link between the Superkilen and the Green Route bike paths giving it a sinuous shape in order to extend the site's crossing journey. An ascending bike ramp is also introduced acting as a link between the EXTERIOR/public and the INTERMEDIATE/common levels and fostering the local access journey with its circular shape.

At this stage we also have identified the functions and their overlapping principles according to the three project's levels (fig 52). The EXTERIOR contains commercial, services, indoor and outdoor market as well as public plazas and park. This level is located right at the ground floor and will be an active part of the project's urban identity. The INTERMEDIATE level accommodates entrances, lobbies, leisure facilities, library and exhibitions spaces as well hostel, auditorium and canteen. In relation to the master plan, this level is a connector between all the buildings, which creates a strong horizontal link and is expressed on the facades. The INTERIOR level is mainly representing the relationship between living and working spaces. Not all of the functions are overlapping. For example, the canteen only has a catering function, but according to our hypothesis it will be used more than a traditional one because of the continuous flow of people present in the building. During the day the canteen is occupied by workers, while in the evening it can be used by hostel roomers or become a place for casual dinners for permanent residents.



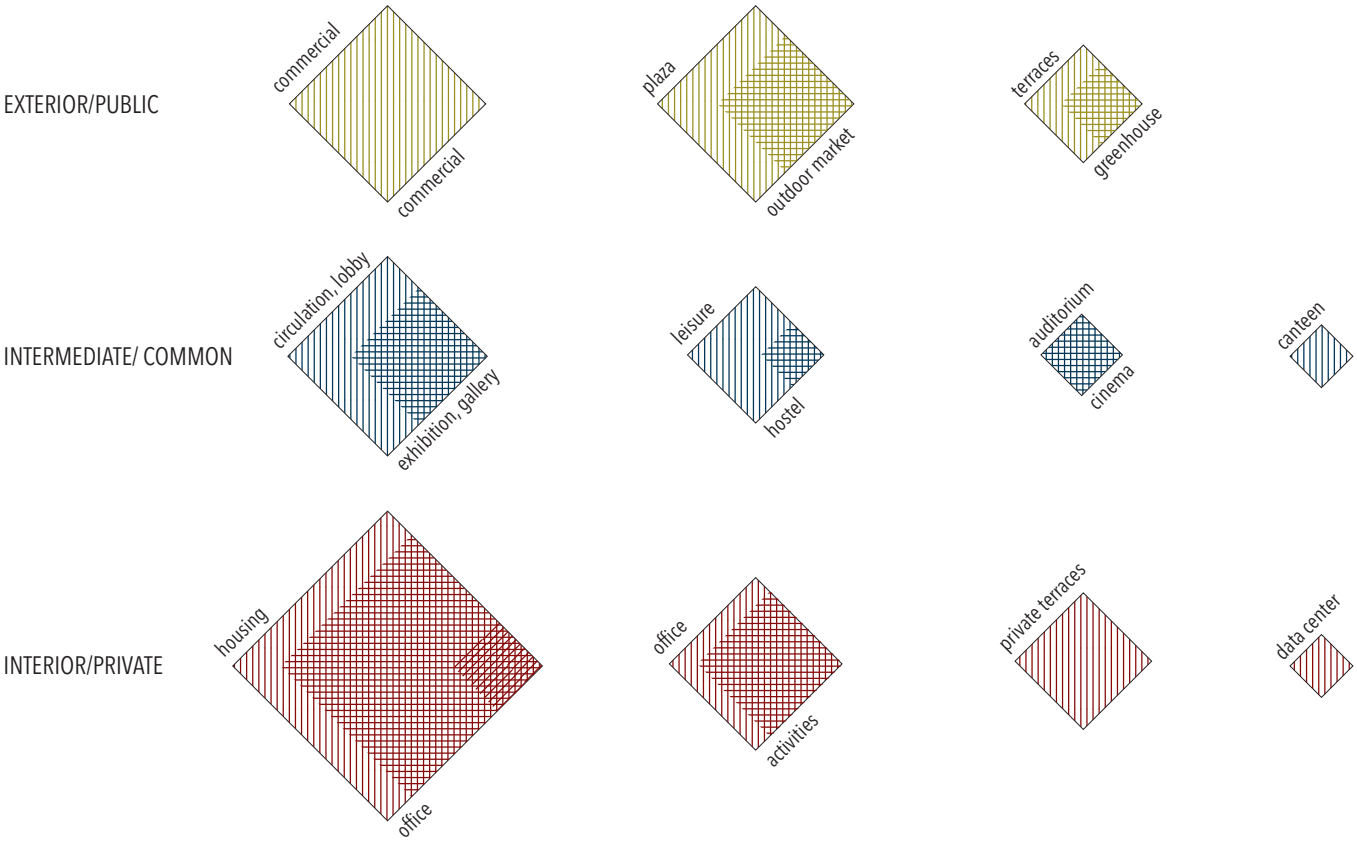


Fig 51. **Master plan strategy in steps**

Fig 52. **Program divided in three privacy scales illustrating overlapping functions**

LAYOUT AND GRID

The concept of Space Metamorphosis requires a specific design for the unit which will accommodate both Living and Working, the layout of the unit have then influenced the grid of the entire master plan.

Following the knowledge from case studies and space scenarios analysis, a few steps were necessary to achieve the desired light conditions, flow pattern and hierarchy between different zones. As a starting point we took a unit layout similar to the Hong Kong apartment and to the Abalos & Herreros' project (fig 53). In such a layout, the entrance of the unit is taking one of the facades and creates a gallery-like circulation. Moreover, according to our findings, it would be favorable to have two entrances to the unit and there should be a certain visual and physical distance between them. Following that, we have rotated the plan 90°, which allowed us to place both entrances on the side. However, in this option the lighting of the space became problematic. As the modules were located along the facades, moving them inwards only allowed some parts of the unit to get light and an outside view. This led to the final step where modules were rotated 45° and allowed to bring light and connection to the exterior as well as to create spaces with clear hierarchy, whereas in previous steps, spaces were more monotonous.

The design of the unit with a 45° interior has affected the overall grid of the building complex and exterior public spaces (fig 54). In the master plan scale, there are two different characters: soft, representing the park and hard, representing the Superkilen, which are linked by the Space Metamorphosis project. Those two characters are united by a timber grid on the side of the Superkilen and a concrete grid on the side of the park.

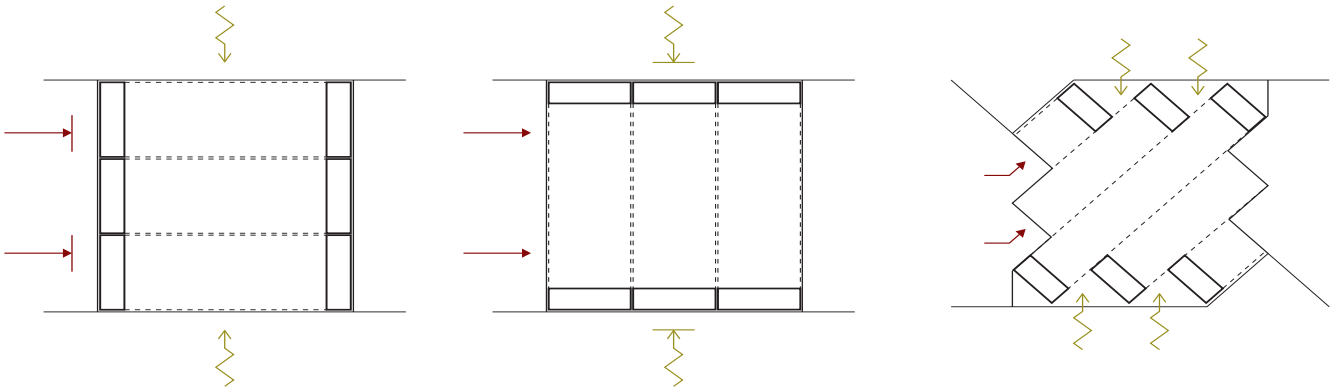


Fig 53. **Steps explaining the units' layout organization development from orthogonal to rotated**

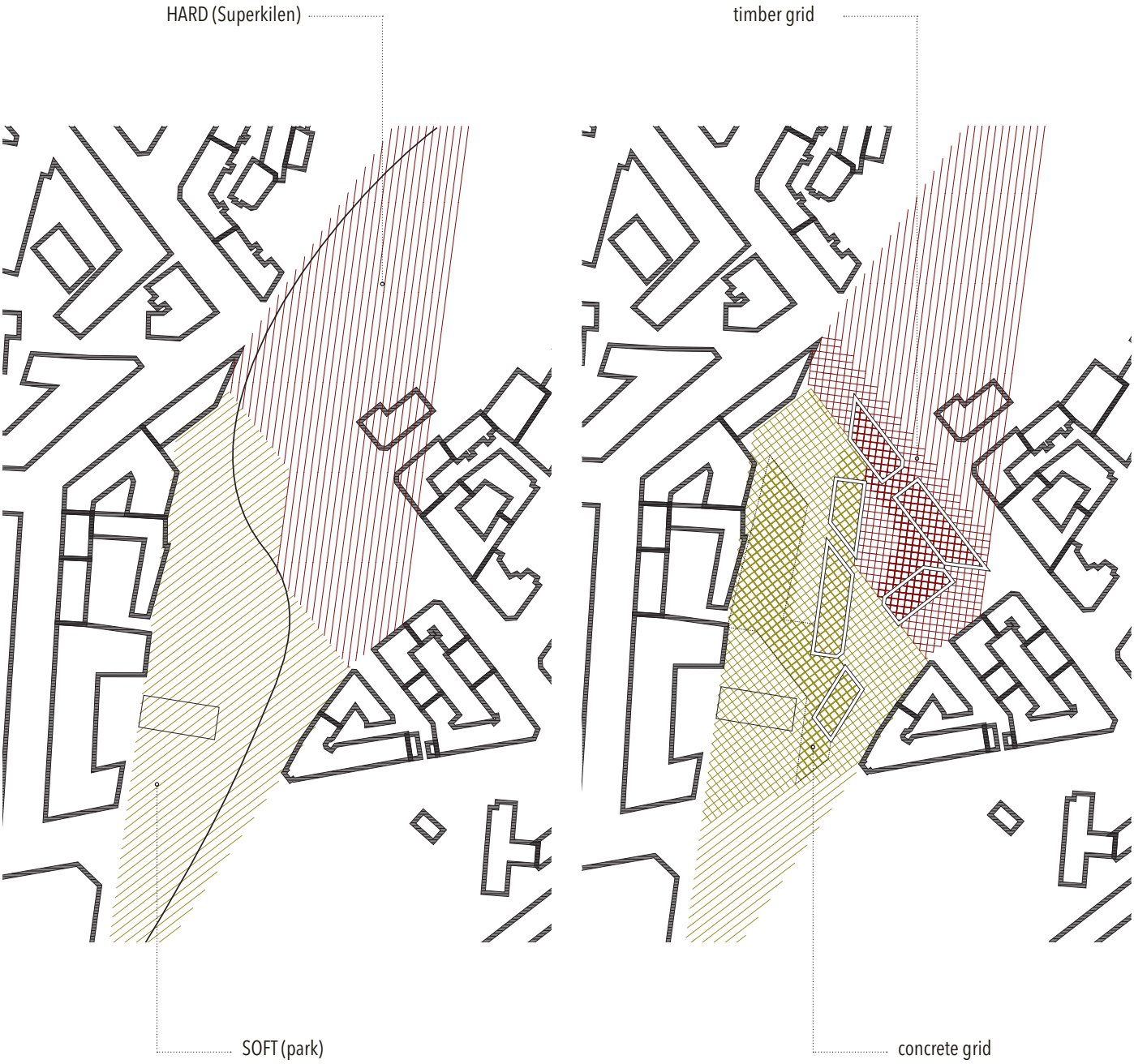


Fig 54. **Conceptual master plan diagrams illustrating the relationship between two characters of the area and positions of the project's grid.**

OUTLINE

The following chapter will introduce how the concept of Space Metamorphosis is applied to a particular site and will give an overview of each of the three main scales: EXTERIOR/public, INTERMEDIATE/common and INTERIOR/private.

This overview will be following the three scales in their respective multiple configurations and highlight their differences, qualities and main aspects. They will each be displayed in plan and section.

It was chosen to represent each scale in two different states. These two states are resulting from the earlier studies that were made according to different functions which were required by the local plan. Both states will be referred to as Day and Night configurations in order to simplify the process even though their precise respective durations might vary.

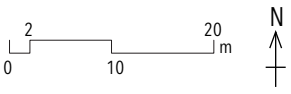
EXTERIOR. The ground floor will focus on showing relationships between the existing surroundings and the project and highlight some design features and facade expressions.

INTERMEDIATE. The common floor will be illustrated by the example of leisure or lounge area transforming into hostel rooms.

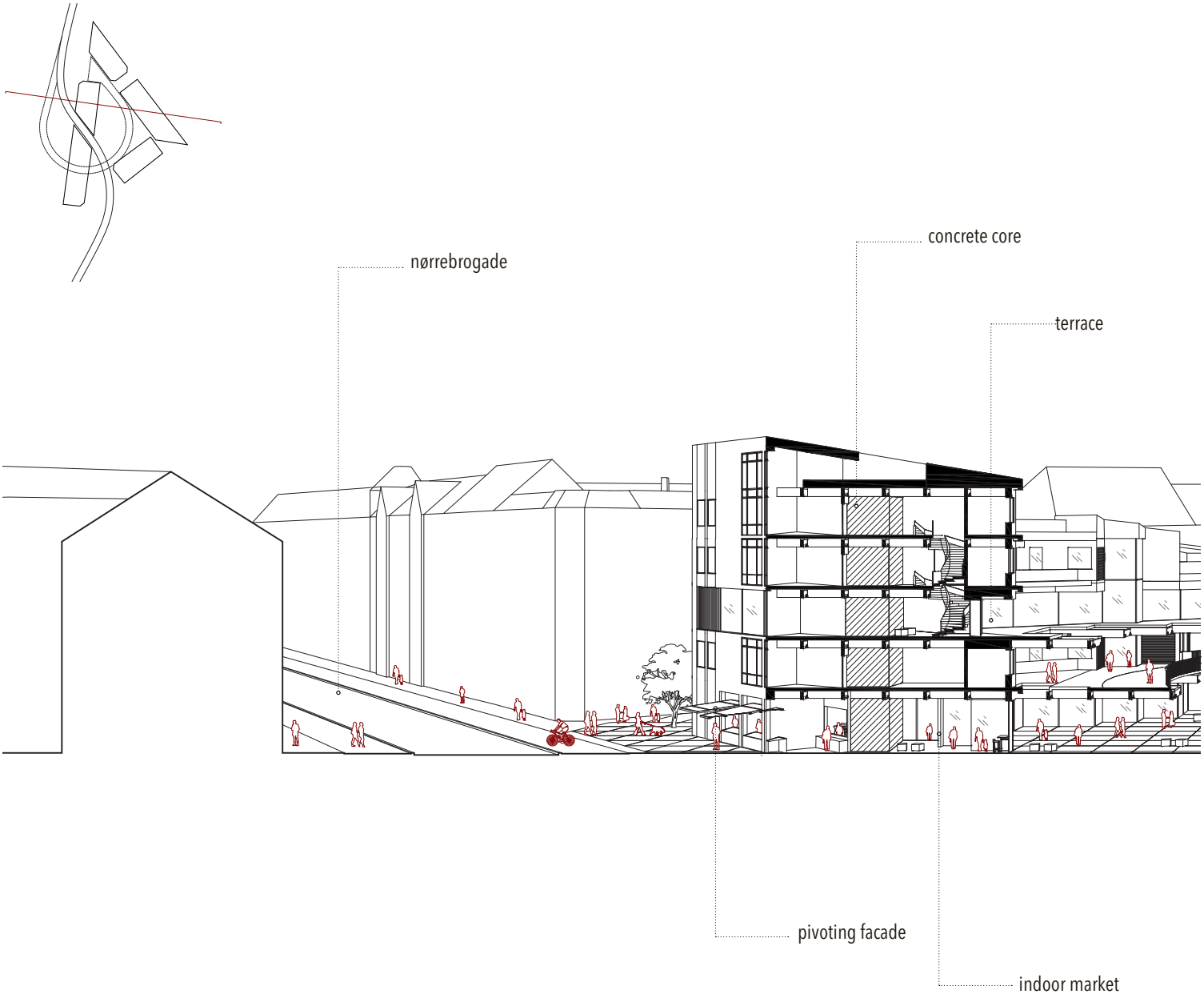
INTERIOR. The unit chosen to represent the interior layer of the project is the most representative in number and in size. Just as the hostel part of the common floor, these units are transforming twice a day in order to adapt to changes of use and users.

EXTERIOR/
PUBLIC

Fig 55. **Ground floor plan**



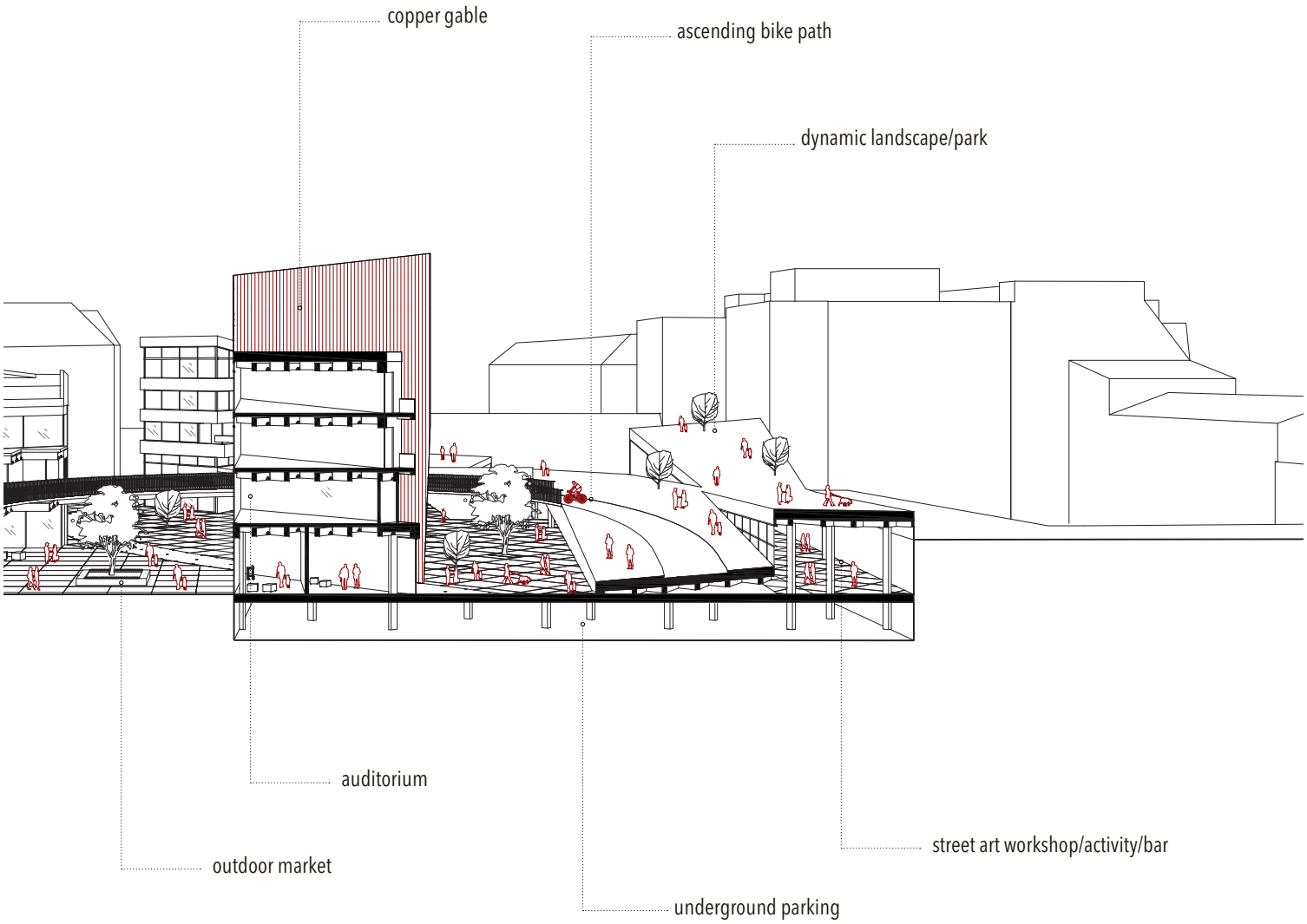

traffic
moderator
plaza
restaurant
cafe
service
market
outdoor
market
street art
workshop/ bar
service/
activities
market
pedestrian street
with bike parking
existing
skate park
service



The ground floor houses a café/restaurant in its northern corner, a market in the eastern one and different service oriented rentable areas to the west. The internal square is used by the market as extension when the weather allows it and can be transformed to host other events. By creating pivoting facade elements, in the morning, when the market is open, the street facade appears to be more inviting, while in the evening it stays more reserved. The dynamic landscape lying on the western border covers the underground parking and shelters a large activity space acting as street art workshop during the day and bar/disco at night. Several landscape elements distributed according to the surrounding functions such as lighting, flower beds or sitting urban furniture help to define every part of the ground floor fabric.

The totality of this exterior space is public, but while the aim is to have it dynamic and vibrant during the whole day, some areas are highlighted during the night and some blurred and sieved in order to satisfy the change of environment and users.

