1+1=3: The exploration of space efficiency

An integrated design approach for a flexible-use construction

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Abstract

The paper tries to find solutions about increasing space efficiency in architecture nowadays. The research define space efficiency in detailed aspects, each aspect is explained by special analyze, illustrations and case studies.

The paper chooses work and lives as two main themes in a building for they are normally complementary in time. All kinds of work and live space are defined and classified by a list of characters (which includes use time during a day, publicity, stuffs in space, etc.)

After space analyzes and functions analyze the paper combine these two aspects together and provide a series of special layouts to adapt different needs.

All these researches are done in typological way to make sure the result can be used in other place rather than just the context. Designing a new type of construction that can be used during whole day is then possible, based on the output of the paper and the situation of the context and environment.

Keywords: space efficiency, work space, live space, typology, prototype

Main research question

How to create affordable architectural space with high space efficiency?

Introduction

Nowadays the need of space has been a serious problem in metropolitan areas. The rent price in central area of New York, Tokyo or Hong Kong become extremely high. Even in Amsterdam, value of office buildings in Amsterdam increased the most of all cities in the world. In the third quarter of 2018 Amsterdam offices' value rose by 27.4 percent[1].

How to make full use of central area of these cities then becomes a valuable research question. For architect, this question means to increase space efficiency, which means in same time more space is provided or more people is using the space; or the space can be used in more time during a day.

All innovations need their land to grow. For exploration of space efficiency, the marineterrein are can be a suitable place for experiment. The location of this place is good: it is just near the city center and central train station, which means the land value is high enough to be used effectively.

Also, the site has an innovative atmosphere and future vision, and its function is suitable for space efficiency experiment[2]. Now the site's main function is office, and the landlord specially chose innovative companies to work here, giving them good environment and basement to develop freely. For example, this place have new type of rental office, people can just rent a desk to be their flexible work place and they will also be provided a studio to make their idea come true. Many young and small groups chose this place to realize their dream.

Although the site has its ambition to create an innovation port of Amsterdam or even in Netherland, they are facing with a problem of limited usable space. The marineterrein area used to be fully controlled by navy. Changes have been happening during recent years. Part of the area now is public reign and can be used by citizen. But in early this year, the navy changes their minds and decides to stay in the marineterrein area[3]. This means that the size of usable space will remain in a longer term.

A new research and a new building, that not only explore new way of space efficiency to make cities better, but also provide more space for the context, can be a suitable vision.

Methodologies

First, the research separates space efficiency into different types, each type is established by case studies. After the analyze of examples, a sub-conclusion is made that explains the characters of each type are summarized to show the positive and negative aspects of them.

Second, the research makes the final conclusion that comes with these case studies and analyzes. A potential list of connections that can achieve higher space efficiency is established.

In the last part, the paper shows all 12 prototypes with potential connections between function and solution. Each prototype is aim for a certain target group.

1. The “waste” of space

To start with whole discussion, core questions have to be established. Did space is wasted?

Fig.1. Rudolf von Alt, Salon in the Apartment of Count Lanckoronski in Vienna (possibly 1869)

Fig.2. Z Wilhelm Bendz, Interior from Amaliegage with the artist’s brother, 1829

The painting above shows the living room in an apartment in Vienna. The space that people mainly stay occupies just half of the room. The other half is all for aisle. Also, the height of room is higher than nowadays' apartment room, all extra height is just for more paintings on the wall or a big ceiling lamp.

While the other one show a room which is much smaller and also with more functions in Denmark. The height is much lower than the first one; the painting also shows a high table for standing people, which save some space. There is nothing on ceiling, rather than a huge lamp.

All of this are not to say that the first one "waste" something, but for building which has limited space, there is still possibilities to make the room be used more effectively. Before modern ages, the function and suitable of space still remain unclear. The building of different type of people usually has huge gap. The rich man's room often occupies much space than normal citizens. On the other side, normal room has to adapt more functions and also provide standard live condition with limited space. So from different paintings in same period we can preliminarily find some attempts people did to increase space efficiency, though such phenomenon does not mean old nobility buildings waste space because the supply of space or them is much looser than now. Such limitation and People's resistance to it always exist.