Fig 56. **Site section**


copper gable
ascending bike path
dynamic landscape/park
auditorium
outdoor market
street art workshop/activity/bar
underground parking

INTERMEDIATE/
COMMON

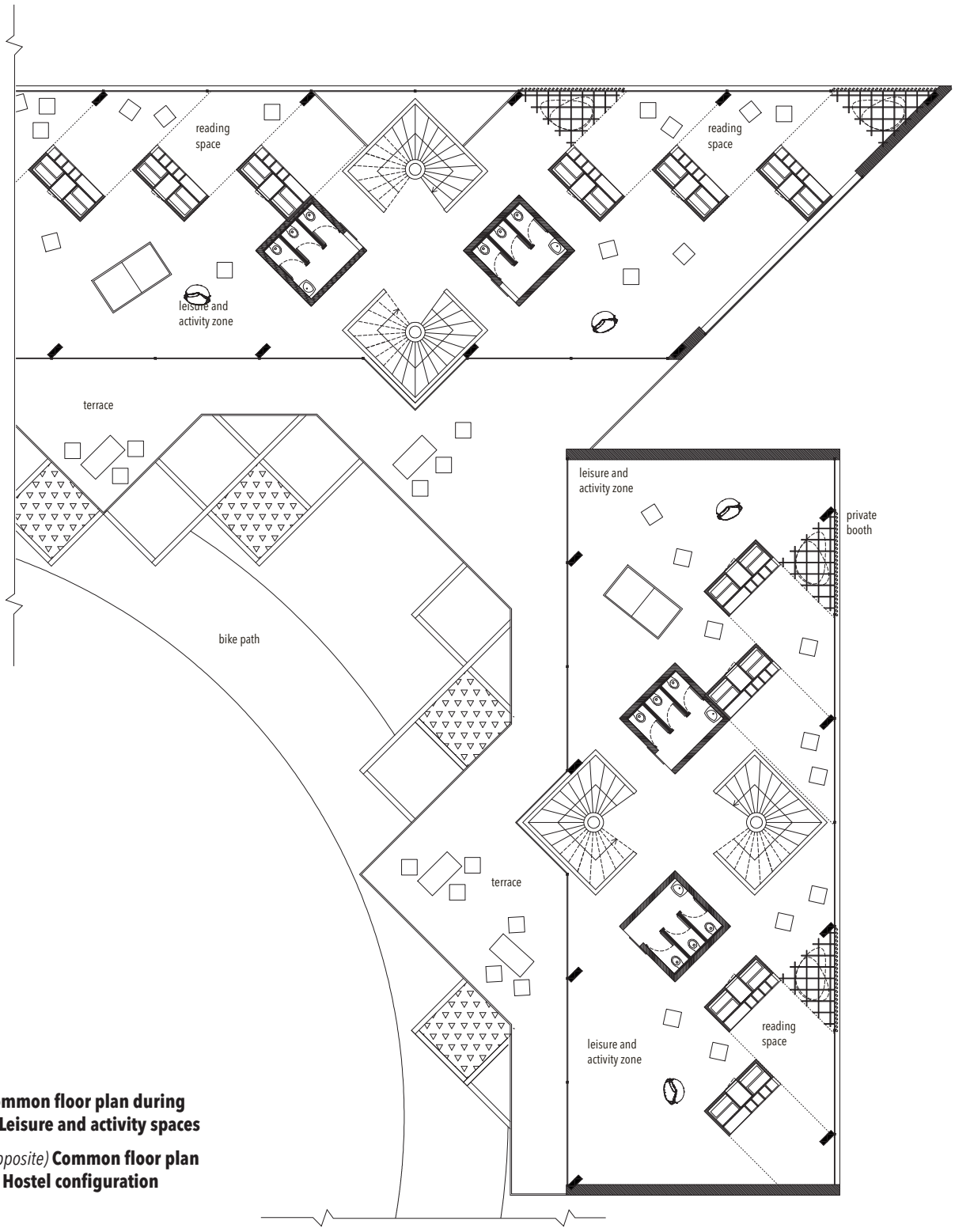


Fig 57. **Common floor plan during the day. Leisure and activity spaces**

Fig 58. (opposite) **Common floor plan at night. Hostel configuration**


høstel
høstel
hostel

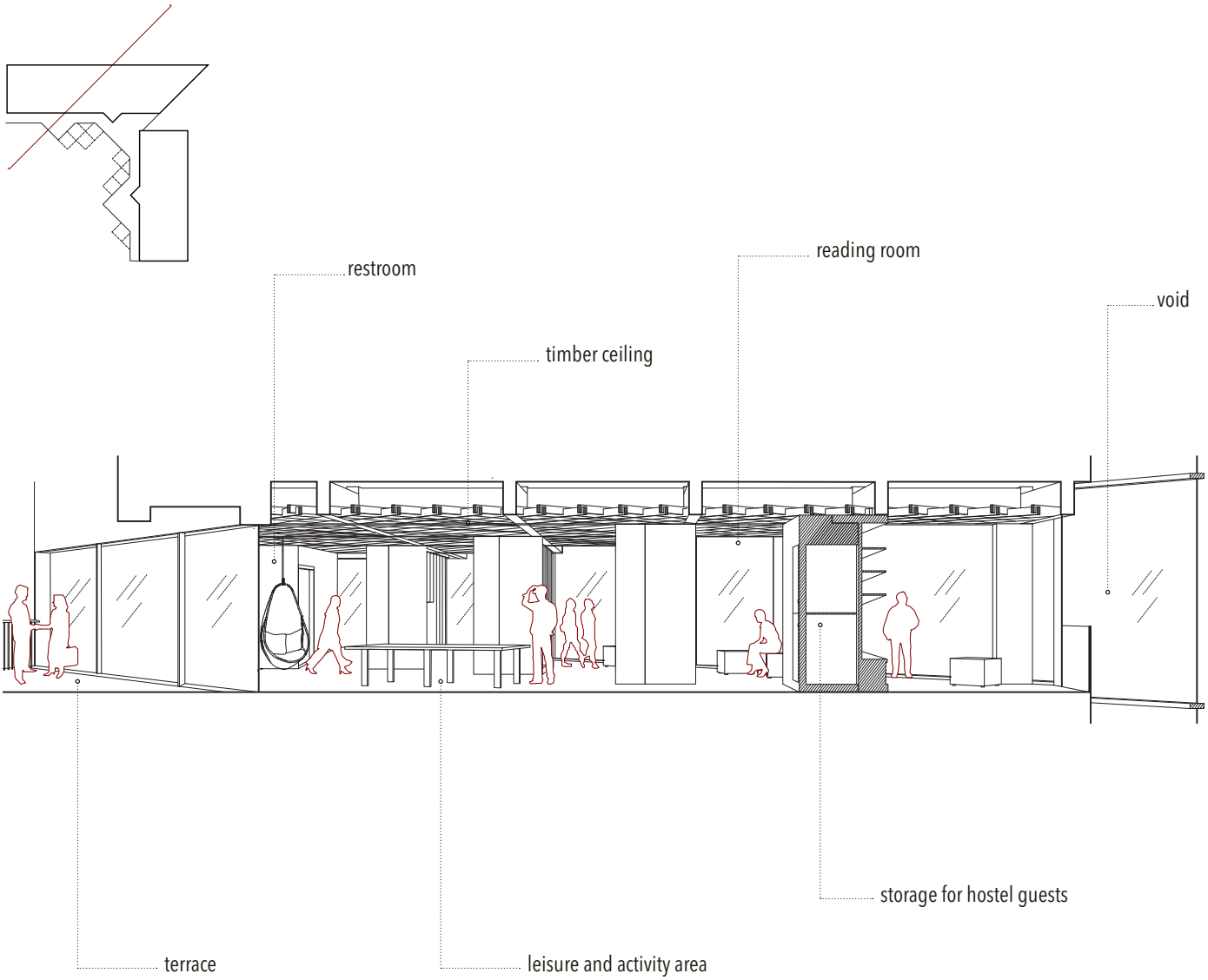
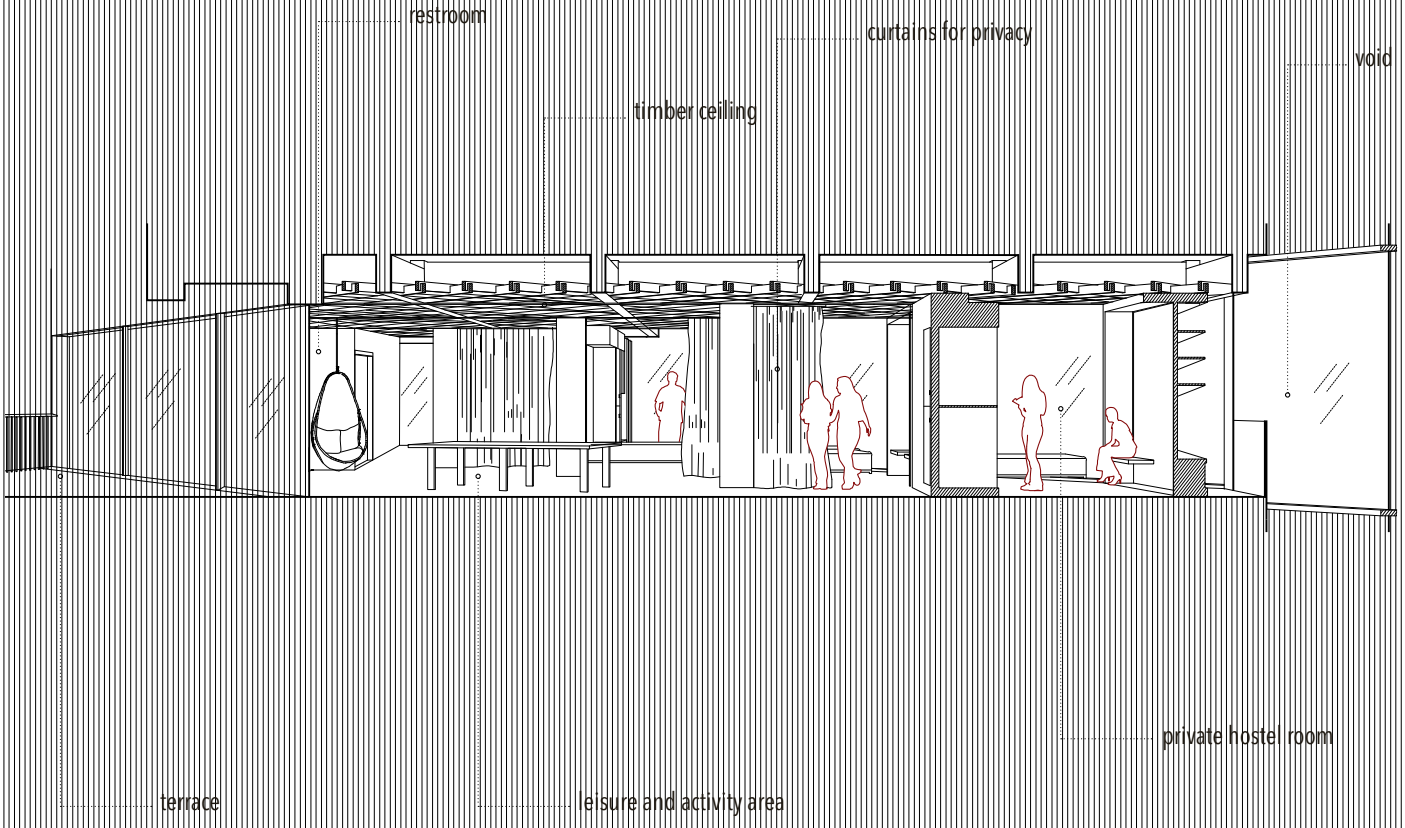


Fig 59. **Common floor section during the day. Leisure and activity spaces**
Fig 60. (opposite) **Common floor plan at night. Hostel configuration**

The common floor's organization is meant to mainly be a large open plan including both vertical shafts and horizontal flows. Depending on its situation in the project, the common floor accommodates different functions. On top of the cafe/restaurant is located a canteen; a conference room, some printing facilities and a laundry are positioned in the western wing and the main large resting area stays in the eastern corner on Norrebrogade. In order to satisfy the need for privacy, private booths were inserted periodically along the common floor's facade. These booths can be seen as small cocoons where one can isolate himself, either to work or to rest, away from the surrounding tumult.

As shown on the plans and sections, the same layout expands and contracts according to Time in order to let certain function manifest while others are relegated in the background. In this case, the space transforms from a lounge/hobby space into a hostel. Thick modules containing storage units, necessary furniture as well as a small library can open up and create large two-bed hostel rooms. This transformation process not only changes completely the inside atmosphere but also has an important influence on the facade expression.


restroom
curtains for privacy
void
timber ceiling
terrace
leisure and activity area
private hostel room

INTERIOR-
PRIVATE

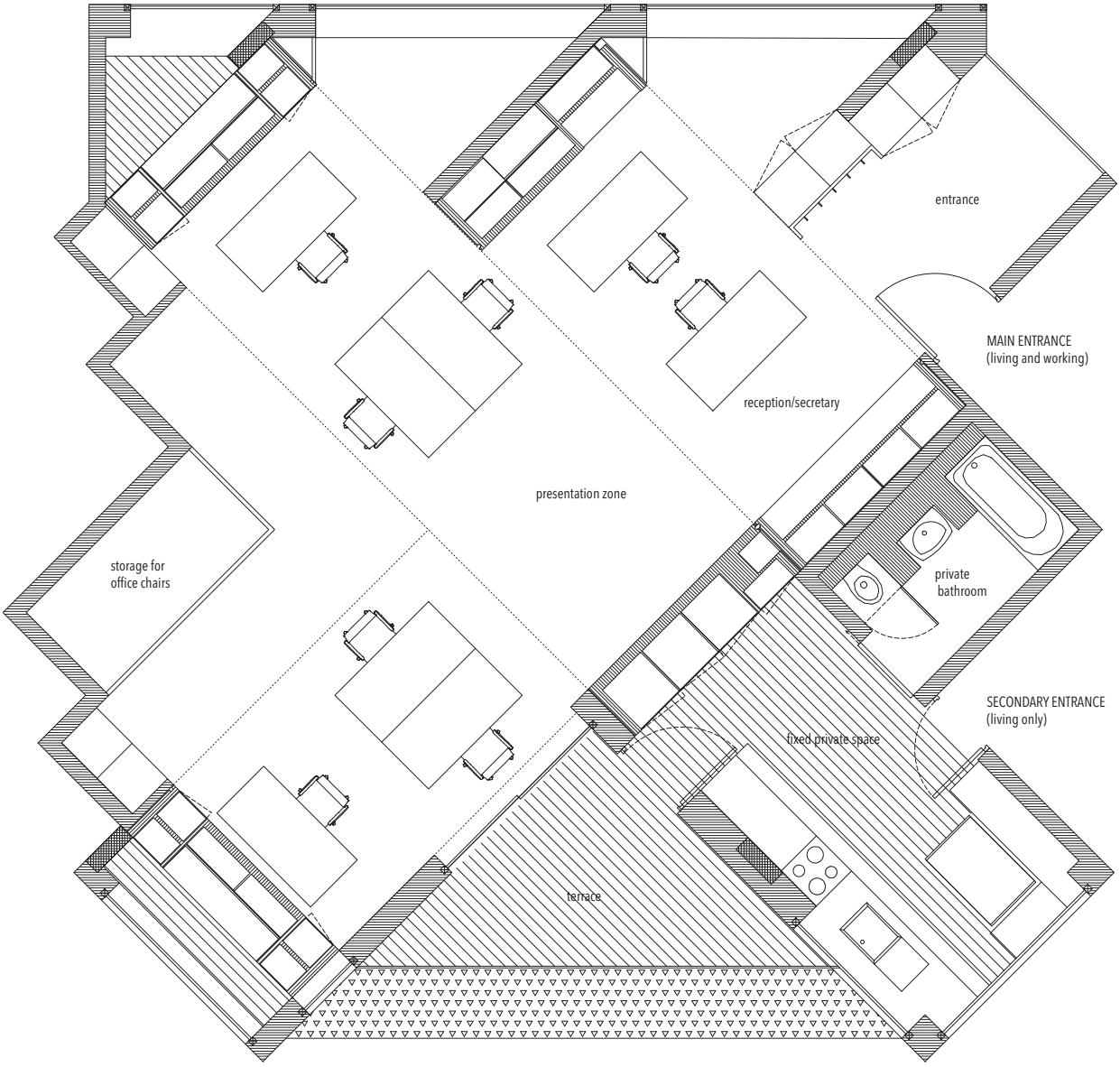
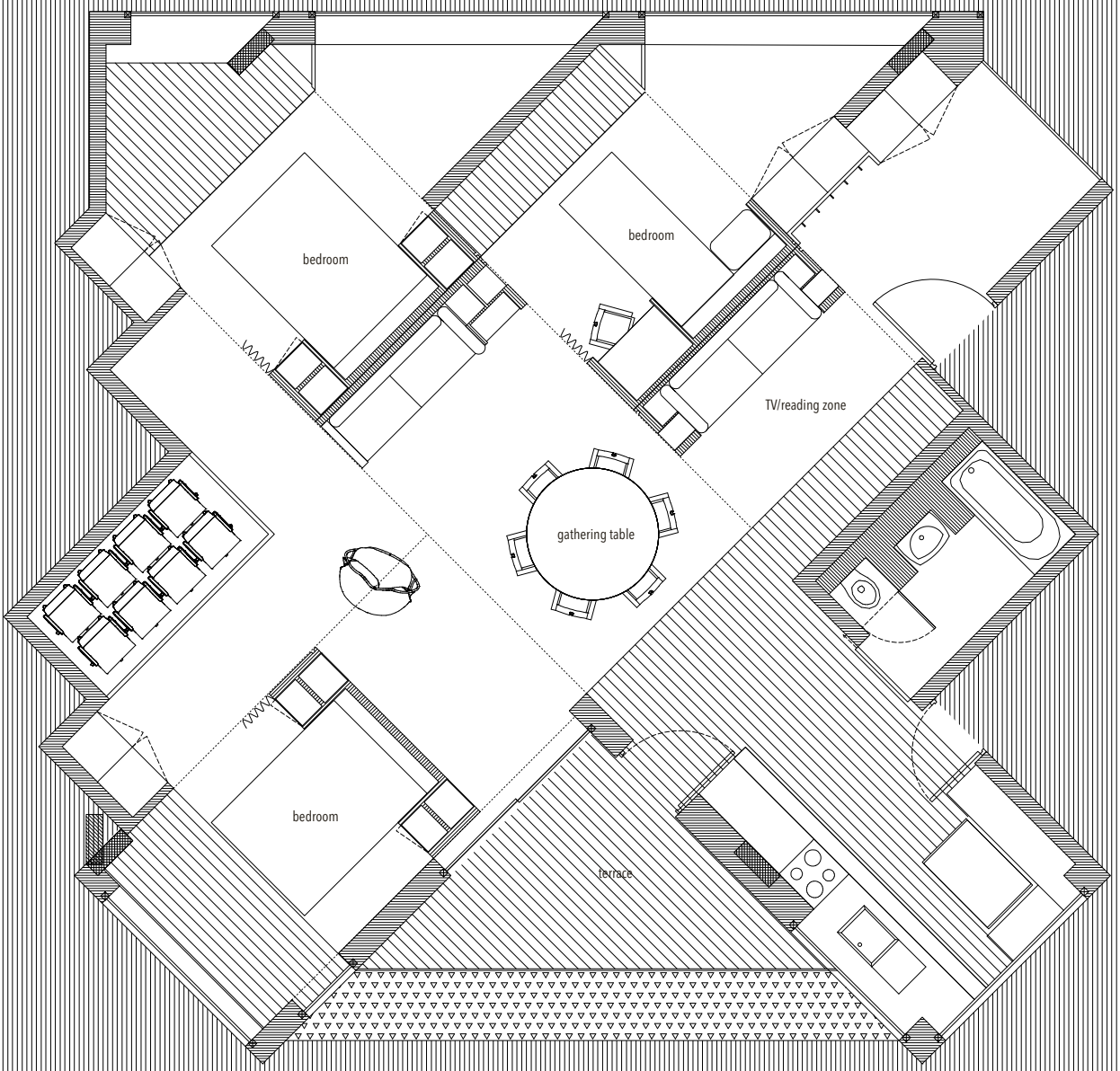
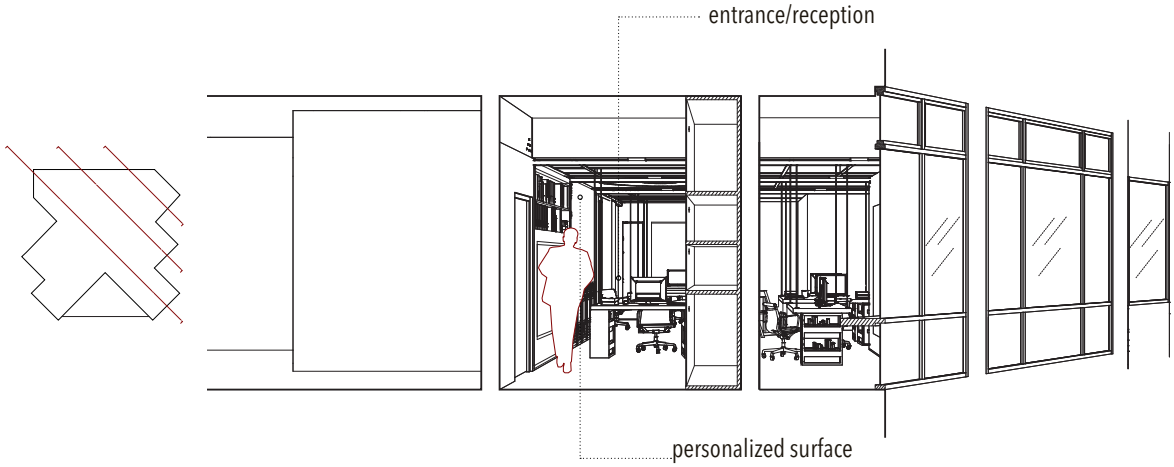


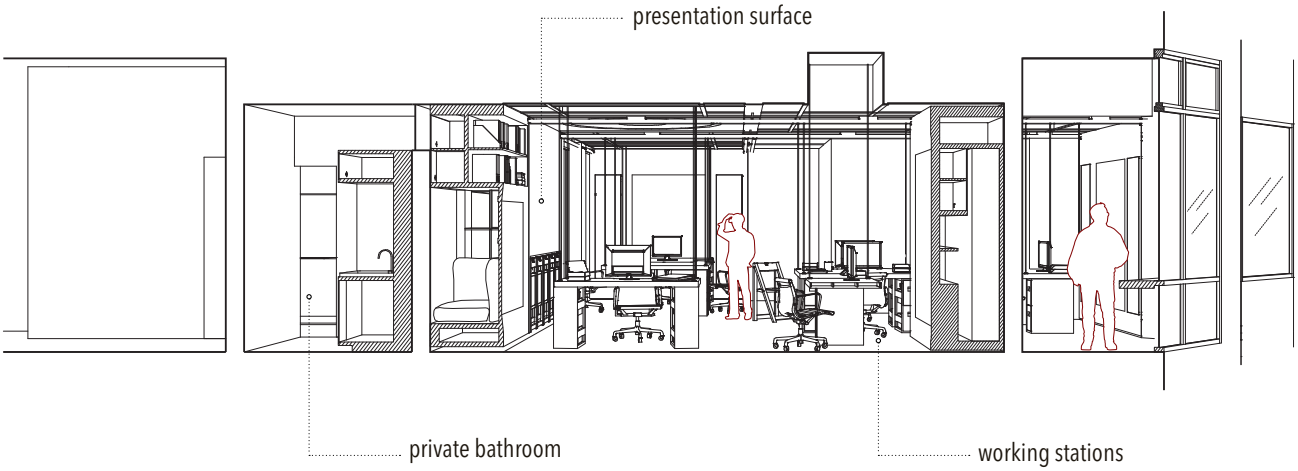
Fig 61. **Unit plan during the day. Working configuration**

Fig 62. (opposite) **Unit plan at night. Living configuration**

Shifting from Living, to Working, to Living again, is achieved by moving several different modules. These modules changing positions are all altering the amount of light entering the different sub-spaces newly created and covering or revealing different surface treatments as well as complete furniture elements. Directly accessible at all time because of the division of the entrances, an emergency private space able to be self functioning at all time is housing the kitchen and has access to the bathroom and terrace. We envision that all module movements could be automated and triggered by the users' entrance magnetic pass to strengthen the user's belonging feeling.


bedroom
bedroom
TV/reading zone
gathering table
bedroom
terrace





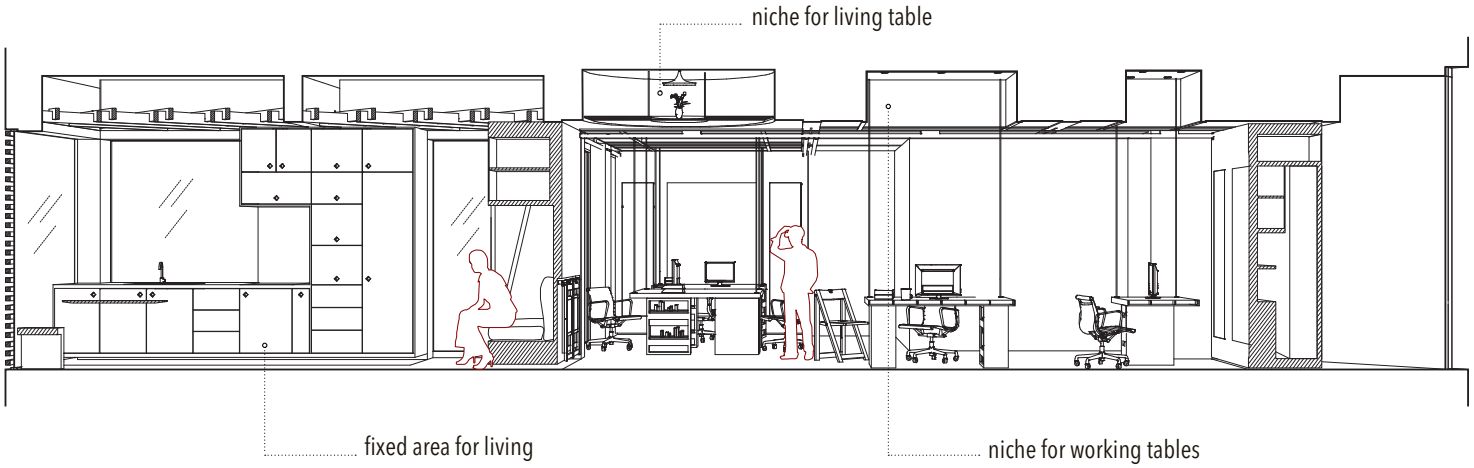


Fig 63. **Unit sections during the day. Working configuration**

Fig 64. (opposite) **Unit sections at night. Living configuration**

The 45° structural plan allows to increase the placement possibilities of the modules inside the main space and creates a focus point in the heart of the living space. To reinforce this sense of gathering, the main table was placed there in the case of the Living configuration and the main presentation surface for the Working setting. Working stations retractable in the ceiling recessed niches allow Working users to keep their belonging in place and provide a diffused ever changing lighting for the Living environment.


unfolded module
bedroom
table legs
terrace
unfolded tv/reading module
private bathroom
bedroom
bedroom
south light shading
gathering table
working tables in the niche
kitchen is connected to the living room
sitting arrangement
suspended chair

STORY BOARDS

In order to better illustrate the potential and qualities of the Space Metamorphosis concept, this part will set the stage for three different characters each with a specific time frame and routine inside the project. Through their actions and uses, they will show the project from the user's perspective at a more detailed level than it was presented in the Outline chapter. Each story will be described with a narrative which becomes personal and relates to experiences and connections. We think that the building will reinforce the idea of community and human relationships and therefore will conduct to using special phrases or slangs, for example: "N hall" representing Norrebro staircase or "COM" meaning common floor.

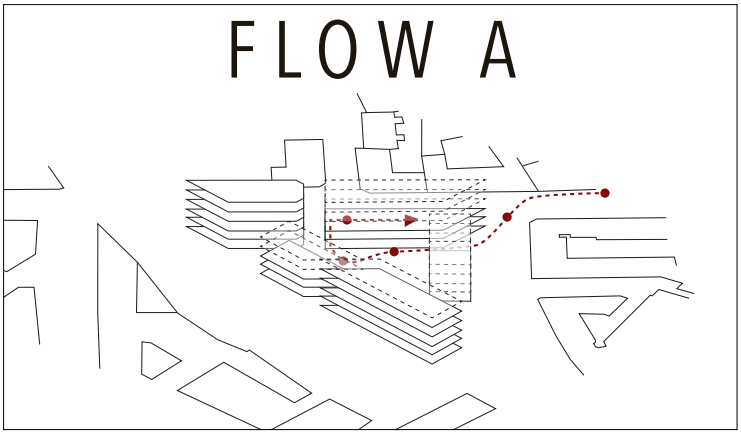
FLOW A is the story of a young person who just arrives in Copenhagen and stays in the hostel. He is not familiar with the building and is discovering exterior and interior features of the project on his way.

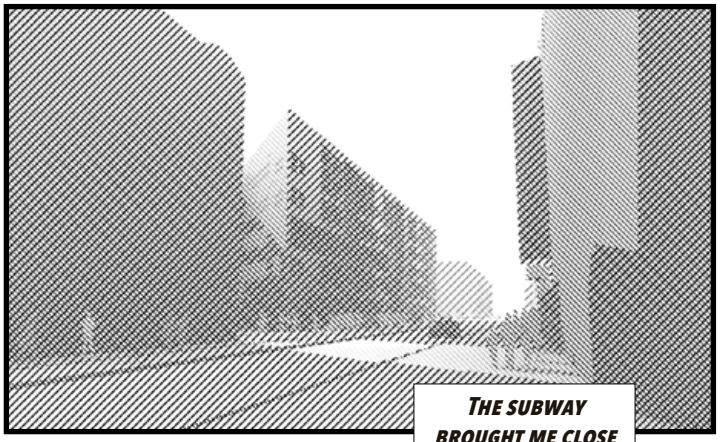
FLOW B is about a man who does his job in one of the Working spaces. He has a routine of arriving every morning by bike, work, socialize, enjoy his time in the building and leave in the evening, when working hours are over.

FLOW C tells the story of a woman living in a unit and working in another area of Copenhagen. From Monday to Friday, she usually leaves in the morning and returns at the end of the day.

Fig 65. (next pages) **Collage of renders illustrating exterior and interior features of the project**

FLOW A

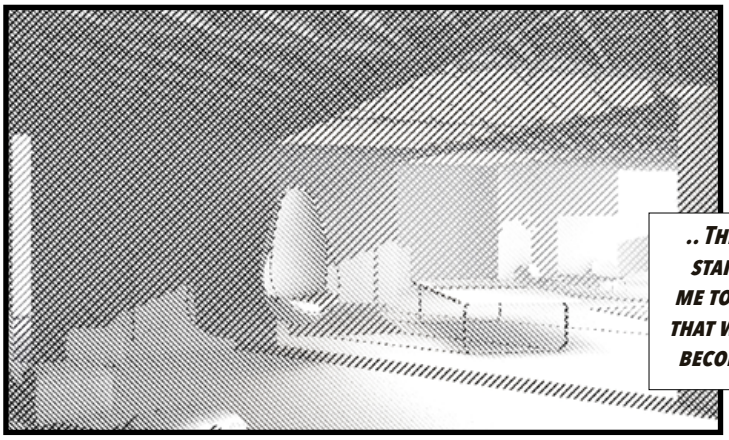




The subway brought me close to my hostel as the late afternoon sun was reflecting on the copper facade...

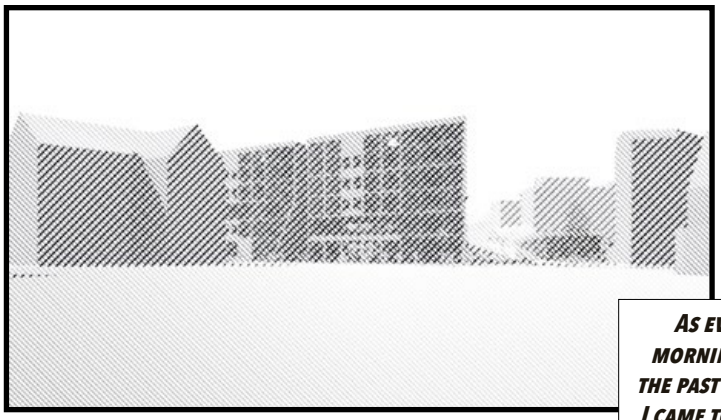
... Many people were still outside the building, probably because the market was still open...

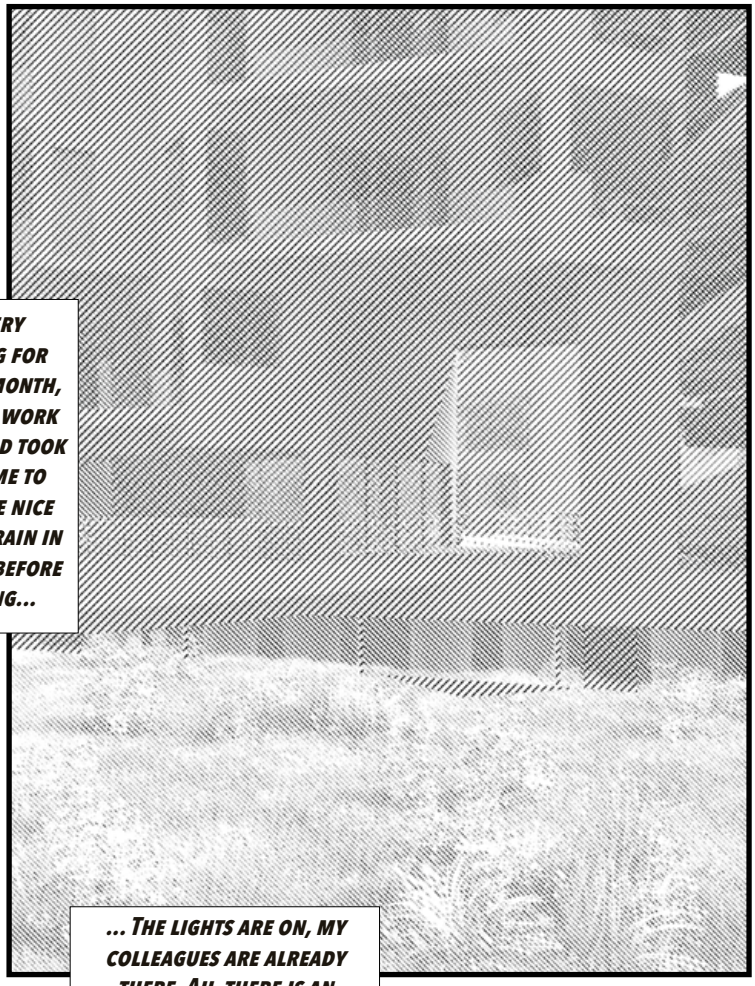
... I THEN ENTERED AN ENCLOSED SQUARE PARTLY COVERED BY WHAT APPEARED TO BE THE BUILDING'S STRUCTURE COMING OUT...



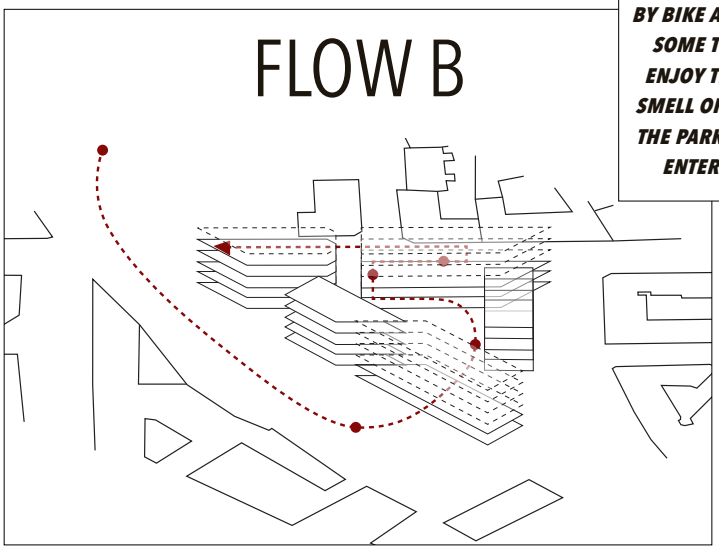
.. THE LARGE WOODEN STAIRCASE BROUGHT ME TO THE LOUNGE AREA THAT WOULD APPARENTLY BECOME OUR ROOMS ...

... AMAZINGLY MY ROOM WAS ACTUALLY ALREADY UNFOLDED AND WAITING FOR ME, BUT LET'S HAVE A QUICK TABLE TENNIS GAME BEFORE GOING TO BED!



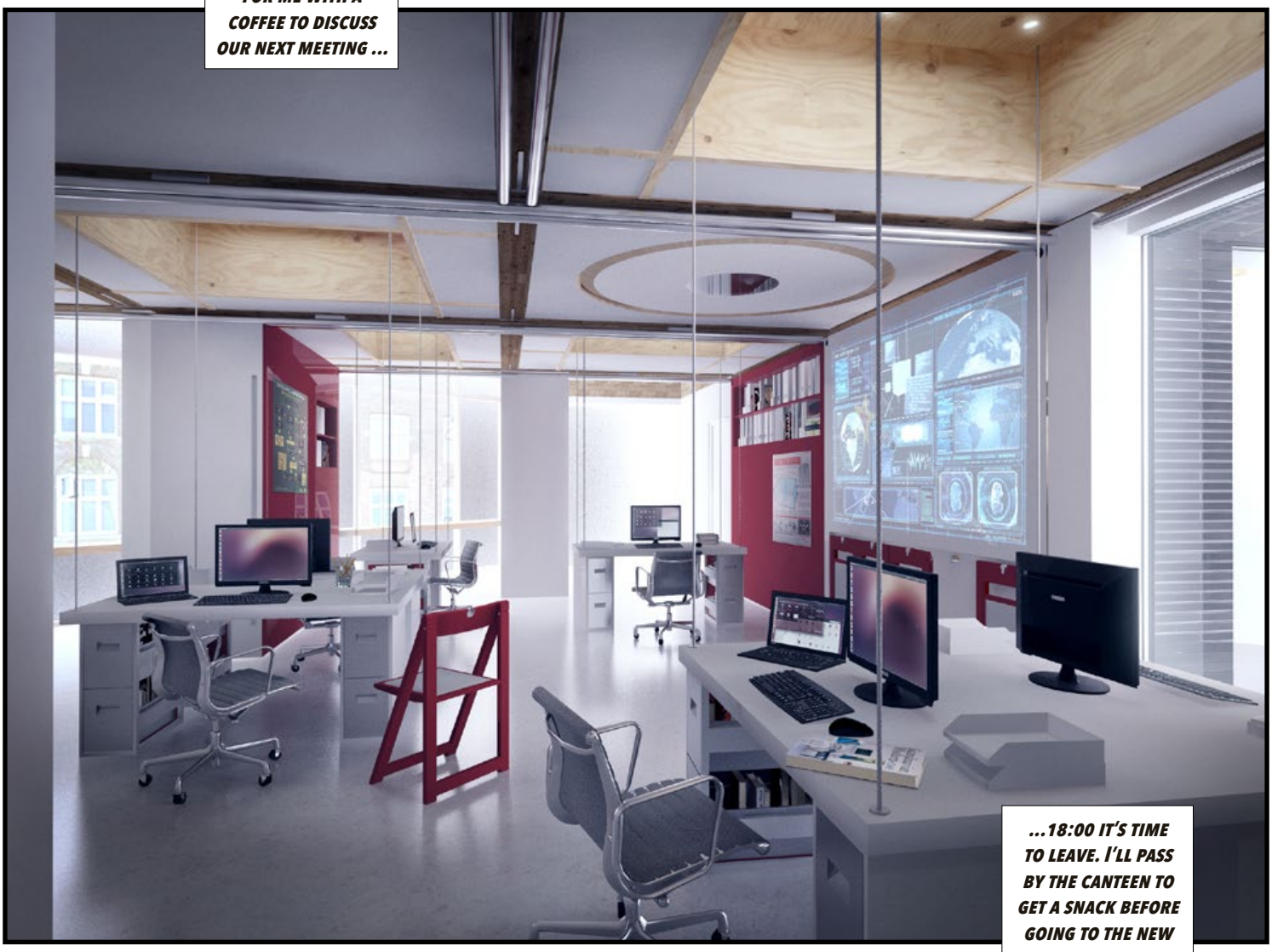


As every morning for the past month, I came to work by bike and took some time to enjoy the nice smell of rain in the park before entering...

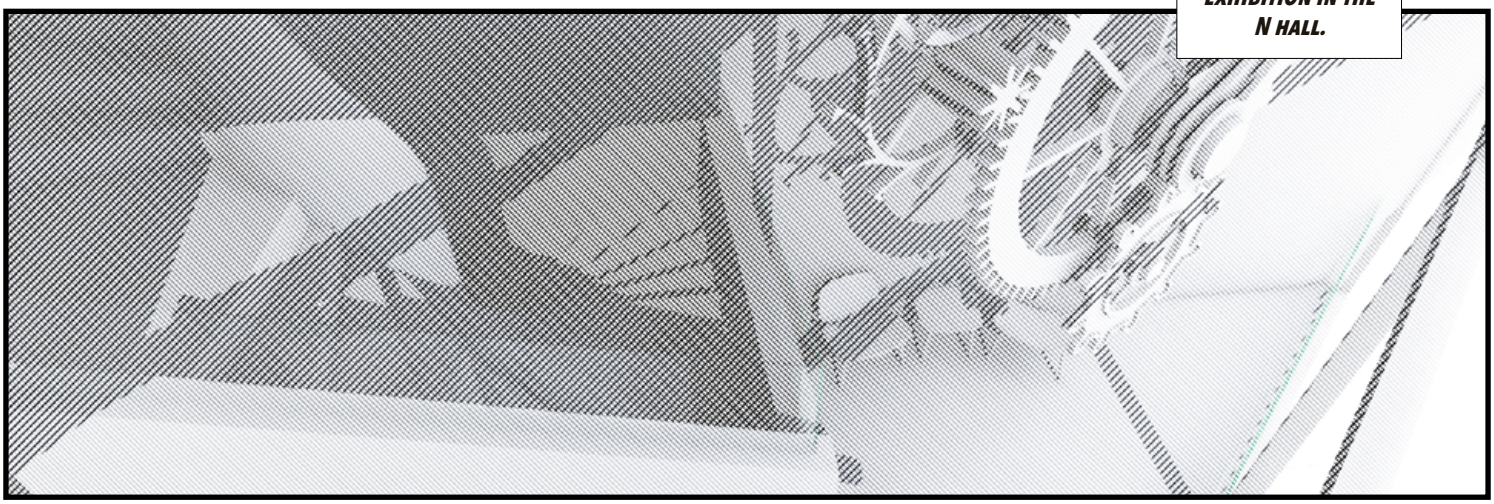


... The lights are on, my colleagues are already there. Ah, there is an exhibition opening today, we should all go after work ...

... I met Lars in the COM while going up. He was waiting for me with a coffee to discuss our next meeting ...



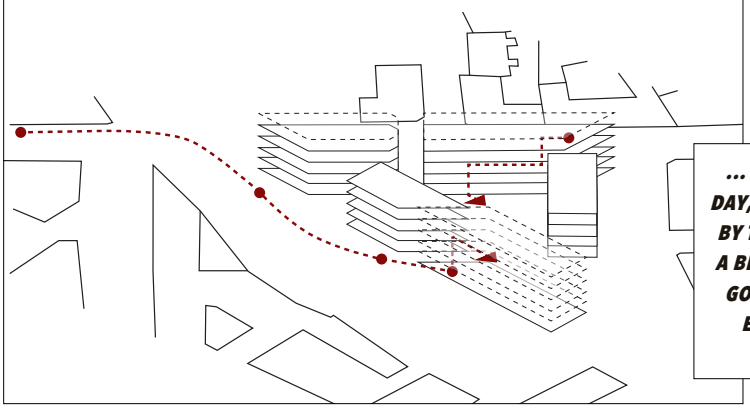
...18:00 it's time to leave. I'll pass by the canteen to get a snack before going to the new exhibition in the N hall.



I WOKE UP EARLY AND FULL OF ENERGY AGAIN TODAY. IT'S BEEN LIKE THIS SINCE I MOVED IN. I STILL HAVE TIME TO ENJOY A COFFEE IN THE SUN BEFORE WORK...

... THE DAYS ARE GETTING SHORTER AND THE APPLE SEASON IS THERE IN THE MARKET DOWNSTAIRS. I'LL GRAB ONE FOR LUNCH!