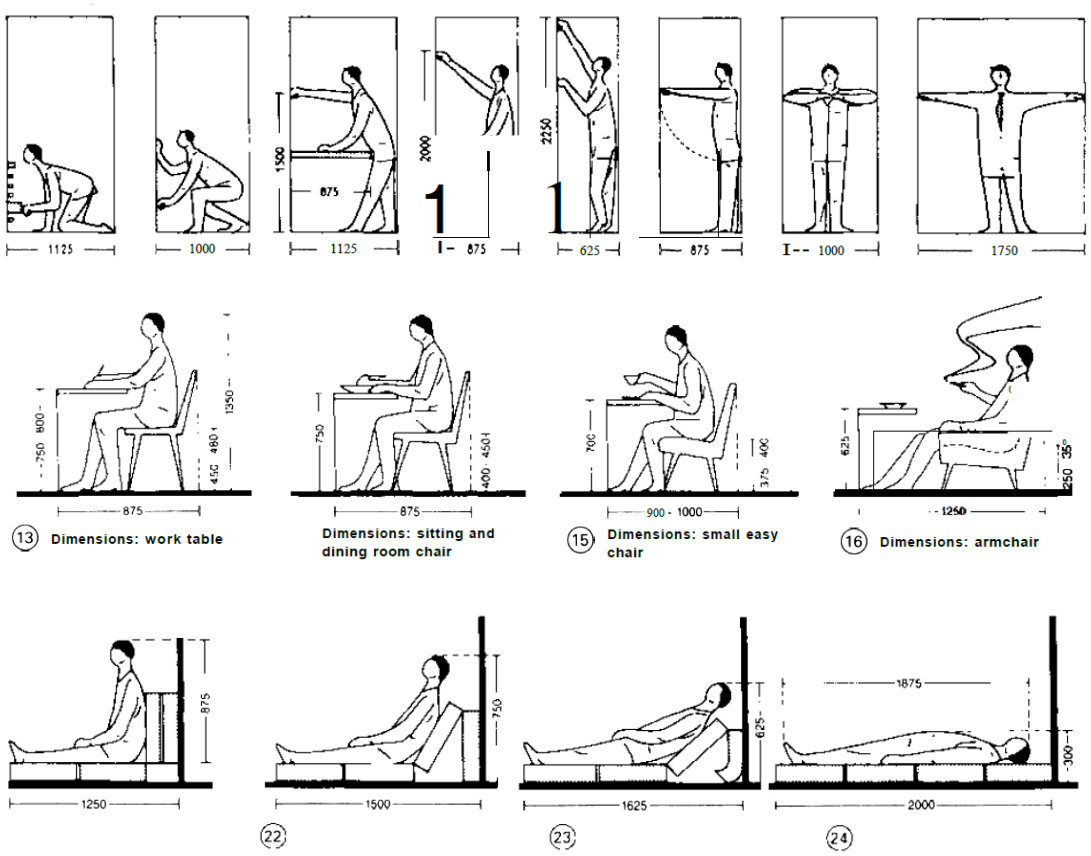


Fig.3. The Space requirements of various body postures. Architect's Data, P17.

Modern architecture theory studies now give us more accurate data about all suitable space scale of human activity. Such data is even smaller than a normal apartment room in 19 century. Have such different promoted more effective use of space? Even if we have already fully realize these attempts, Is there still something missing of space efficiency? Can we even put the result even further?

2. Explorations of space efficiency

What is space efficiency? Generally it contains three main aspects. First is the quantity of space, generally calculated in terms of floor area though occasionally volume may also be relevant; second is the number of users, both potential and actual; third is the amount of time the space is used.