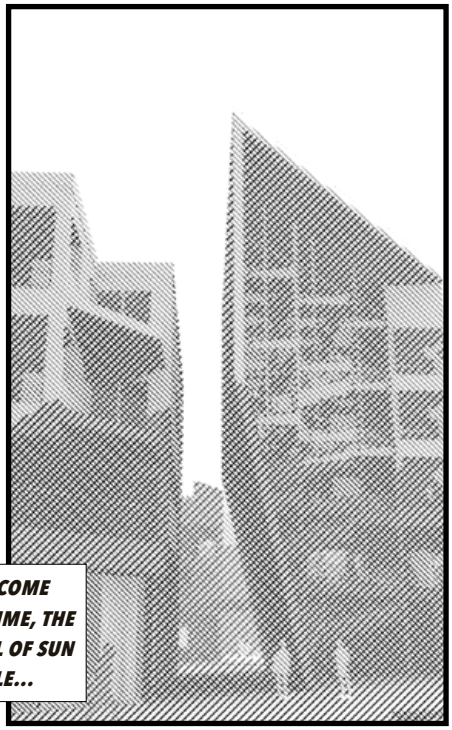
FLOW C

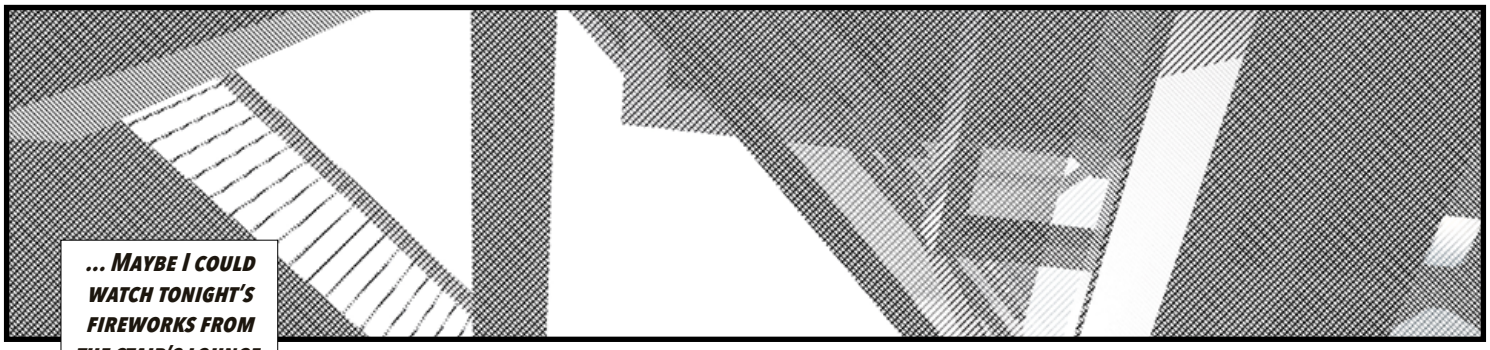


...7 HOURS LATER

... IT WAS A TOUGH DAY, I THINK I'LL STOP BY THE CAFE TO TAKE A BIT OF SUN BEFORE GOING UP. I MIGHT EVEN RUN INTO CASPER! ...

... I like to come back at this time, the square is full of sun and people...





... Maybe I could watch tonight's fireworks from the stair's lounge, the view must be perfect. I'll ask Julie if she wants to join ...

SPECIFICATION & PROCESS

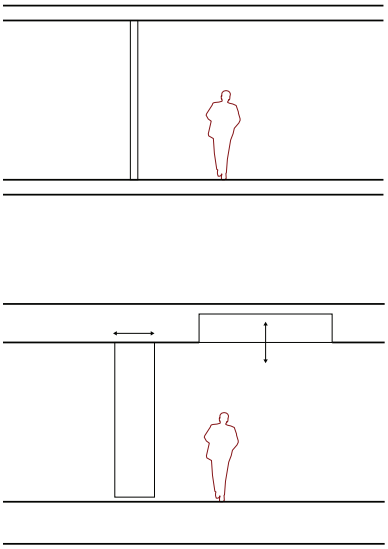
This chapter is focusing on explaining the Process and Specifications of key design elements of Space Metamorphosis : modules, facades, structure, energy demand and details. Each element is illustrated with diagrams, renders and technical drawings.

Chapter about vertical and horizontal modules explains the concept, design solutions, materiality and detailing.

Following the same principle the general concept of the facades is presented and the differences between day and night configurations are highlighted.

Using the PAD (Performance aided design) method, structural elements of the grid were calculated and evaluated. It also includes general considerations about the acoustics.

Energy demand together with indoor comfort simulations are completing this chapter with relevant diagrams and results.



MODULES

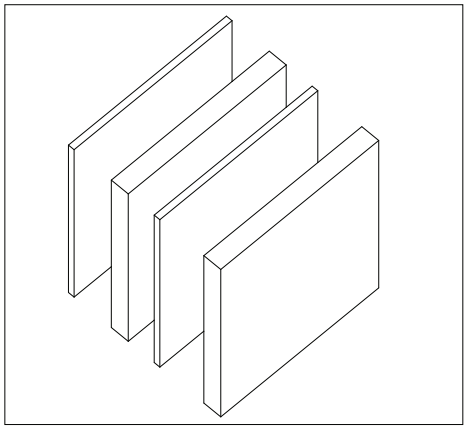
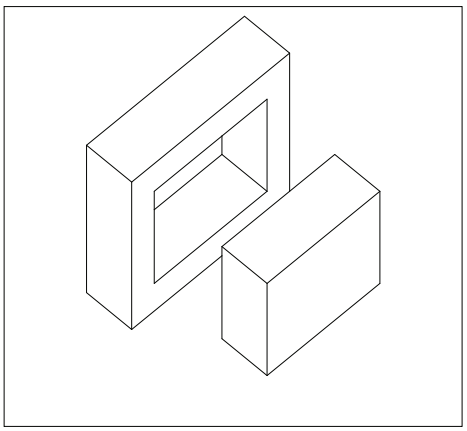
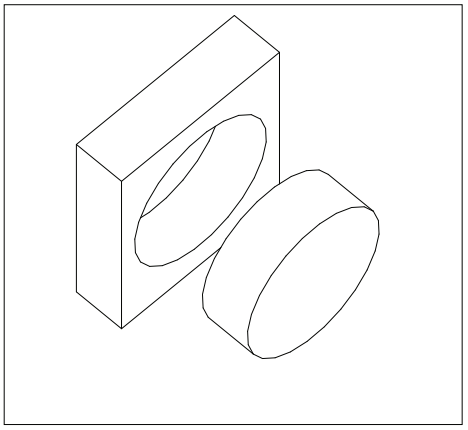
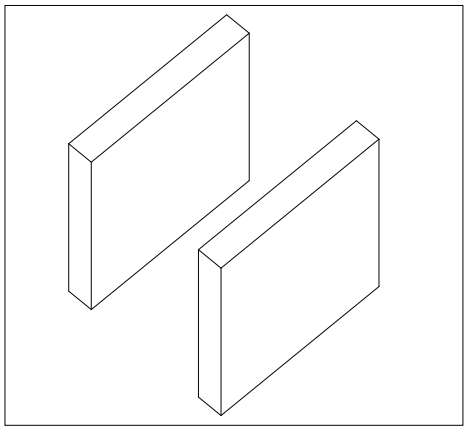
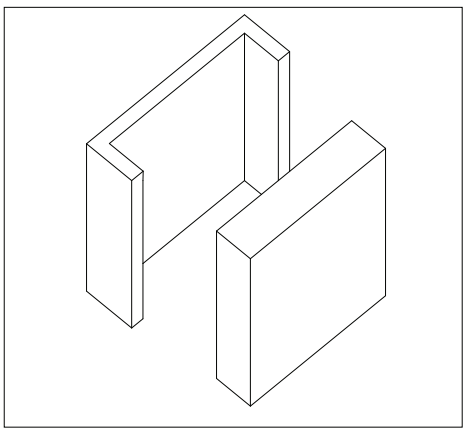
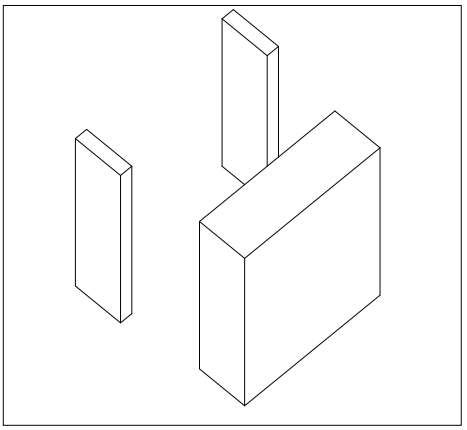
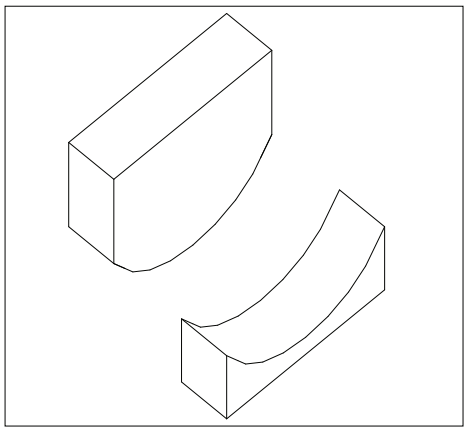
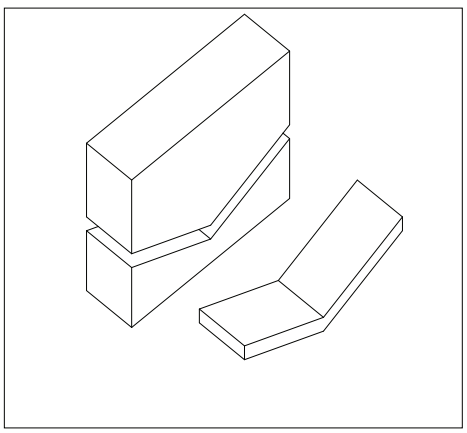
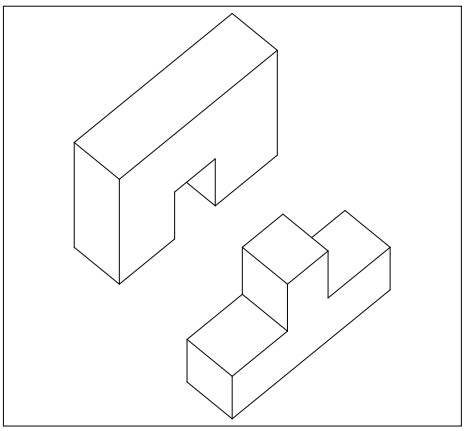
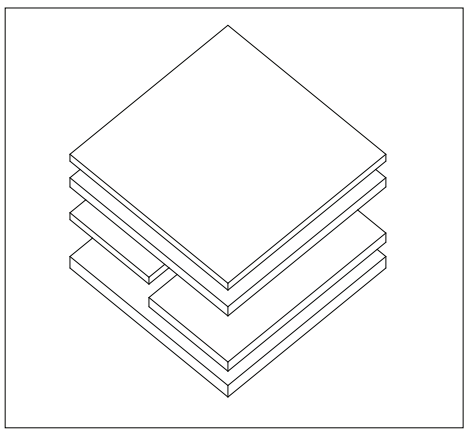
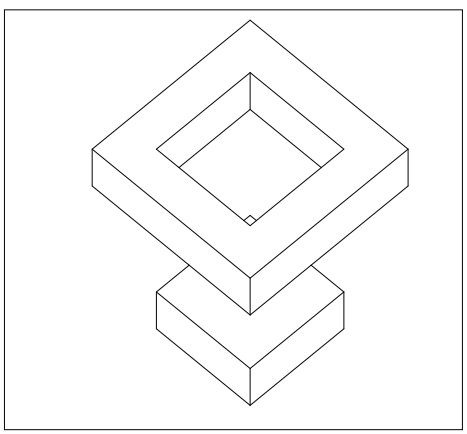
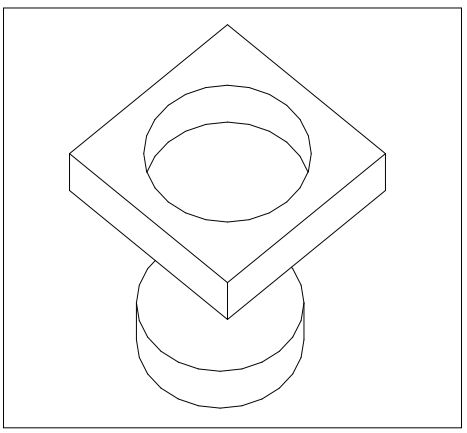
The main difference between traditional spaces and Space Metamorphosis is the introduction of horizontal and vertical modules, which allow transformations to take place.

The modules' sizes were influenced by their relation with the grid structural system as well as by the spatial hierarchy that we wanted to achieve. The first stages of the design were focused on the idea of layering. In order to introduce the right amount of privacy and personalization, the principle was either to work in pairs or to divide the modules in several parts - two preferably. Two main categories were drawn from this principle: the additive where layers were only superimposed and the negative where one element was the negative of the other one. Their thickness was then given by their content which was set according to their position and accessibility. The same kind of principle was applied to the deep ceiling where it was finally chosen to place tables and lighting appliances.

The final modules are divided into three main classes: sleeping, living and working. The first class encompasses the hostel module in which two beds are placed along with storage units for its fixed interior part and a library and a sitting place on its outside mobile part oriented towards the north windows. The two bedroom modules, also belonging to this class, in their main moving element contain one bed and either storage spaces or a working desk. The second class contains all other modules more orientated to leisure and storage such as the one closing the kitchen and making it a fully functioning studio when separated from the rest of the main space. The third one is for the retractable working stations. They can either be double or simple and can accommodate all the necessary office desk furniture needed because of the depth of the ceiling. The very internal structure of the tables is designed in order to avoid the multiplication of lighting appliances for both functions. By introducing a grid-like structure at the core of the table and a translucent surface treatment we allow light to be diffused for the living space. This diffuse atmosphere is then influenced by what is left on the table's surface by their users, reinforcing their awareness about the Other.

Fig 66. **Comparison of traditional ceilings and walls with the introduction of horizontal and vertical modules**

Fig 67. **Study of volume possibilities for the horizontal and vertical volumes**

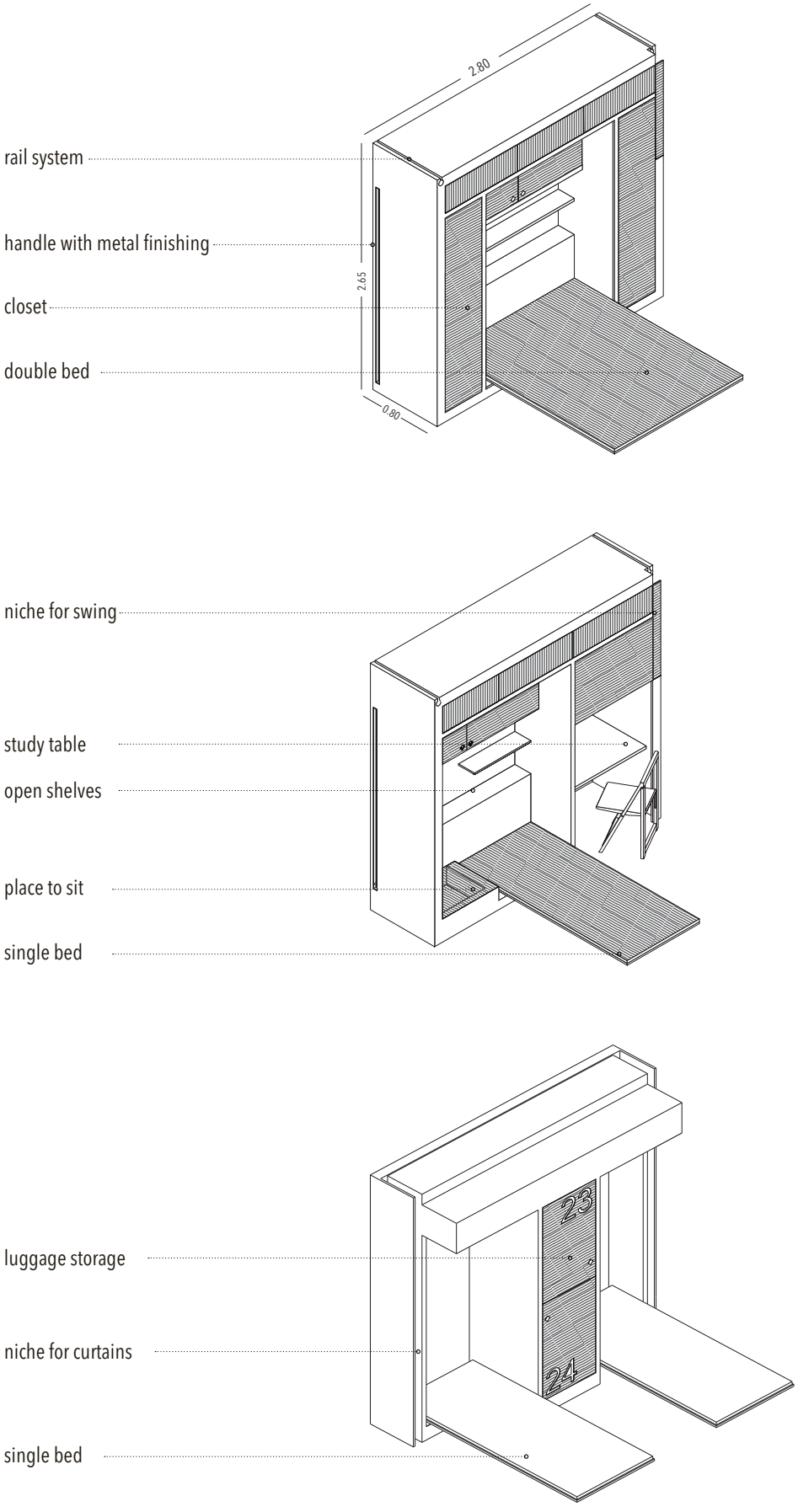
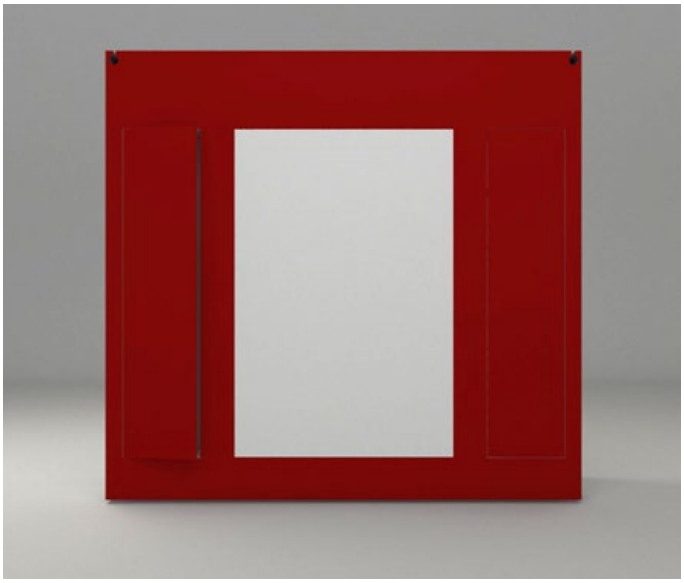
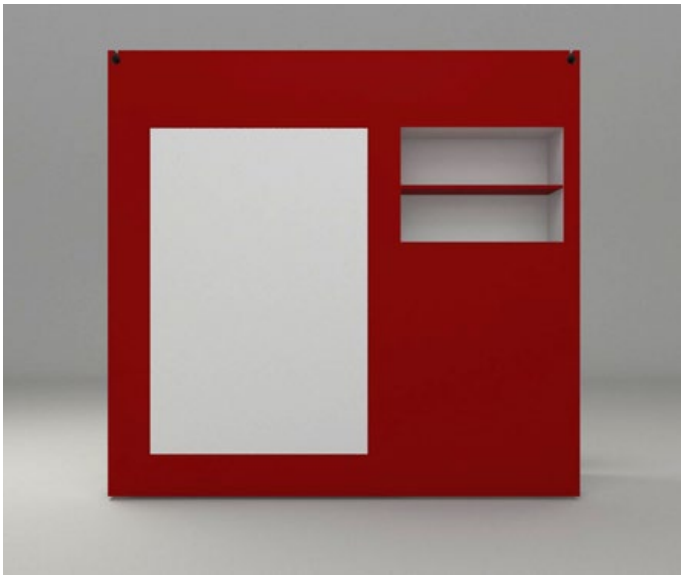


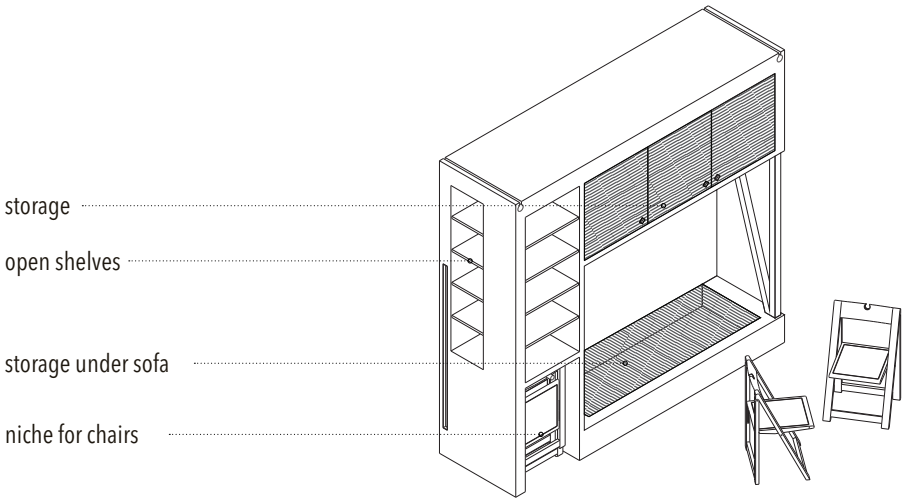
Fig 68. **Axonometries of three different sleeping modules and renders showing possible personalization of the surfaces**

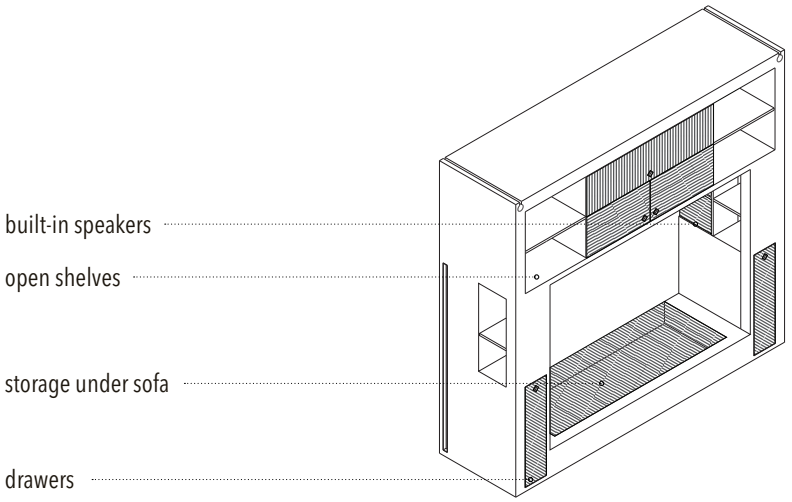
LIVING SURFACE

WORKING SURFACE









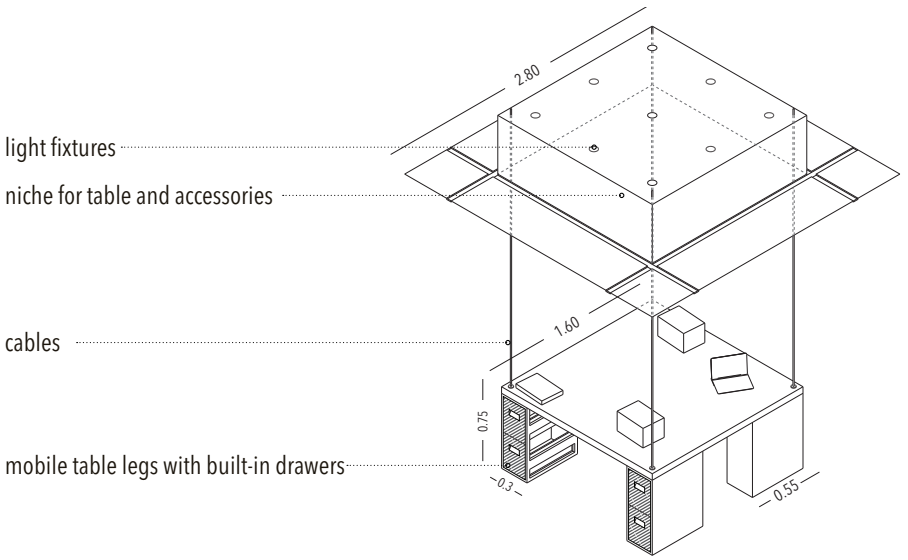


Fig 69. (top and middle) **Axonometries of living modules and renders showing materiality and possible personalization of the surfaces**

Fig 70. (bottom) **Axonometry of working module and renders showing the change of lighting effect**

LIVING SURFACE

WORKING SURFACE

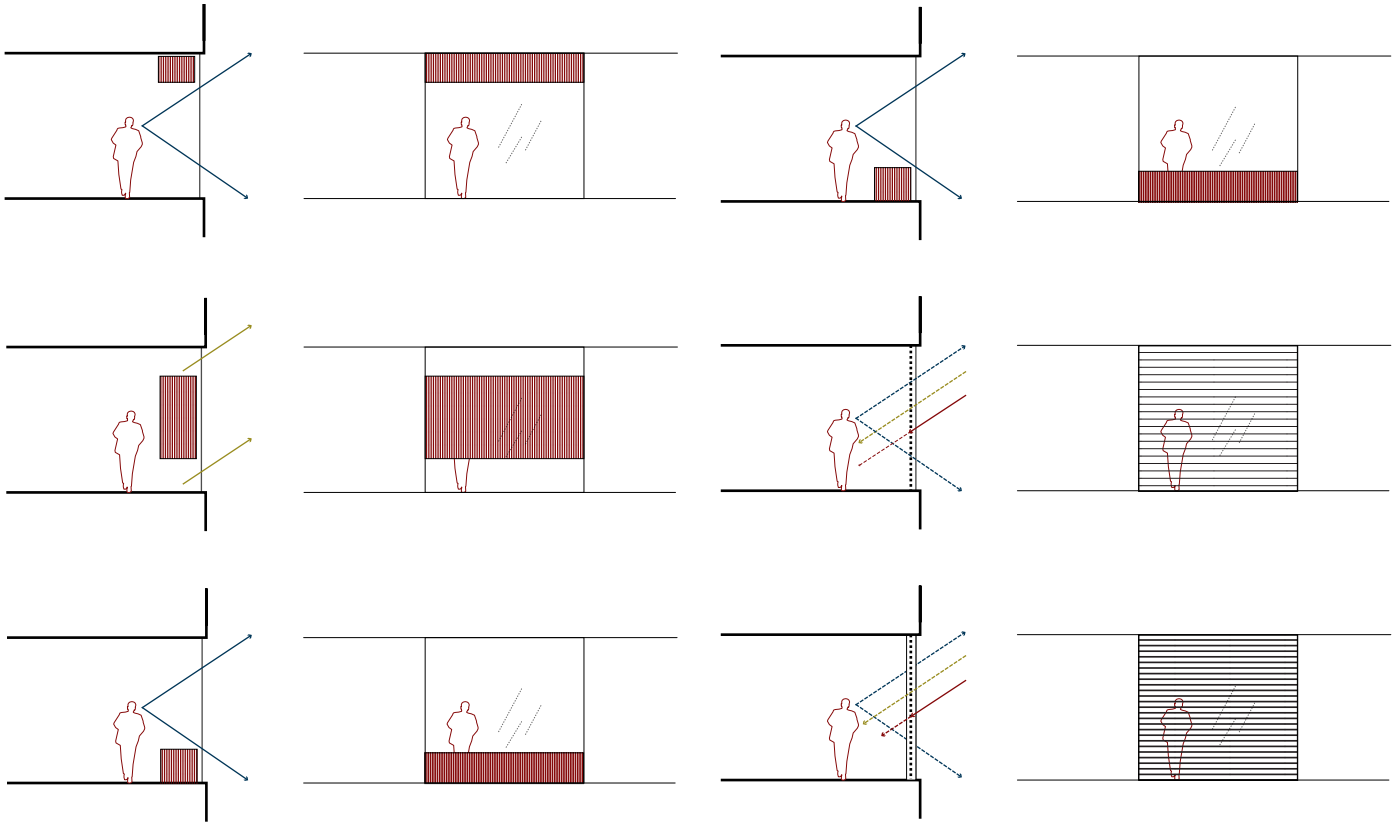
FACADES

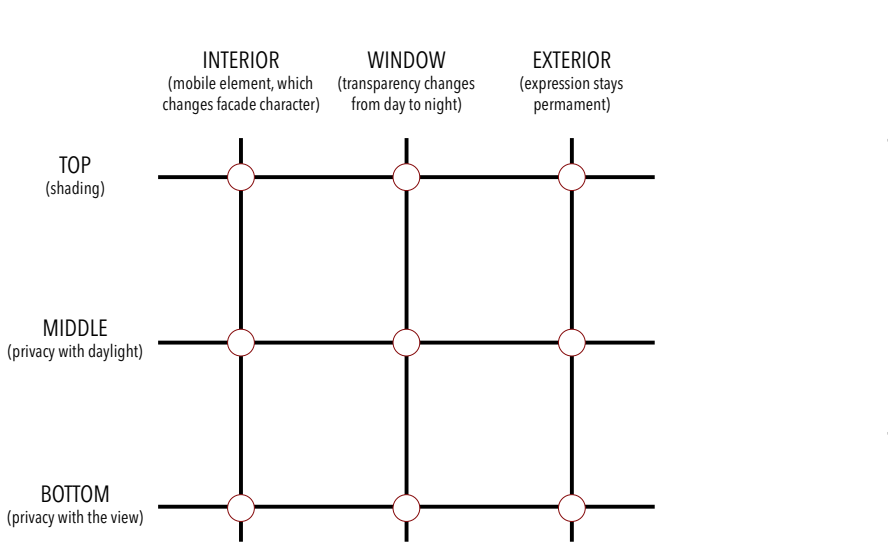
The principle that guided the facade design is the same that the one used for the module as they are strongly interrelated. While moving and in one of their static position, the modules are changing the transparency degree of the facade expression. In the case of some bedrooms or in the common floor for example, the inside environment in immediate proximity with the facade changes from totally obscured or totally transparent to the opposite. The shift between Living and Working state also illustrates an important change in expression as the support needed for the working tables are removed from what used to make the window sill. More than being only table supports they allow to get more privacy in the bedrooms and to let more light enter when the workplace needs it. The glass treatment in these main window outer panes is different again to increase the privacy degree without compromising the light intake.

This work on layering gives the opportunity to have the facade reflecting the building's internal life depending on its users. On the ground floor, the market stalls pivoting overhangs also treated with frosted glass allow, when open, to shelter clients from rain and, when closed to let light in and grant passers-by the opportunity to have a peek at the products.

Fig 71. (opposite top) **Study of facade layering in terms of privacy, views, daylight and sun energy.**

Fig 72. (opposite bottom) **Matrix of possibilities for facade layering**





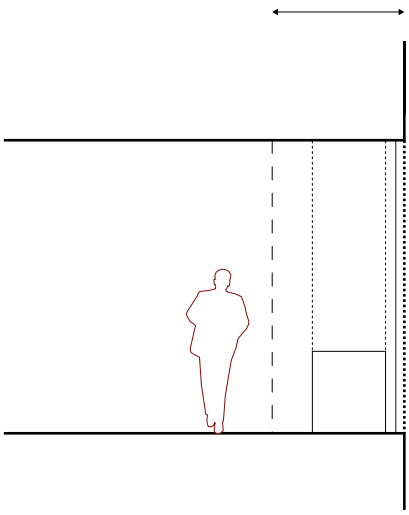


Fig 73. **Concept of mobile layering**

Fig 74. **Conceptual diagram and render of the facade expression during the day**

Fig 75. **Conceptual diagram and render of the facade expression during the night**

STRUCTURE

The structure has an important role in the project as it reinforces the concept of Space Metamorphosis and brings tectonic qualities to the spaces. Therefore the process of defining the structural grid and supports was performed in steps and feedback loops, which ensured more informed design decisions.

According to the Performance Aided Design (PAD)[19] method (fig. 30), the process starts with defining form and geometry using intuitive understanding based on previously acquired knowledge. It is also based on a specific desired expression and functionality.

The next step is performance simulation, which includes static schemes, hand calculations and Robot* structural analysis. Good acoustics in all different spaces are also considered and supported by the structural elements.

The last step is construction orientated, where main details are developed using different tools, such as hand sketching, 3D modeling and physical models.

***** *Robot* - structural Analysis Professional software provides engineers with advanced BIM-integrated analysis and design tools to understand the behavior of any structure type and verify code compliance

[19] Lecture by Dario Parigi

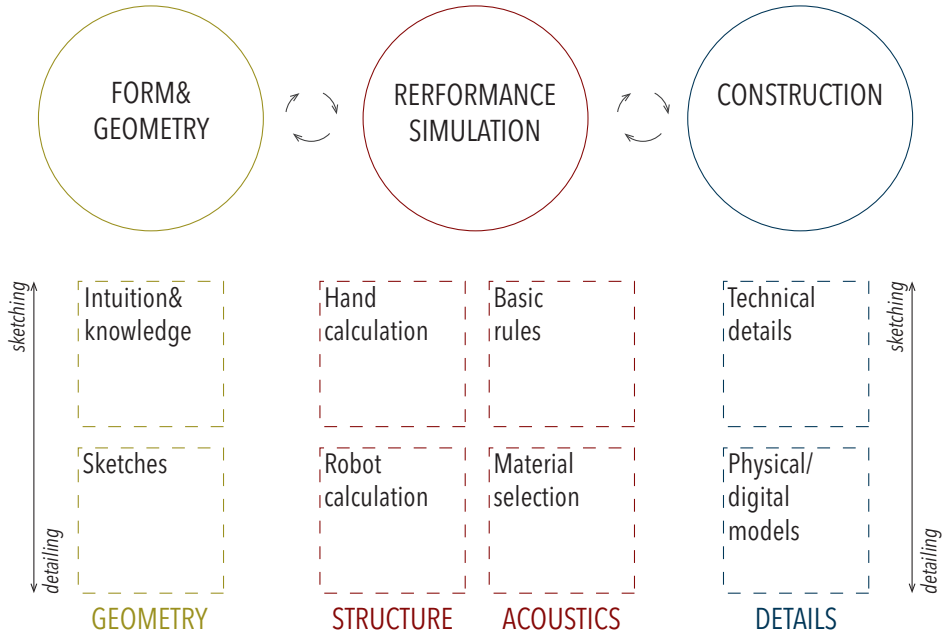


Fig 76. **PAD method diagram**

FORM AND GEOMETRY

The first step where form and geometry were defined was the sketching phase. We were looking for a general structural principle, which could support the concept of metamorphosis. An important aspect was to create a structure which would allow modules to move easily in the X and Y directions and would require a minimum amount of supports. To cover large column free areas, we chose a grid structural system (fig 77) which combines structural efficiency with appealing architectural expression. In order to obtain better spatial qualities and maximize the distance for modules to move, it was decided to work with a quadratic diagonal grid "in which the members are oriented in an oblique manner to the supporting structure along the edge, therefore, it has great stiffness and substantial reduction in deflection."[20]

In this phase we relied on our intuition, knowledge from previous projects and built examples to define the beams' cross-section. The proportion of the beams and their material were also influenced by functional and aesthetic parameters (fig 78). In order to implement the Space Metamorphosis concept, the depth of the ceiling is an important element as it lodges working tables, lighting fixtures and will also bring architectonic qualities to the spaces.

Following those requirements it was decided to work with a diagonal grid composed of intersecting timber beams supported by columns (fig 79). Timber was selected because of its texture, natural and warm look as well as its low embodied energy and local availability. However, as plain timber beams require many supports due to their size restrictions, it was decided to replace them with glue-laminated elements because of their larger inherent strength that can allow larger spans. According to our assumptions and to the other size requirements, an appropriate cross section for the beams would be around 200*600mm. In the following steps, this dimension will be used as a starting point for structural calculations.

Fig 77. (opposite top) **Grid examples**

Fig 78. (opposite middle) **Desired aesthetic expression of the ceiling and functional performance**

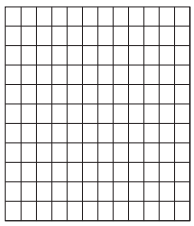
Fig 79. (opposite bottom) **Axonometry of the grid structure, highlighting different structural members**

[20] Stucture and Form Analysis System

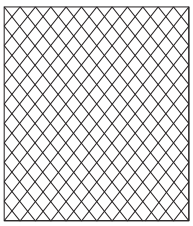
supported beams

transferring loads

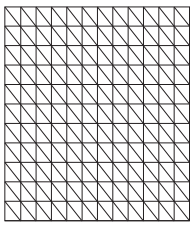
secondary beams



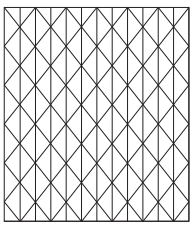
two way grid



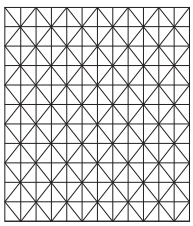
diagonal grid



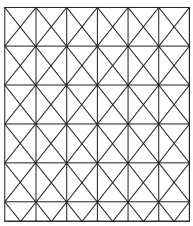
three way grid



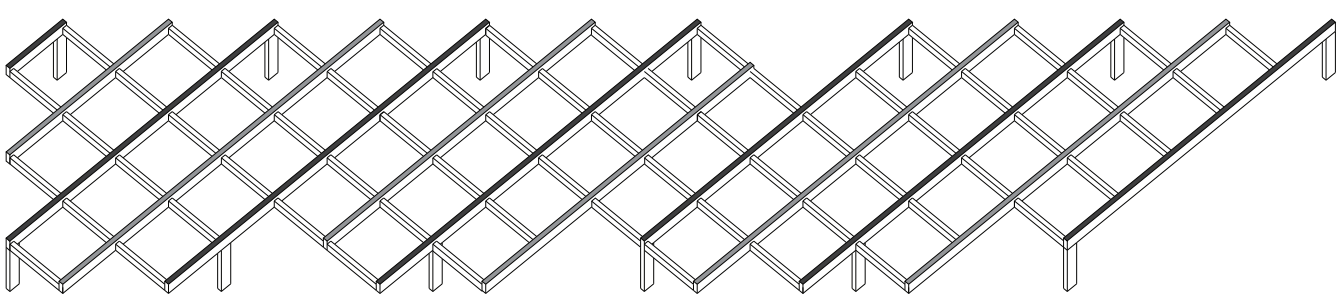
two way grid



four way grid



four way grid



PERFORMANCE SIMULATION

The process of member verification was performed gradually from simple hand calculations, which included only few parameters at the start and evolved in more complex Robot model calculations. Detailed calculations can be found in Sketches & Numbers chapter pages 138-139. The simulations were based on the principles of Limit State Design, which can classify the structure as satisfactory or unsatisfactory. "A limit state is a condition of a structure beyond which it no longer fulfills the relevant design criteria." [19] The design process involved a number of assumptions, such as critical load cases using combination rules, sizes of members, as well as supports and releases between members. The aim of the exercise was to verify that no limit state was exceeded and to ensure a safe structure.

As a starting point, we analyzed a single member (fig 80) of the structure to get a general idea about the resistance of the selected cross-section. The simple calculation allows us to remove constraints to focus on certain parameters

Using a given formula (detailed calculation can be found in Chapter Sketches & Numbers) it resulted in a not satisfactory bending strength (1.23). Following that, the cross section of the beam was increased to 250*600mm, which reduced the ratio to 0.99, which is considered to be satisfactory.

Fig 80. **Scheme for single beam hand calculation**

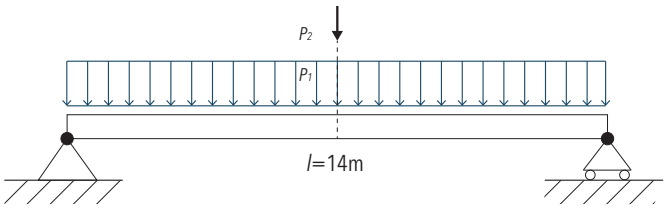
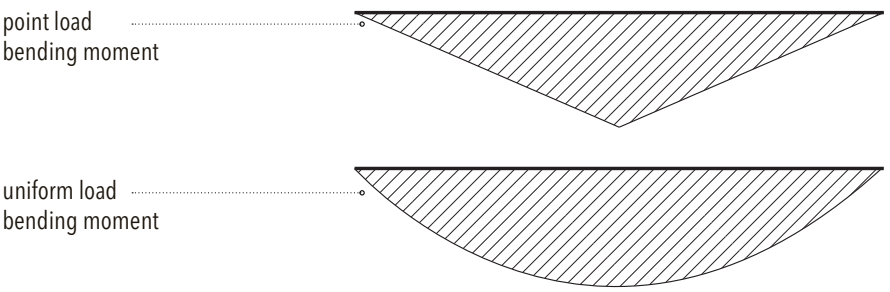


Fig 81. (opposite) **Performance of structural elements according to Robot calculations and comparing two cases with different positions of modules**



[21] Eurocode - Basis of Structural Design, 2001

module position

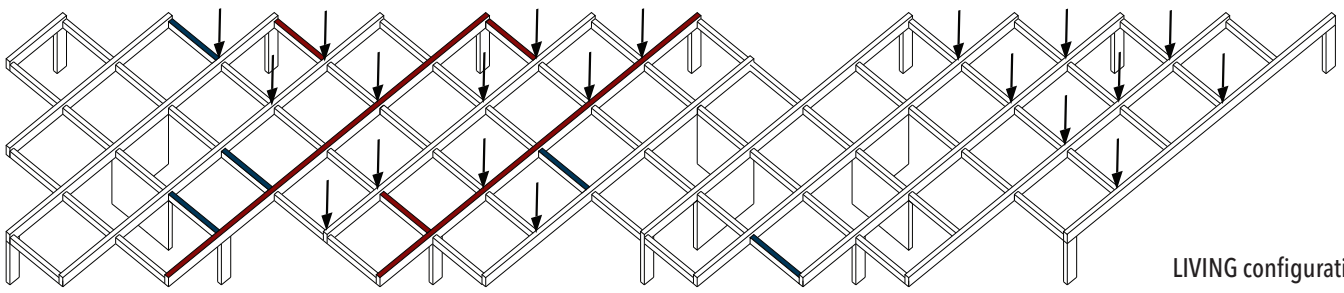
beams with high performance ratio

beams with low performance ratio

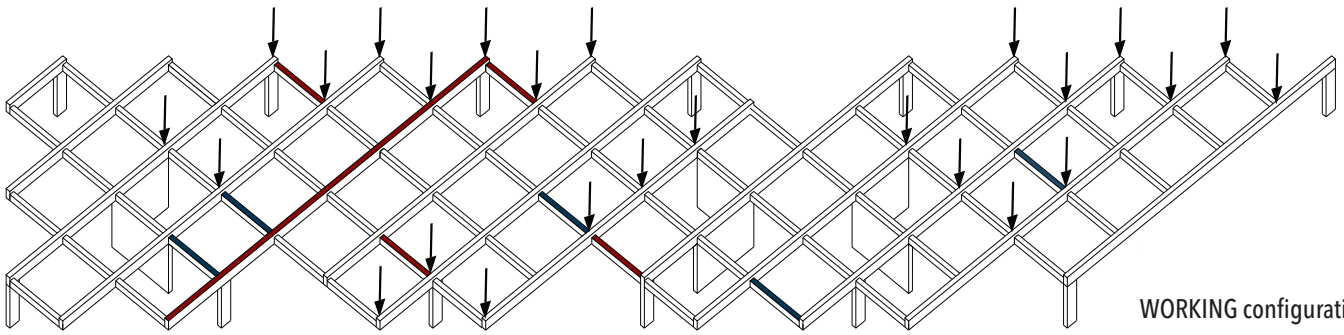
As the structure is a diagonal grid, where forces are distributed, the next step of the performance simulation contained a member verification within the grid geometry in Robot (fig 81). Here we went from verifying only one member to a system of members. It was decided to take the grid of only one floor as a representative example of the project. The principle guiding the results obtained on this floor, can be applied to other floors and similar buildings in the master plan as they will have the same parameters.

Performance simulation started with a cross section 200*600mm for main beams and 200*500mm for secondary beams. As in our project the modules are moving and create nodal force in different parts, it is important to mention that we performed the simulation on both day and night arrangements. In this simulation we were comparing different glue-laminated timber types in order to get the most efficient performance.

The conclusion of the Robot study is that the most optimal solution for this structure will be to use GL28s 200*600mm for main beams and 200*500mm for the secondary beams.



LIVING configuration



WORKING configuration

STABILITY STRATEGIES

This paragraph will illustrate strategies regarding wind deformations and structure cantilevers. Those parameters were not included in the Robot calculations as they require more parameters and assumptions. As a complement to Robot simulations, we will discuss possible strategies to prevent unsatisfactory structural behaviors caused by external forces and cantilever. These strategies will be discussed at a conceptual level pointing out advantages and disadvantages of certain solutions.

Looking at the current frame of the grid it suggests a possible deformation caused lateral forces such as wind (fig 82). In order to prevent the movement of the structure, it is possible to use utility rooms as stabilizing cores for the whole building. In addition, those cores are made of concrete for energetic purposes.