Why these start to be a problem? In metropolitan areas where city have already a high density and land value, the quantity of space usually be limited. Also, the high rental price makes things harder. Because of this, new ways to increase space efficiency from the other two aspects is needed.

How to research? According to the aim of research, new innovative ways come with limited space situation and high land price. So one basic research condition is to improve space efficiency with fixed floor proportion (this does not include potential virtual space that more than human scale $2.2m_4$).

Two main ways to solve this problem then are established. One is reducing personal space consumption, which makes same space contain more people; people also get lower cost for they occupy less space. The other is increasing the use time of the space, which decreases the special waste and reduce price.

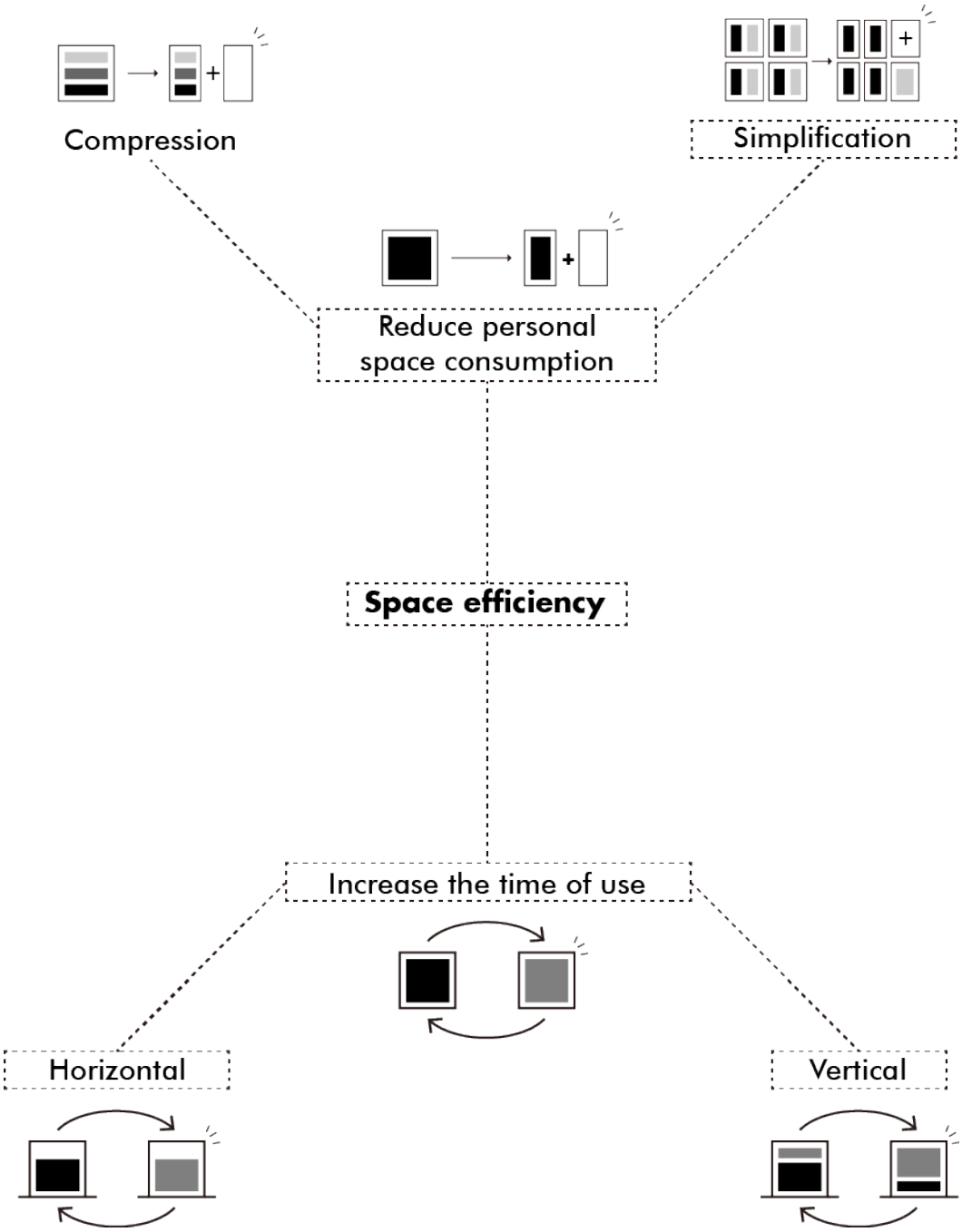


Fig.4.Illustration of space efficiency in typological way

2.1. Reduce personal space consumption

Make people use less space and make space contains more people is a common way to increase space efficiency in metropolitan areas. This approach can be divided into Compression and Simplification according to the strength of action.