The concept of Space Metamorphosis suggests that the structural grid comes outside to create a greater connection between exterior and interior. The intention is to cantilever the grid, so that there are no need to support it by columns on the outside. This brings a challenge to stabilize the structure as the load applied on the cantilevered part will destabilize the structure. If we assume the grid to be a solid element it will deform as shown in the fig 83. There are different solutions to stabilize the grid, for example it would be possible to pull the other extremity in the same direction and fix it deep into the ground. This solutions requires a lot of ground work. Another solution will be to use the weight of the top floors as counterweight to balance the system. As the floor with the cantilevered structure is located on the first level, it means that we can count on the weight of three to four floors, which we assume to be enough. Another counteracting force is the weight of the many modules suspended to the structure opposing the deformation caused by the cantilevered structure. Moreover the cantilever part is partly situated in the corner between the two perpendicular building making it more stable.

Regarding transport and assembly, we envision that the glue-laminated beams and main connection elements should be pre-assembled before being transferred to the site, where the primary and secondary beams would be put together. The welding of the rails should be done last in order to absorb the tolerances of the grid system assembly.

Although acoustics is not the main focus of the project and functions do not need specific acoustic performances, the chosen structural principle allows to provide good acoustics in the common spaces where the flow of people will be the most intensive (fig 84). Because of the specific cross-section of the beam, there is a space between the grid where a secondary wooden structure is introduced in order to better absorb and minimize sound reflections while emphasizing the spatial experience of the spaces. It also helps to diffuse the light, which creates a more cozy atmosphere while having the ceiling gradually disappearing behind it. The floor finishing is polished concrete, which reflects the sound, however interior has many textile elements, such as thick curtains and soft furnitures, which absorb the sound.

Fig 82. (opposite top) **Beam bending moment**

Fig 83. (opposite middle) **Beam bending moment when structure is cantilevered**

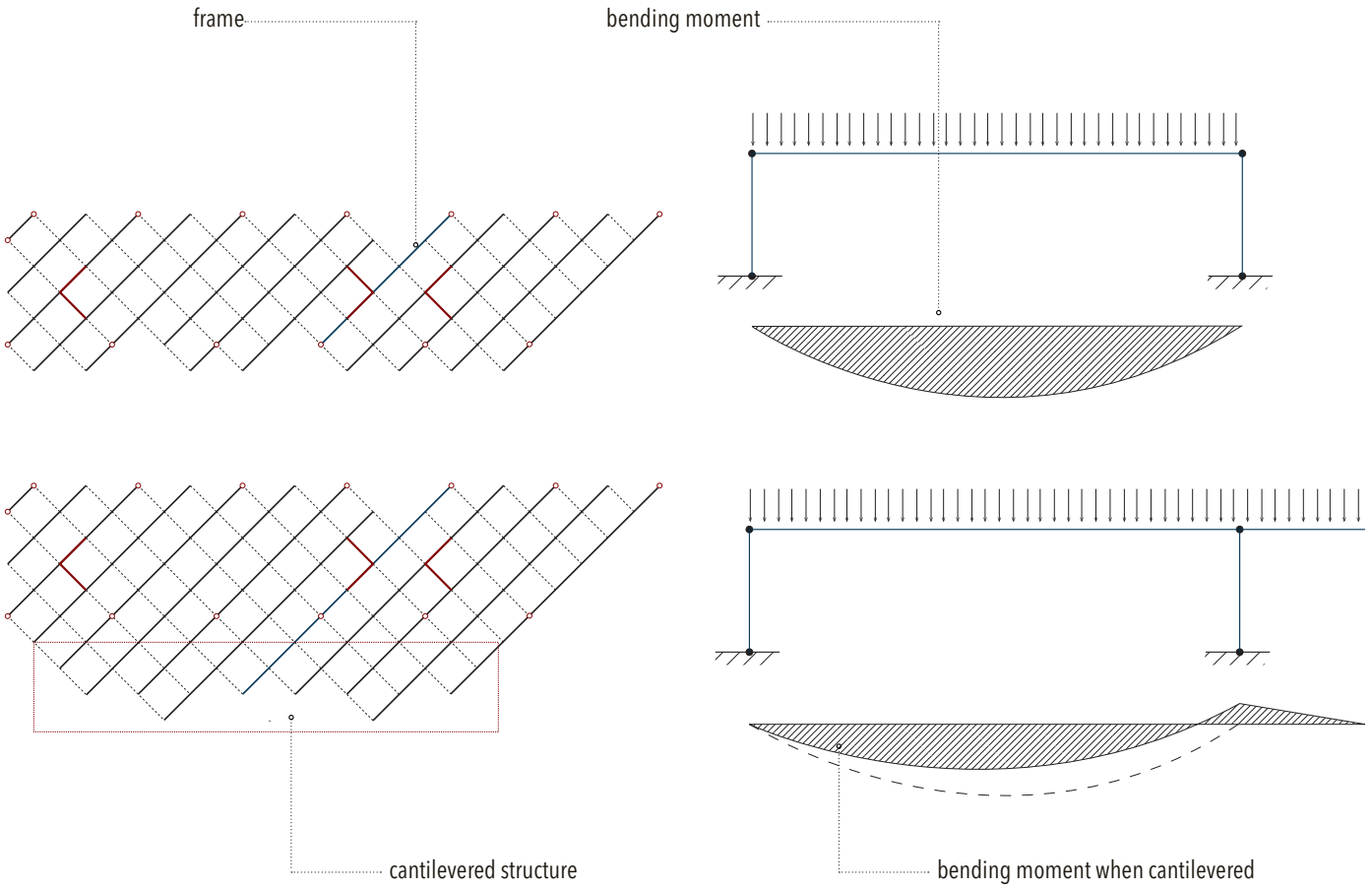
Fig 84. (opposite bottom) **Ceiling expression, which also absorbs the sound**

supports

beams 600x200mm

beams 500x200mm

shear walls



INDOOR COMFORT

As one of the starting point behind the whole Space Metamorphosis concept, energy performances and indoor comfort were set as an important engineering and architectural challenge of the concept. According to our hypothesis, overlapping functions would decrease heating demands as the energy generated by function A could be used for function B. It is at the core of the idea of the Space Metamorphosis concept of maximizing potential of available resources.

As part of the sustainability approach a number of technical calculations were done in order to ensure a good indoor environment and low energy demand according to the Danish Building Regulations for Br10 Class 2020.

In order to confirm the stated hypothesis two specialized softwares were used: BSim and Be10. Both programs complement each other as BSim provides results regarding indoor comfort of one unit and Be10 focuses on the overall energy use of the whole building.

The challenge of the calculation was to set appropriate parameters. As the same space is being used for two different functions with different requirements it was necessary to find some common points or use the maximum as a worst case for the simulation. Both softwares are designed in a certain way that only one function can be tested at a time, creating certain limitations throughout the process.

The unit chosen to be simulated is situated in the middle floor in the north/ South orientated wing of the project. All along the design process, a constant attention was set on possible heat gains and losses. The positioning of the windows, their size, the balconies and different shading strategies, sizes and expressions were strongly influenced by the energetic aspect of the project. Confirming our first intuition about the possible complementarity of the two functions, the first analysis showed an already well performing scheme (fig 91). A few more iterations were necessary to improve the overall energy consumption and to reduce overheating in the summer. The size of the windows had to be altered as well as their operable area, which resulted in 25%, in order to maximize natural ventilation (fig 90) during summer taking advantage of the rather narrow floor plate.

Thermal mass also had to be increased in order to store and delay solar heat gains and this was achieved by replacing the mass timber main partition walls between units and in the bathrooms by concrete. This change of material had a positive influence on the interior atmosphere as it balances the strong presence of timber of the supporting structure.

Constant studies on the interior lighting conditions were also performed throughout the entire project. The simulations were carried out in winter in order to have the worst case scenario at table height (fig 93). The minimum resulting daylight factor is of 3 percent in the Working scenario and 2 for the Living one in the center of the unit.

*****_BSim_ - Integrated PC tool for analyzing buildings and installations.

*****_Be10_ - Calculation program which demonstrates the energy requirements of the building according to Danish Building Regulations

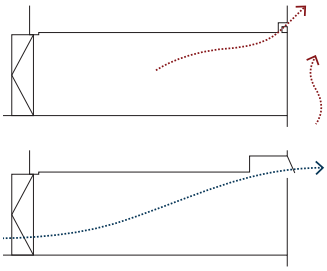


Fig 90. **Ventilation strategies:**
1.Stack ventilation using the void of the staircase
2.Natural cross ventilation

Fig 91. (opposite left) **Comparison of three simulations in BSim, the same unit was evaluated in three cases: Living only, Working only and Hybrid**

Fig 92. (opposite top right)
Temperature analysis in Working+Living configuration

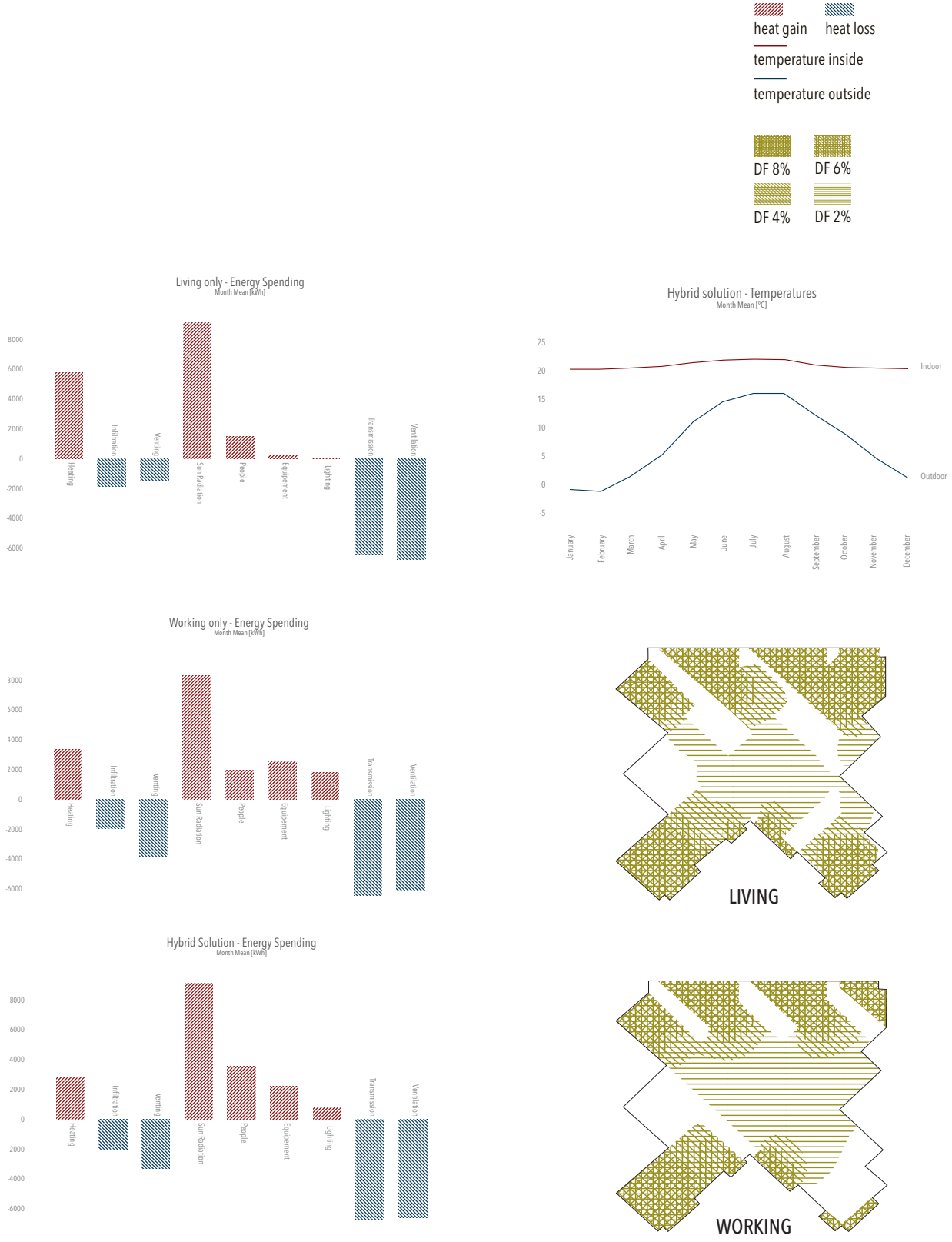


Fig 93. **Velux DF (daylight factor) analysis in winter comparing Living and Working configuration.**

ENERGY DEMAND

The energy demand is calculated using Be10 software according to energy requirements in the Danish Building Regulations for Br10 Class 2020. The aim of the exercise was to evaluate the project according to building standards and see if it would use less energy than a traditional building.

To meet Class 2020, dwellings should use less than 20kWh/m² a year, while offices and other buildings can use up to 25kwh/m². As the nature of the Space Metamorphosis building is hybrid, it was assumed, that in order to be within the regulations the building should use maximum of 25kwh/m².

In order to perform the calculations we set a number of parameters, which are described in the Sketches & Numbers chapter (p. 140). Because of the concrete floor slabs and concrete cores with utilities, the building is assumed to have heat capacity of 120Wh/Km², which helps to store the heat and reduce heating requirements.

While working with the program we made a number of observations. We noticed an important relationship between internal heat gain and the amount of windows. Because of the desired facade expression and the need of natural light, the building has many windows, which result in high transmission loss. However, because of the big amount of internal heat gain, the heating requirements are balanced.

Be10 requires to put the amount of hours for which the building is in use. During the study, we have noticed that when we reduced the amount of hours in use (in office buildings, spaces are normally in use only 40 hours a week) the energy demand is increasing, meaning that if the building is occupied all the time, there is less wasted energy.

The final result we got in Be10 is 23,7kWh/m² per year, which is in between of Br10 requirements for housing and office. If we assume that, in the selected plot, a classic building would be built according to the local plan's required areas and energy consumption of Class 2020, the difference between traditional building and Space Metamorphosis' energy consumption is small. However, as this energy amount should be multiplied by the area, and we have already illustrated that the project with the same area requires less built square meters it also results in less energy consumption. To conclude, Space Metamorphosis has 1,3 times more usable area and it consumes 1,2 times less energy than a traditional project with the same built area.

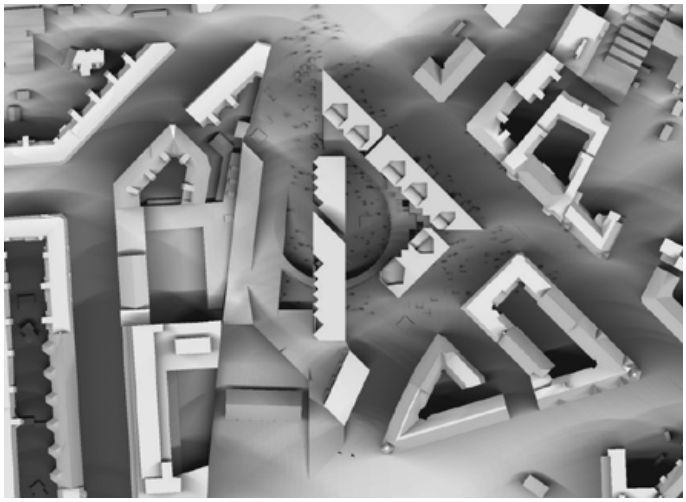
Moreover, the local plan is encouraging to use solar panels as source of renewable energy. The sloping roof allows us to place solar panels at 15° oriented south-west that decrease the energy frame to 14,9 kWh/m², which is 2 times less than the building proposed by the local plan. The concept's core idea of being always in use also allows the energy produced by the panels to be directly used on site, thus minimizing transport losses. Solar panels with the combination of roof terraces are achieving both goals of the local plan: using renewable energy and delaying the rainwater.

Fig 94. (opposite top) **Building orientation and exposure to the direct sunlight in summer and winter**

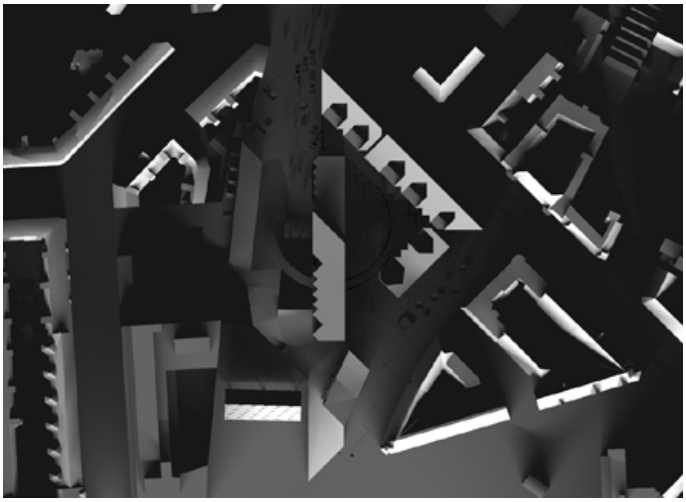
Fig 95. (opposite middle) **Facade exposure to the direct sunlight in summer and winter**

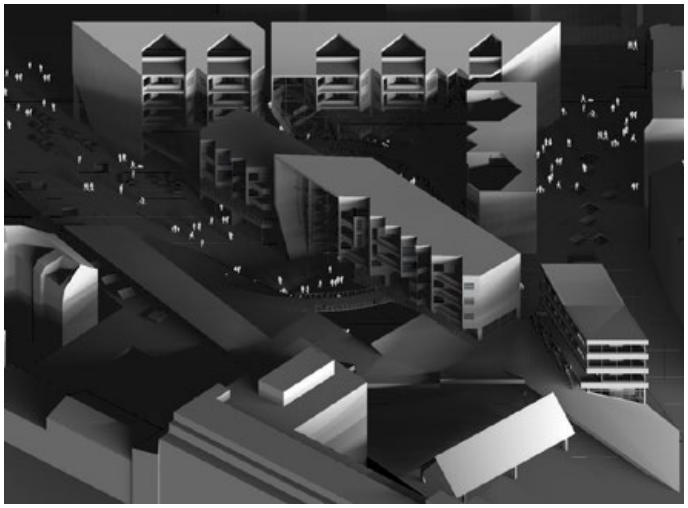
*Fig 96. (opposite bottom)***Table illustrating the difference of energy demand between local plan's proposal and the Space Metamorphosis project with and without photo-voltaic panels**

SUMMER (21st June)



WINTER (21st December)





	local plan			*Space Metamorphosis*				*Space Metamorphosis + PVs*			
	built m²	*kWh/m²*	*kWh*	*built m²*	*used m²*	*kWh/m²*	*kWh*	*built m²*	*used m²*	*kWh/m²*	*kWh*
LIVING	3,450	20	**69,000**	6,139	3,865	23.7	**145,494**	6,139	3865	14.9	**91,471**
WORKING	4,150	25	**103,750**								
TOTAL	***7,600***		**172,750**	***10,004***			**145,494**	***10,004***			**91,471**

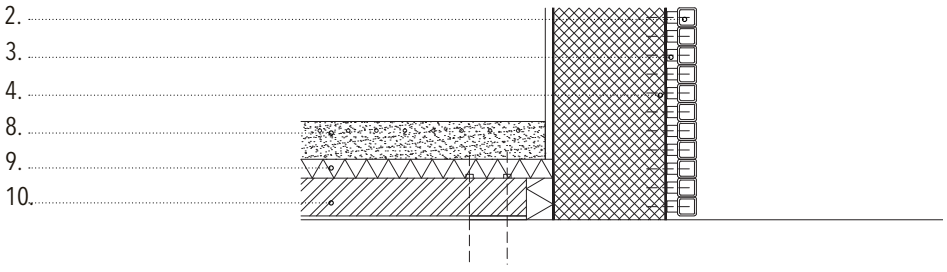
Fig 97. **Interior of Zumthor's Home for Senior Citizens showing layers of the ceiling structure**

DETAILS

1. Detail between interior and exterior (structural beam which comes outside)

Structural grid is coming outside to create a greater connection between exterior and interior and acts as supporting structure for the circular bike link. The aim is to use the whole building weight to allow the grid to span outside without having any additional support in the public square, making it more appropriate for usage changes. In order to have the grid acting as a rigid element, it has to be continuous and not be separated at the inside/outside limit. Doing so, one main problem occurs: a thermal bridge created by the interruption of the insulating layer if the facade.

To find an appropriate solution, we looked at references with the same challenge, such as Peter Zumthor's Home for Senior Citizens (fig 97). Following that, the detail evolved and the proposed solution is dividing the meeting between the beam and the wall in two places: one that stops humidity and another that stops cold. This method keeps moisture from stagnating between the beam and the cladding because of the ventilated air gap present between the beam and the cladding. Thanks to the deep ceiling of each floor, it is also possible to insulate the beam coming from outside in order to avoid any cold transmissions that would cause condensation.