2.1.1. Compression

Space compression means that although the size of space is smaller, but the user of each space remains unchanged. In other words, a private space will still be private after compression. Every kind of space has its minimum size, so such approach also has physical limitation. On the other side, the level of space comfort also decrease by the compression. As a result, different degrees of compression create space with different character. Case studies with this different level are showed and analyzed to find the detailed influence of this approach.

When the level of space compression is not high, then the core quality of space can almost remain high by taking some remediation. Such way of design often appears in central urban area. The case study CitizenM hotel besides The Tower of London is a clear example of this conclusion.

Fig.5. Room's interior of CitizenM.

Source:

https://www.architectsjournal.co.uk/buildings/shared-space-14sqm-bedrooms-sheppard-robsons-hotel-for-millennials/10014602.article

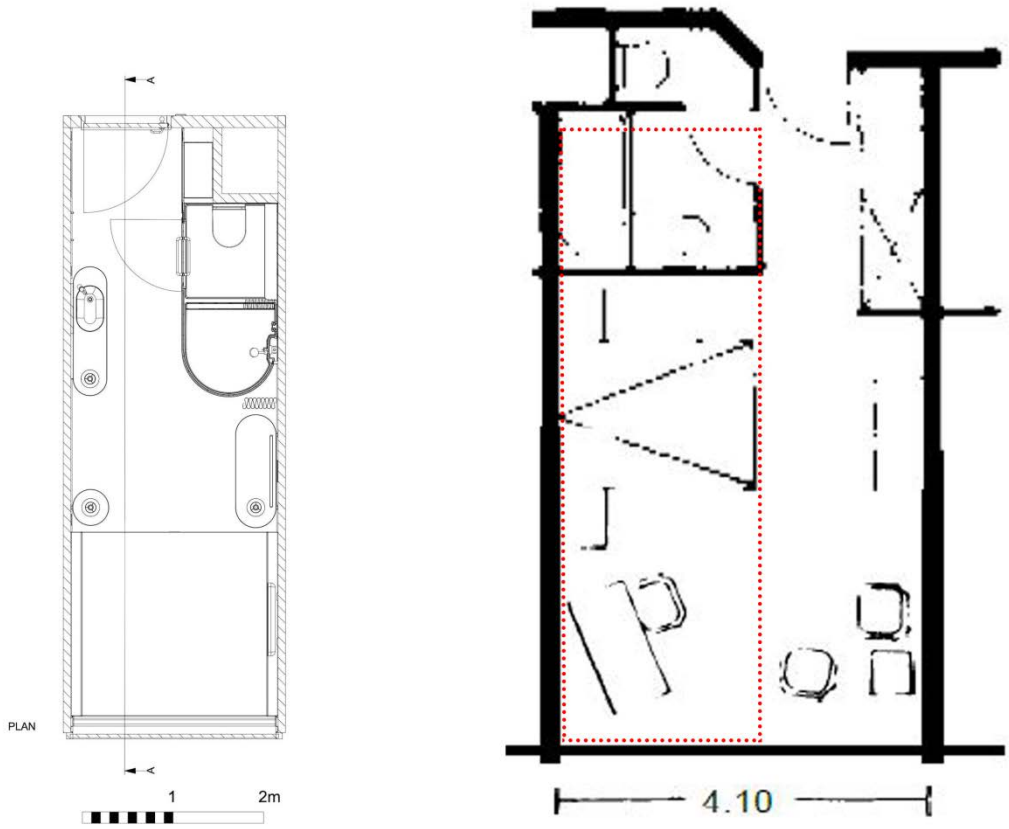


Fig.6. Illustration: The comparison between the room of CitizenM and standard hotel room

Source of left plan:

https://www.architectsjournal.co.uk/buildings/shared-space-14sqm-bedrooms-sheppard-robsons-hotel-for-millennials/10014602.article

Source of right plan: Architect's Data, P465.

The illustration above shows the plan of a standard room of CitizenM and standard hotel room according to the Architect's Data. The CitizenM's room remains all of normal room functions, from toliet, wash tap, shower room to cabint, table and chairs. The core reason why it keeps all functions but only occupies less than 2/3 of a standard room is compression. The room cut most of walkway. First, the room combines toliet's all walk space with main corridor in room, to realize this functions in toliet are separated into the room. Space for people to go on bed also be halfed and integrated into main corridor. Closet space is also halfed. Work and rest zone still exist but they are put together and can be transferred to each other.

Such way of design of course same space to contain more rooms. On the other side, it also limited aim user. It mainly for visiters and young people with short stay. The king-size bed just have one direction to go on, which is inconvenient for user to gst in and off of bed. The corridor is nerrow and it maybe harder for disabled people to turn and place their wheelchair. The work zone is also not enough to work comfortablely, etc.

In conclusion, such space increase space efficiency by compress space of every function, at

the same time the arragement of room make it harder for people to stay longer during a day, and limited aim user. Such space is suitable for tourist to have good rest during night, but they normally won't stay during day time.

2.1.2. Simplification

When the limitation of total space is even bigger, some private space can be cut and transfer into public space. At last all private space for a person will be compressed to extreme size. Building that is arranged in this way usually face with more limited space or more demands.

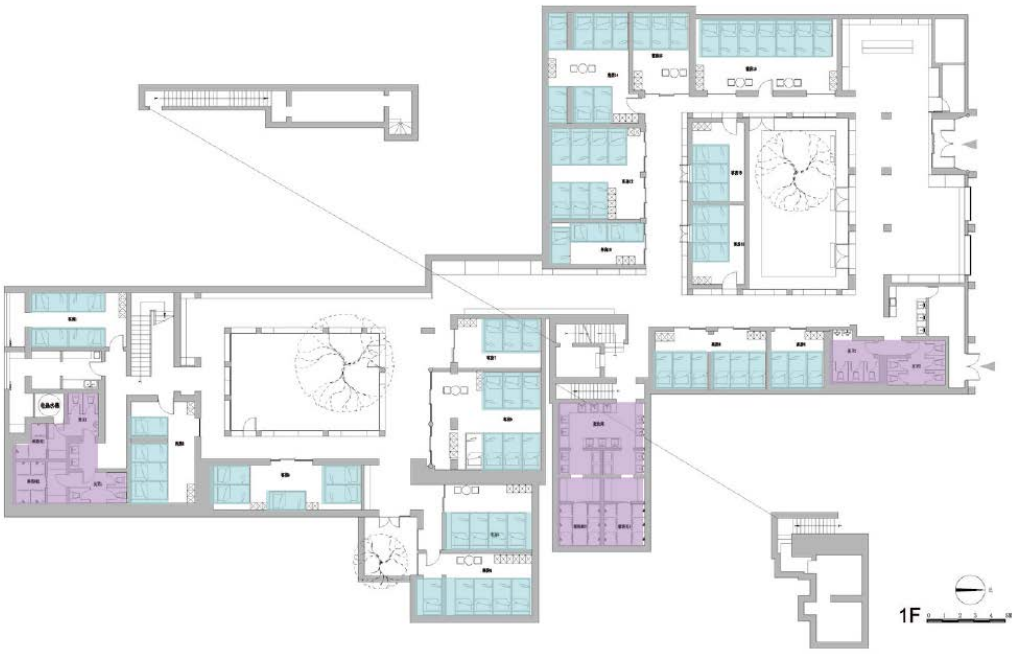


Fig.7. Illustration of floor plan of Xiezuo Hutong Capsule Hotel, Beijijng

Source of floor plan:

https://www.archdaily.com/886515/xiezuo-hutong-capsule-hotel-in-beijing-blue-architecture-studio?ad_medium=gallery