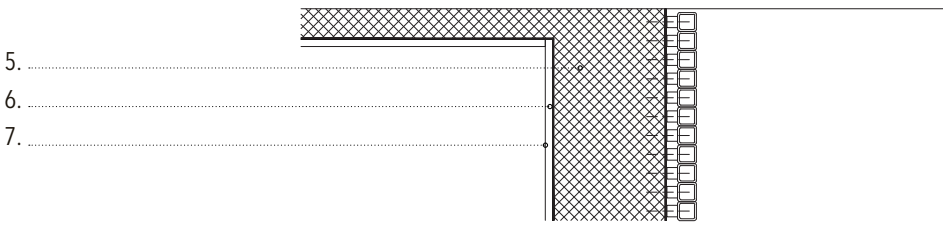
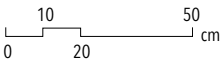
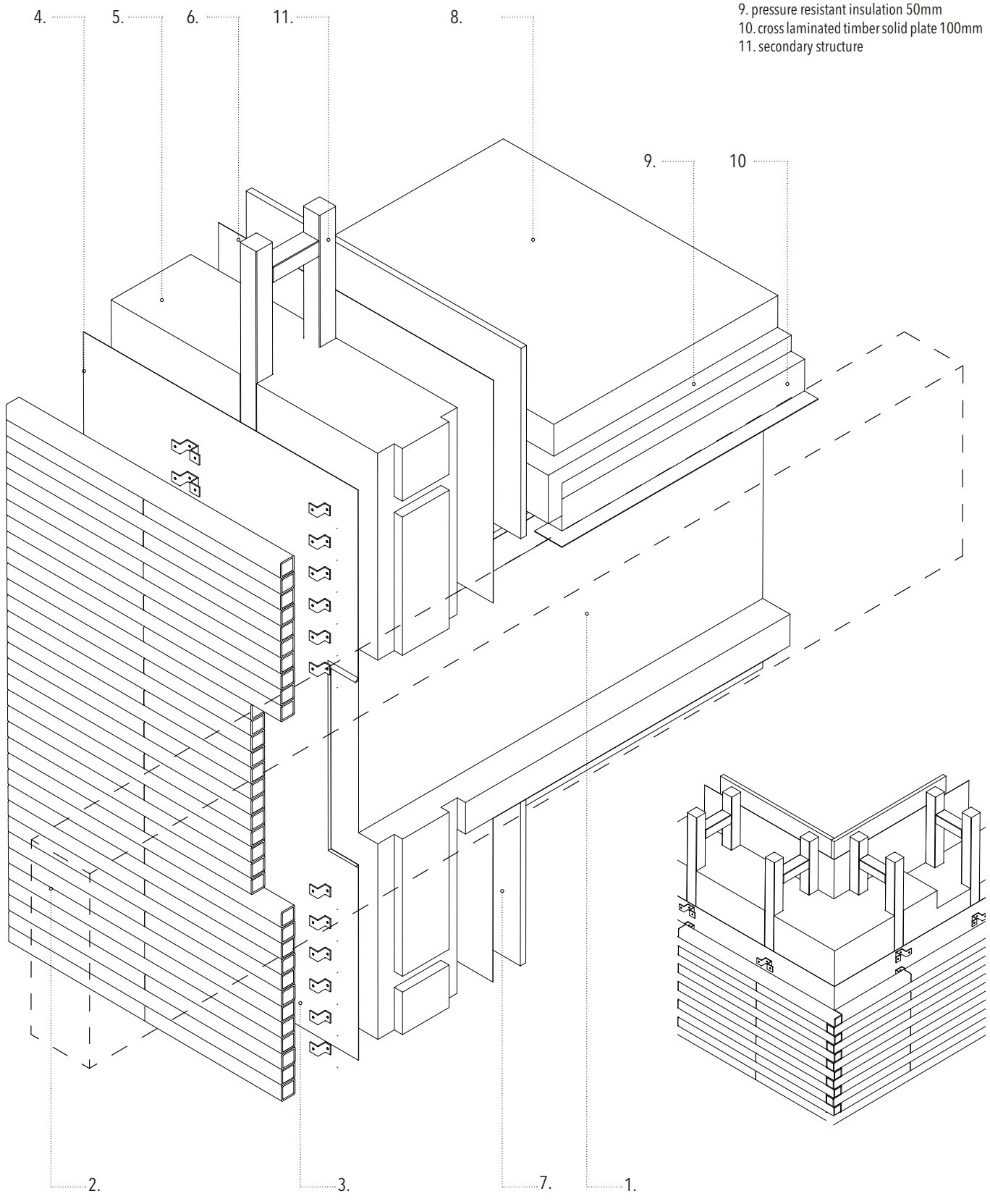


Fig 98. **Detail section**

Fig 99. (opposite) **Axonometry of details: wall and corner**



1. beam 600x200mm
2. terracotta cladding 50x50mm
3. ventilated air gap
4. rainscreen
5. ROCKWOOL insulation 300mm
6. vapor barrier
7.plasterboard 20mm
8.concrete slab 100mm
9. pressure resistant insulation 50mm
10. cross laminated timber solid plate 100mm
11. secondary structure



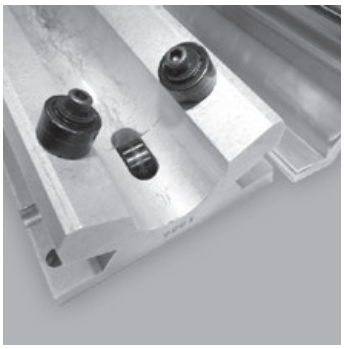


Fig 100. **Possible solution of railing system**

2. Interior detail between two beams

A structural grid was partly chosen because of its rigidity and ability to span long distances and some iterations were necessary to choose the proper connecting steel elements between each beam. Big considerations were set on the aesthetic impact that such connections would have on the atmosphere in the inside spaces. After several tests, the connections with the largest amount of visible steel were dismissed because of their too industrial and rough look. The chosen specific connection also allowed us to customize the placement of the nails while staying inside the limitations advised by the manufacturer.

3. Joint between beams and rails

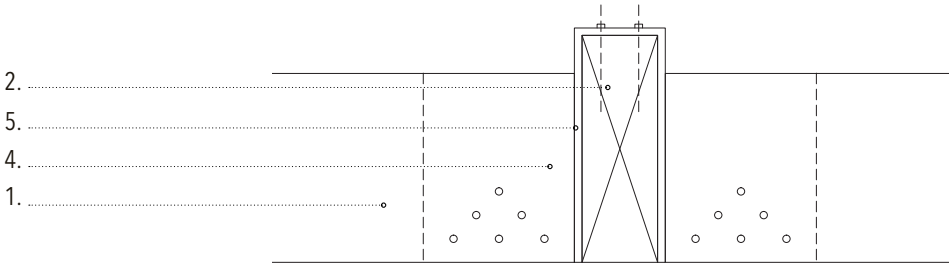
This connection was the most difficult to design as we didn't have any prior references with the same variables and constraints to guide us.

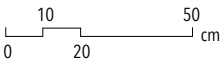
The first idea was to attach the rails on the sides of the beams but that option was quickly dismissed because of the impossibility for the glue-laminated beams to accuse that kind of vertical force tearing off its layers apart and because of their non alignment with the beam's central axis which would have caused the beams to buckle. The force needed to be transferred as vertically as possible so we chose to place the rails just beneath the beam with their tension elements both reaching for the top of the beam to apply the load. The rail itself having a tubular shape is then welded to the vertical tension plate going through the beam. The connectors placed inside the modules are similar to those used in roller coasters or industrial sliding doors (fig 100) using rubber wheels of opposite direction to stabilize and follow the rail.

Fig 101. **Beam to beam detail**

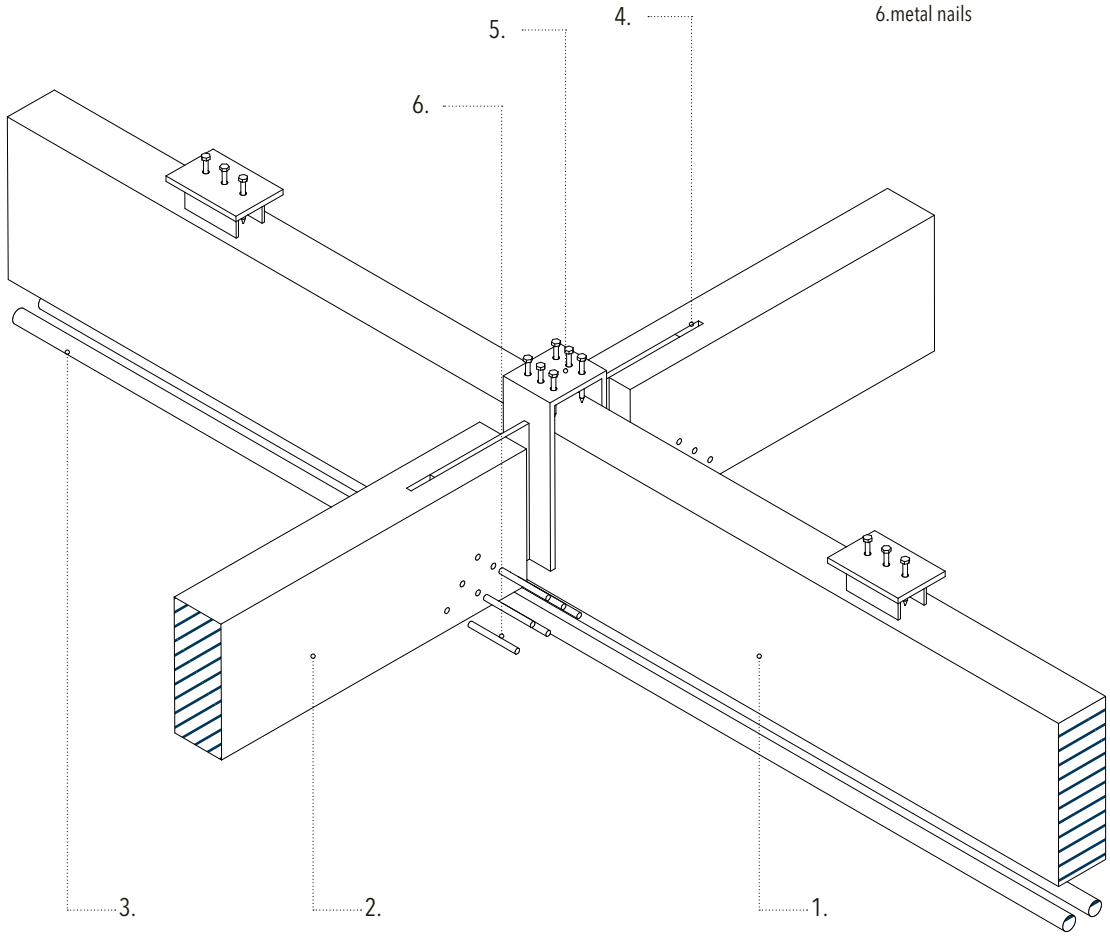
Fig 102. (opposite top) **Axonometry of the beam to beam connection and rail fixings**

Fig 103. (opposite bottom) **Renderings of the details showing both interior and exterior**





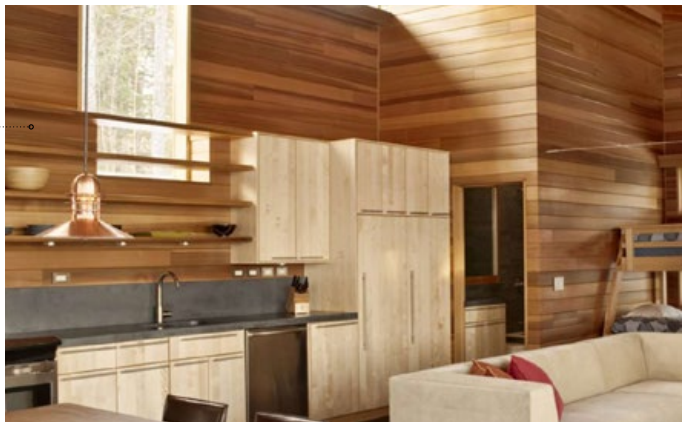
1. main glue-laminated beam 600x200mm
2. secondary glue-laminated beam 500x200mm
3. steel rails
4.concealed metal plate
5.metal saddle
6.metal nails



Exposed glue laminated timber structure is highlighting tectonic qualities of the construction as well as acting as space divider.

Polished concrete floor is easy to clean between the function changes and floor heating keeps it warm and pleasant for walking.

Different types of timber finishes are used for interior walls, module niches and furnitures. It is natural, sustainable and tactile material.

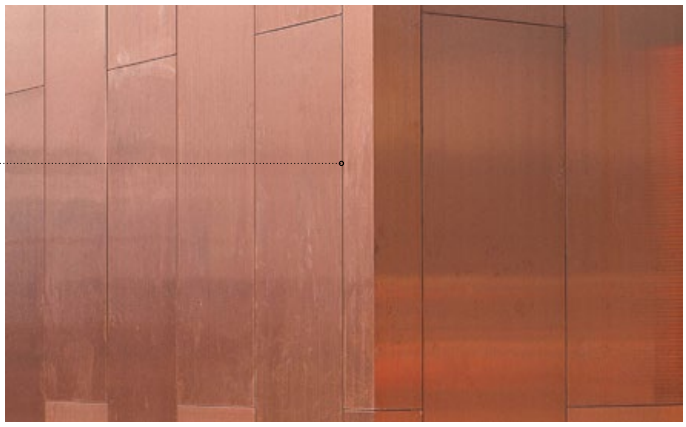


To contrast the wood finishes, the Working side of the modules is made of Corian which is solid smooth and easy to maintain.

Fig 104. (both pages) **Examples of selected materials, highlighting the main purpose of using them in the project**

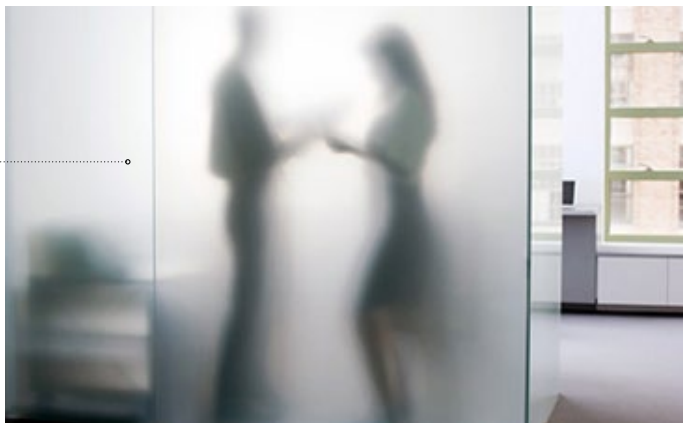
Hollow ceramic cladding is a sustainable, efficient, long lasting material, which allows to explore different degrees of transparency and privacy.

Copper is a material which can be found on the facades and roofs in Copenhagen. It creates links to time an existing surroundings and gives a character to the gables.



Fabric is used a lot in the project to create privacy and underline desired domestic atmosphere. It furnishes the spaces, can be easily hidden in movable modules and can be personalized by users.

Frosted glass has the great ability to let the daylight inside while maintaining privacy. It is intimate, and gives depth to the facades



REFLECTIONS

This project's focus is the application of a new typology created after thorough research and studies in the field of sociology, urbanism, architecture, engineering and design aiming at proposing a viable solution to decrease the current overconsumption of space and resources in today's society. This is achieved by collecting and synthesizing available data through our own vision and interpretation.

Mixing function appears evident, why not using the same light bulb throughout the day instead of manufacturing two? It however also means that, apart from overlapping functions that might be reduced or complementary ones benefiting more people, concessions have to be done because of the inherent necessary complexity of the concept. Like a living organism, there has to be many actors for the whole to function.

Due to the experimental nature of the project, several architectural and engineering challenges were set at the beginning of the thesis. While all were considered, some were more successful than others in their implementation and detailing.

The balance of relationships between public and private is achieved through the introduction of three privacy levels which are establishing a hierarchy between spaces and their connections and separations. Using the structural grid, the connection between exterior and interior appears to be strong and the experience continuous. The personal booths which have a high degree of privacy, are contrasting with the open plan of the common floor and gives users the choice to isolate themselves if needed while being within the building complex. The transition areas, such as sitting arrangements between units or staircases exhibiting art works, act as a linking thread between public, common and private. As the main focus of the building complex was the design of a unit accommodating Working and Living functions, other spaces were developed with less details and therefore could be developed even more to support the vision of maximizing the potential of spaces.

The project supports the differentiation between mobile and immobile which was established as an important aspect of space transformation concept. The necessity of leaving some spaces static is giving a feeling of security to their users. The fixed room - or emergency room - in the main units is designed to function as an autonomous studio if needed, providing all basic needs for unusual situations. The structure and facades are designed as rather static elements which are supporting the concept, but which configuration stays unchanged. It would be possible to propose, for example, a solution in which the facade would be more interactive and dynamic, however such transformations would require either more energy to operate with an automated system, or more user participation if the system is manual. According to our vision, neither of them would be satisfactory as the idea is to decrease the energy demand and reduce the amount of operations so that the process of transformation appears as simple and familiar as possible for its

users. Following that, our main focus was the design of horizontal and vertical movable modules which are directly connected to the structural grid and, while moving, are affecting the exterior expression of the facades. The way the modules are moving still stays conceptual as we did not find any current good references of similar system which would have several configurations that could be activated remotely when changing function. What we believe to be a positive note for the concept is the rather rigid time frame. When the Working configuration's time is up, for example, at 17:00, it is mandatory to free the space, thus giving time to enjoy other activities such as, family, friends, sport, gardening, etc.

One of the main design challenges that we faced was to give the right level of personalization for both Living and Working configurations. We understand that, for many users, it is a crucial aspect as they want their home to represent their character just as businesses want to put forward their brand and identity. The concept therefore suggests a principle of double modules, which allows one side of the module to be used for Living purposes and the other side for Working needs. By putting both modules together, one configuration containing decoration, storage, personal belongings, etc. disappears while the other one, which again contains personalized surfaces of another function, reveals itself. In this relation the notion about the space being used for other purposes completely disappears, as users cannot see, touch or know it. However, in order to maintain a sense of collaboration and the curiosity and awareness about The Other, modules containing tables are designed in such a way that it gives a glimpse of the presence of other users. In our opinion such contrast between elements create a balance between exposing and hiding personal belonging. It appears more subtle and is not violating privacy.

The principle of grouping movable modules and hiding working tables in the deep ceiling have added spatial qualities related to creating different atmospheres. Moreover the position, form and materials of the windows have reinforced the difference between Working and Living modes. Living configurations also have a greater hierarchy between spaces, the finishings of the modules, attention to details and a lot of south-west light gives the space a glowing warm atmosphere. By contrast, the Working layout appears to be more open plan, with mainly light finishes with some bright accents and diffused north-east light. Comparing the same space from the Living user's perspective and from the Working user's one, the space appears with a completely different character.

Efficient energy utilization aiming at maximizing its potential is an engineering challenge of the project for which we had to consider many variables from the start in order to satisfy the demands for both functions. This appeared to be a difficult exercise, firstly because of the lack of the references of well performing hybrid spaces and secondly because of the nature of simulating softwares. Our hypothesis was based on the idea that, by overlapping functions, the energy demand would decrease as the produced energy would be used more continuously. In order to confirm it, simulations were done in available programs, we however had difficulties to compare them with any existing building, because of the many parameters to be considered. The chosen solution was then to compare them between different space configurations within the project and that proved the hypothesis right. However, it is important to mention that the available softwares, such as Be10 and BSim, are not designed to perform hybrid simulations as they are orientated towards a mono-function building organization. Therefore, in order to perform a more detailed and accurate analysis of energy use, some modifications would have to be made in the different softwares which would allow specific hybrid relationship simulations.

To conclude, the project's implementation in a particular site at a particular time in a particular city have a very strong influence on the outcome, meaning that there is no direct recipe for the Space Metamorphosis concept. There are some principles to be considered, but its implementation strongly depends on its surroundings. Moreover, users consideration and their ability to welcome such a concept is crucial. Their living environment and cultural habits are therefore very important as well. In Copenhagen, there is a high demand for affordable accommodation and a strong awareness about sustainability, therefore the concept is more likely to be applied than in other cities. Our research showed that living habits are sacred and that people's Home is a notion to be dealt with carefully as it symbolically relates to the very intimacy of oneself. Therefore, the intention of the project is to provide users with a familiar solution adding new qualities to their everyday routines. The project is experimental and it does not propose radical and immediate changes, it rather suggests a discussion upon the issue of waste and overconsumption. Because of the lack of reference projects with the same space qualities as Space Metamorphosis, it is difficult to be entirely objective about the feasibility of the proposed solutions. In order to get a fruitful feedback from users, the project has to be implemented and tested, which would probably reveal another layer of consideration and challenges.

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ILLUSTRATIONS

Fig 1 http://www.citelighter.com/science/environment/knowledgecards/urban-sprawl
Fig 2 http://architizer.com/projects/anz-centre/
Fig 3 http://smallhomelover.com/small-space-living/
Fig 4 Own illustration
Fig 5 http://www.archdaily.com/454797/santiago-calatrava-the-metamorphosis-of-space/ *Property of Studio Calatrava © Santiago Calatrava*
Fig 6 http://www.bustler.net/index.php/article/3xlp_wins_skin_digital_fabrication_competition *Image courtesy of TEX-FAB.*
Fig 7 http://critical-gaming.com/blog/2011/3/18/design-space-time-continuum-pt1.html
Fig 8 Own illustration
Fig 9 https://www.flickr.com/photos/darrellg/6218603342
Fig 10 Own illustration
Fig 11 Collage of space references:
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Fig 12-17 Own illustration
Fig 18 http://www.map-france.com/Firminy-42700/photos-Firminy.html
Fig 19 Own illustration
Fig 20 http://uk.phaidon.com/agenda/design/picture-galleries/2010/october/11/gerrit-rietvelds-universe-in-pictures/?idx=12&idx=12
Fig 21 http://hacedordetrampas.blogspot.dk/2011/11/proyecto-en-la-diagonal-de-abalos.html
Fig 22 http://www.archdaily.com/59905/gary-chang-life-in-32-sqm/
Fig 23 http://www.pkmn.es/ALL-I-OWN-HOUSE
Fig 24 http://popupcity.net/flexible-workspaces-for-flexible-workers/
Fig 25-83 Own illustration
Fig 84 http://condicionstemporals.blogspot.dk/2013/03/homes-for-senior-citizens-peter-zumthor.html
Fig 84-103 Own illustration
Fig 104 Collage of material references:
http://corian.no/Corian/no_NO/residential/residential_apps/kitchen.html
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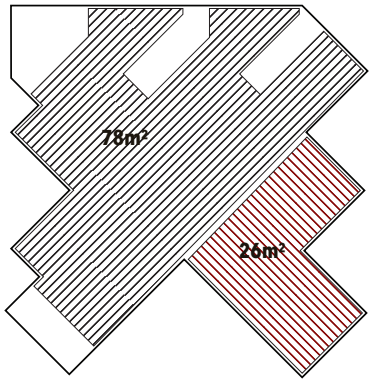
Figures on pages 134-139 Own illustration

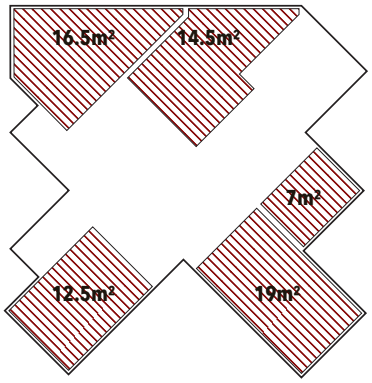
SKETCHES& NUMBERS

This chapter is representing the appendix of the project, where a more detailed information about the program square meters, typologies, parking, complimentary design solutions and calculations can be found.

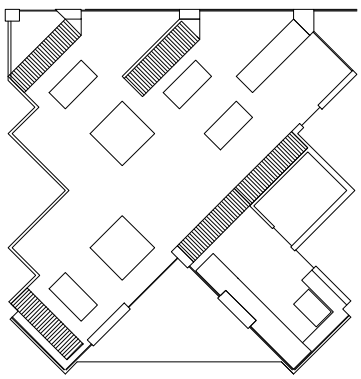
The aim of the project was to design rational solutions for Working/Living units, therefore three types of units were developed, which are following the same principles and can be combined together. The smallest unit area is 75m², which represents the minimum required in the local plan, the most common unit is 118m² and the corner apartment is 135m² with a more spacious living room and an additional special module. All of the units have two entrances and fixed rooms as well as accesses to south, south-west balcony.

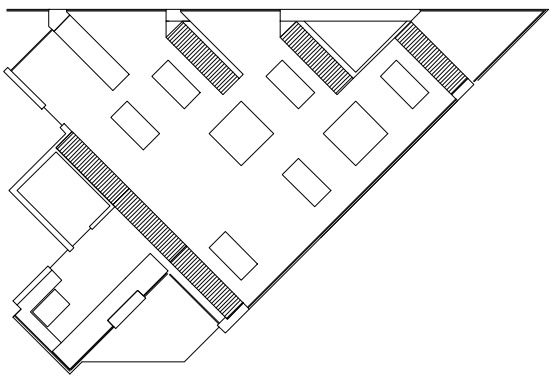


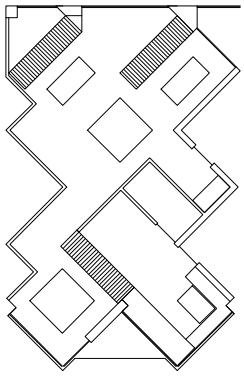
The project has an underground parking with the number of car spaces recommended by the local plan: one space per 100m². The parking structure follows the same grid as the main buildings and is made of concrete.

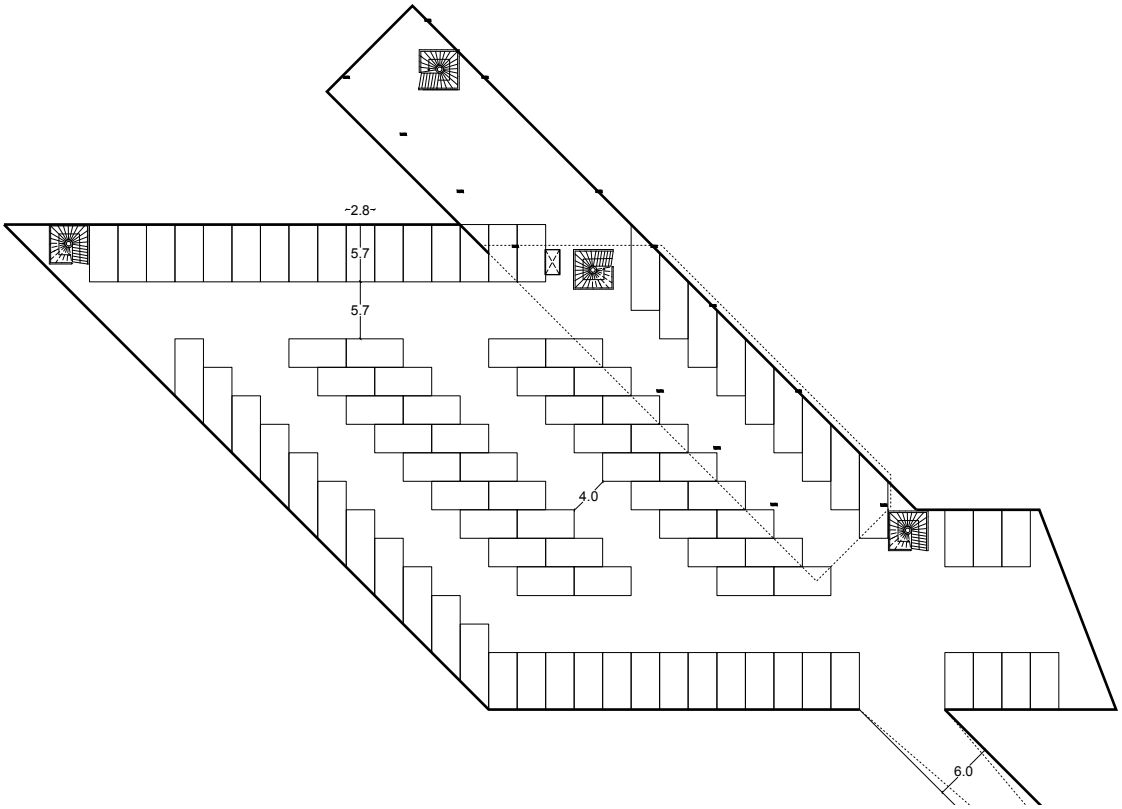


Complementary design solutions, presented on the pages 136-137 are related to spatial experiences and design of isolated exterior and interior furniture elements. Such spaces like the workshop area under the park, staircase halls and private roof terraces were designed to accompany the atmospheres of the EXTERIOR, INTERMEDIATE and INTERIOR levels. Design of outdoor bike parking and tables are adding a level of details to the public spaces strengthening the grid organization concept. The private booth is a proposal for the break space in the common level which take the secondary structure as a base which is then carved by a more organic form designed for comfortable sitting. The design of the bathroom, the special module for corner units and the round gathering table are exploring the different opportunities of furnishing. Bathroom and kitchen are fixed spaces, but in order to create a connection between movable and static, their design is taking inspiration from movable modules. The round table has the same language as the Working retractable tables in the ceiling, however its form and location are emphasizing the idea of gathering, which is a relevant quality for living configuration.

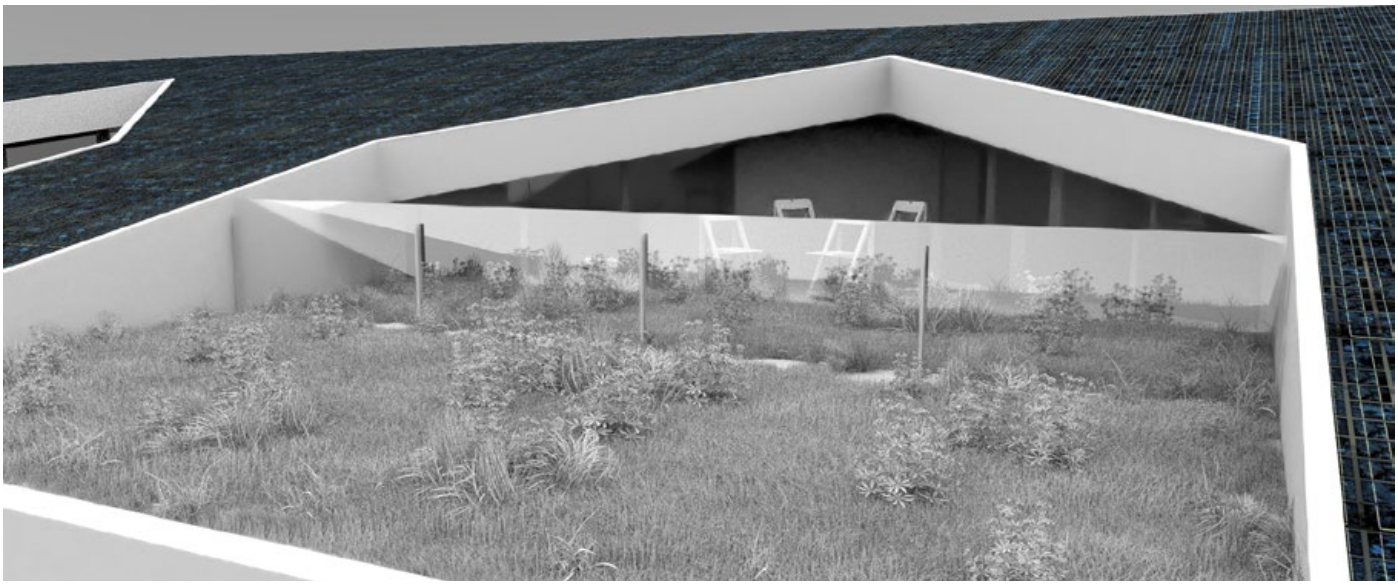


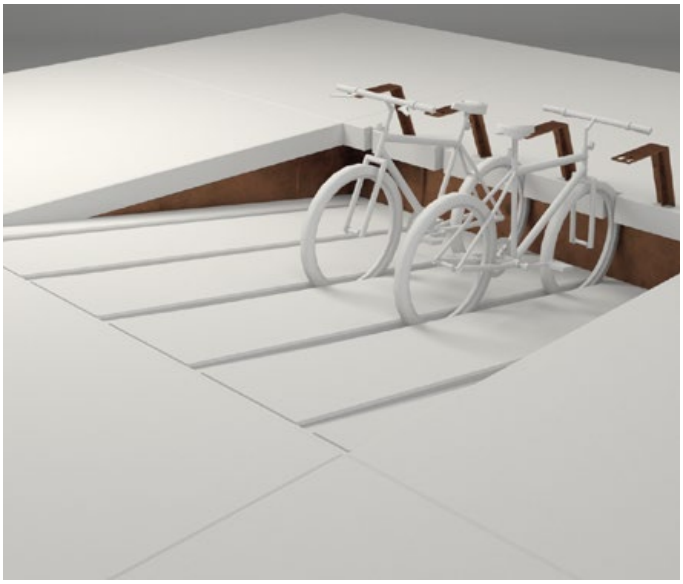


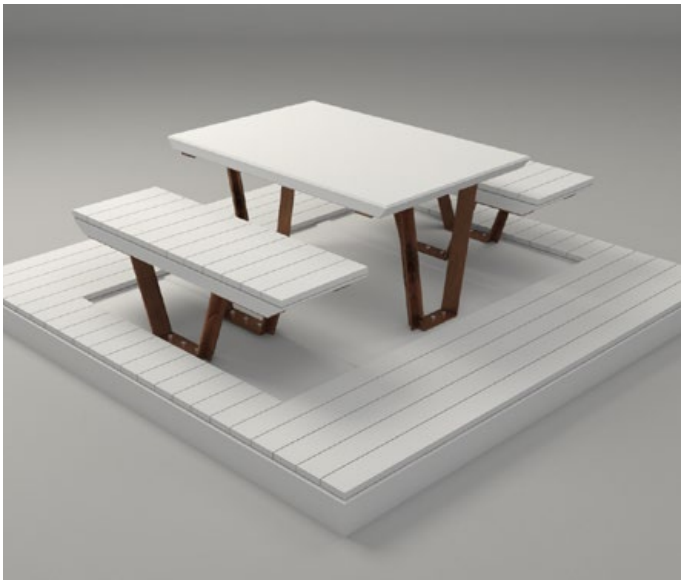


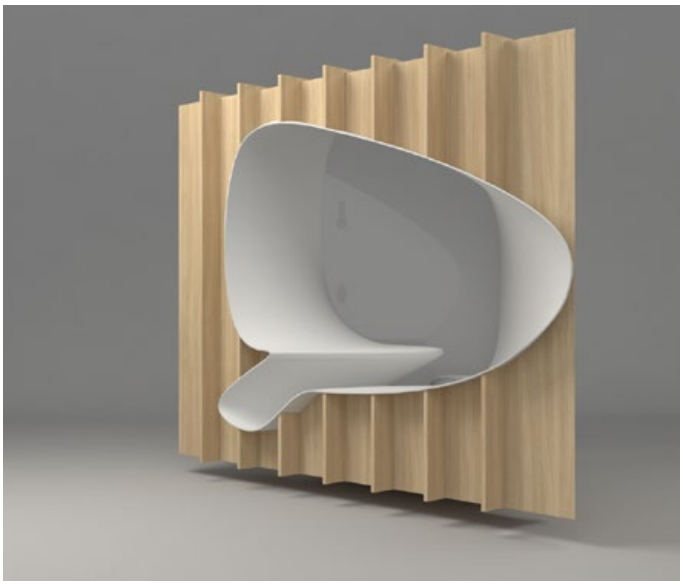


	unit number	*surface per unit [m²]*	*total built [m²]*	*total used [m²]*	*people per unit*	*total built users*	*total users*
LIVING							
big	20	118	2362		4	80	
corner	5	135	677		4	20	
small	5	78	393		2	10	
classic	4	157	629		4	16	
TOTAL	**34**		**4061**	**4061**		**126**	**126**
WORKING							
big	20	78		1555	8		160
corner	5	89		444	10		50
small	5	52		258	6		30
TOTAL	**30**			**2257**			**240**
COMMON							
hostel	11	10		645	2		22
gallery/lobby				963			
canteen			245			5	
lobby/reception/other services			1833			3	
TOTAL			**2078**	**3686**		**8**	**30**
COMMERCIAL							
restaurant			328			8	
market	10		779		3	30	
shop and services		20	1166			58	
TOTAL			**2272**	**2272**		**96**	**96**
OTHER							
datacenter			300				
TOTAL			**300**	**300**			
TOTAL			**8711**	**12577**		**230**	**492**
				RATIO: 144%			**RATIO: 214%**

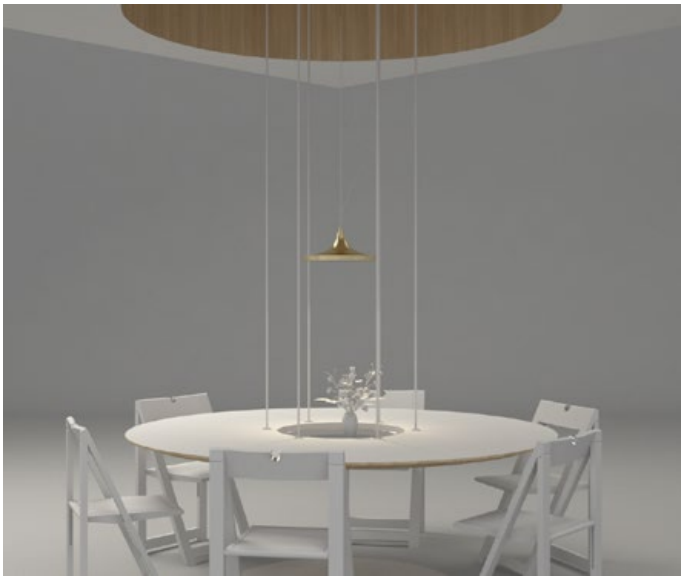









SPACE
META
MORPH
-OSIS



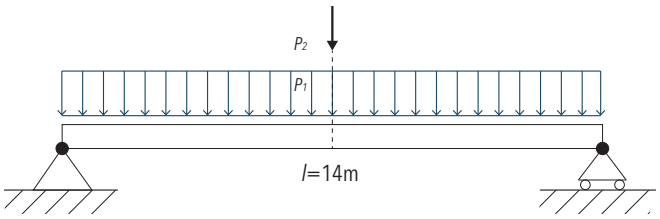
HAND CALCULATIONS

FORMULA TO CALCULATE BENDING STRENGTH

In order to verify the adequate strength, all the applied stresses should be combined and the sum of the ratio of stressed to strength must be less or equal to 1.0.

$$\frac{\sigma_{t,0}}{f_{t,0,d}} + k_m \frac{\sigma_{m,y}}{f_{m,d}} + \frac{\sigma_{m,z}}{f_{m,d}} \leq 1$$

Geometry: rectangular beam, l=14000mm, h=600mm, b=200mm.
Material: Glue-laminated timber GL28, Service class 2
Supports: Pinned and Rolled
Loads: Uniform load (Q_1) including self weight, floor slab and live load. The load of the module is considered to be point (Q_2) load and in placed in the middle of the beam. Load duration is considerer to be permanent K_{mod}=0,6



Glue laminated timber	ρ=3.73 kN/m³	Q=2.24 kN/m²
Cross laminated timber	ρ=5 kN/m³	Q=0.5 kN/m²
Concrete	ρ=24.53 kN/m³	Q=2.45 kN/m²
Live load		Q=2.5 kN/m²

Q_1= 1·G + 1.5·Q (ULS)

Q_1= 1·(2.24+0.5+2.45) + 1.5·2.5=8.94 kN/m²

Q_2= 3,924 kN

$M_1=Q_1 \cdot L^2/8$

M_1=8.94·14²/8=219.03 kNm

$M_2=Q_2 \cdot L/4$

M_1=3.924·14/4=13.734 kNm

$W_y=(b \cdot h^2)/6$

$W_1=(200 \cdot 600^2)/6=12000000$ mm³ $W_2=(300 \cdot 600^2)/6=18000000$ mm³

$\sigma = M_d/W_y$

$\sigma_1=M_1/W_y=219030000/12000000=18,25$ N/mm²

$\sigma_2 = M_2/W_y=13734000/12000000=1,14$ N/mm²

$\sigma = M_1 + M_2=19,39$

19.39/13.44= 1.43 12.97/13.44= 0.96

$f_d= f_k \cdot k_{mod}/\gamma$

γ= 1,25 (Partial factor for glue-laminated timber from Eurocodes)

f_d= 28·0.6/1.25=13.44

module position

beams with high performance ratio 0,8-1

beams with low performance ratio 0,15-0,18

ROBOT

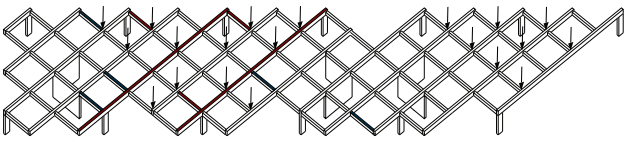
The geometry was created in Robot and, before the results were tested, a number of assumption were set.

Geometry: diagonal grid with rectangular beams h=600mm, b=200mm.
Material: Glue-laminated timber GL24 / GL28 / GL32, Service Class 2.
Supports: Fixed on all the axes in order to avoid instability in the third dimension.
Joints: Fixed, so the structure performs as a rigid element.
Load case: Load combination of self weight, uniform floor load, nodal module force and uniform people load. Load combination works with respect to partial and combination factors as well as load duration class. The case excludes wind force as its effect on the structure would be void because of the nature of the supports.
Design Limit Sate: ULS

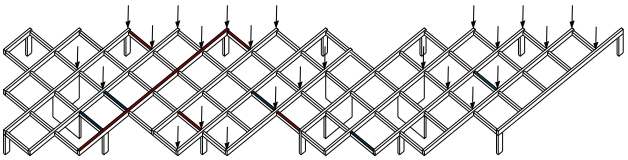
Performance simulation started with a cross section 200*600mm for main beams and 200*500mm for secondary beams. As in our project the modules are moving and create nodal force in different parts, it is important to mention that we performed the simulation on both day and night arrangements. In this simulation we were comparing different glue-laminated timber types in order to get the most efficient performance.

With the supports located on every second axis, the structure proved to be stable and resisted the bending stress, however most of the secondary beams were not used to their full potential. As an exercise we tried to reduce some of the height of the secondary beam from 500 to 400mm, and this improved their ratios without making the whole structure unsafe. There was however still a significant margin on certain elements, so the section was decreased even more to 300mm which improved again their performances but had the ratio of some of the main beams exceed 1.

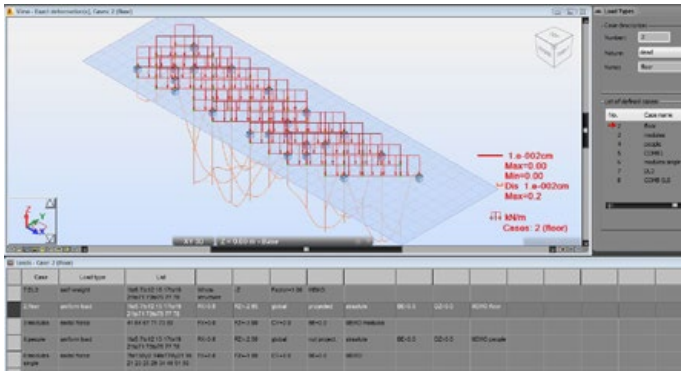
As a last study in Robot, we tried increased the number of supports, they were located on every axis. As a result structural members with low ratio remained nearly the same, and members with the ratio close to 1, decreased to 0,5.



living configuration



working configuration



Be 10

Heated floor area does not include ground floor containing market space, this area is assumed to perform as basement heated up to 15°.

Transmission losses: external walls, roof and floor facing market. Linear transmission losses: windows and doors, cold bridges of the terraces, perimeter of the technical floor.

Windows were grouped according to their orientation, permanent of movable shading.

The combination of natural and mechanical ventilation, with heat recovery was used for the calculation.

Internal heat supply. The number of 4 W/m² is used for people load and 6 W/m² is used for appliances load, witch represents an average for office building. Main heat supply is district heating. The length of the heating pipes is twice the length of the building. Lighting of minimum 200lux is also included .

Building has 4 pumps with nominal power 40W. for the tower model and 3 pumps for the block.

Domestic hot water discharge pipes: The pipes within the heated space is calculated using the provided formula L=n*2*(e-1)*h, the lengh of the pipes outside the heated space is twice the length of the building.

Hot water: District heat exchanger

Area of solar panels is 415m² with a slope of 15° oriented south-west.

CALCULATION OF THE VENTILATION RATES FOR THE KITCHEN AND BATHROOM

According to Category II exhaust air flow in kitchen is 20l/s and in bathroom 15 l/s.
Amount of bathrooms and kitchens-9.

Bathroom area- 5,3-6,9m²
15 × 9/9·6=2,5 l/s

Kitchen area-15m²
20 × 9/9·15=1,3l/s

CALCULATION OF THE AIR EXCHANGE RATE IN ONE APARTMENT.

$$c = c_i + 10\frac{q}{V_i}$$

c is the experienced air quality (dp)
c_i is the experienced air quality of the outdoor air (dp)
q is the pollution load (olf)
V_i is the necessary air flow supply (l/s)

$$n = \frac{V_i \cdot 3600\ s}{1000\ l \cdot V_{rum}}$$

It assumed that 4 people live in the apartment and 8 people work there, according to the given tables such people loads were chosen:
adult - 1 olf; children - 1, 2 or 1,3 olf depending on age
building material load- 0,2 olf
c=1,4 the experienced air quality is determined on the background of the PD (PD is percentage of dissatisfaction)
c_i=0,05 represents the level of pollution in cities

q=(1 olf ·10) + 1,2 olf +1,3 olf + 0,2×78=28,1 olf

V_i=10·28,1/ (1,4-0,05)=208 l/s =2,5l/s per m²

n=208×3600/ 234000=2,39 h^{-1}

Using date obtained from BSim, air exchange rate was calculated again, to see the maximum rate in relation to the amount of openings.

Result from BSim, maximum air exchange rate is in June n=3,8

V_i=1000·234·3,8/3600=247 l/s = 3,4l/s per m2

kitchen
canteen
hostel
leisure/lounge
+8.0m
+4.5m
printing facilities
auditorium
laundry
party/event room
4.0

SPACE METAMORPHOSIS

Common floor plan - SCALE: 1/200
Standard floor plan - SCALE: 1/100

DATE: 27.05.2015