The project located in central area of Beijing, the main form around the hotel is Siheyuan, which are normally one floor traditional courtyard residences. The site occupies two courtyards. Such site condition means that new design cannot excess the height of existing building. Even compressed room may not suitable for this limited space.

In this condition private toilet, shower room and storage (purple part of the illustration) are simplified and transferred into public zones. Rooms for sleep then fully occupied by bunk bed.

Simplification does gain space efficiency by include more people in limited space, it also cost. The scale of sleep room protects people from using during day time. The "privacy space" of a

person is simplified from whole room to just a bad, the scale and space of the bed then only suitable for people to sleep (they will even be influenced by other people on bed during sleep time).

All functions for work and communication in a normal room are also transferred to open space. Such type of design usually provides more public space for people to stay.

Also, such way can effectively decrease the rent cost for users in office building.

2.2. Increase the time of use

Every function works in a certain period, which means same space can be used as different aim in different time. This proposal contains two aspects. The first one is to make horizontal space more effective, such space includes the height that under human scale ($2.25m_5$). This aspect has close relation with human activity and the arrangement of space can be changed by people's hands. The other aspect is to make use of space that people cannot reach: vertical space beyond 2.25m. Approaches then become structural or machine-powered.

2.2.1. Make use of horizontal space

Limited space normally does not have enough space to storage facility for different functions. As a result, this way often works with flexible furniture. Most of furniture are arranged under the height that human can reach. At the same time, different functions work with different furniture. When the purpose of limited space changes from one to another, changeable furniture makes this possible.

Space can be used in high efficiency by using flexible furniture, which makes small room multifunctional and it can be used during whole day.

Fig.8. A flexible furniture that can be transferred from desk to bed.

Source: http://homedesg.co/images/

The illustration above shows detailed data about how this proposal increases space efficiency. In limited room the space for bed and desk can be transferred from one to the other.

This way increases space comfort by provide more functions and free zone in limited room. Normally a small room with bed and desk give people less space to move or stay. When the bed and desk can transfer from on to the other, extra space will appear and it can either be used as free space or be arranged new function.

But normally the user usually remains unchanged in such proposal, which means the space has its privacy and it is hard to be used by different people.

2.2.2. Make use of vertical space

Sometimes room gets extra height but not enough to have extra floor. Such space exists but it is also hard to use because people cannot reach. To make full use of vertical space lift machines are designed and used.

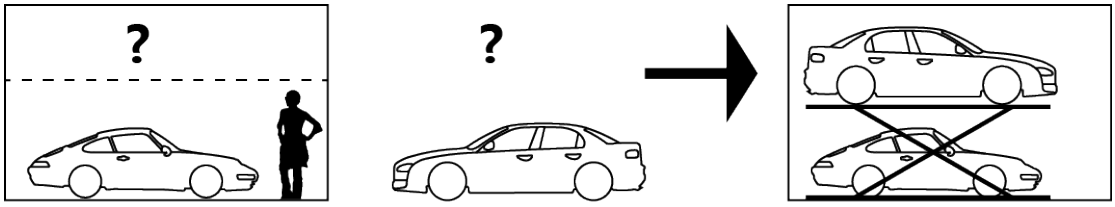


Fig.9. Illustration of lift car parking facility

Illustration above shows how a vertical lifting mechanical parking system works. Two cars can be parked in same space in floor plan. It effectively uses the extra height of space. On the other hand, space under and above the lift structure influence each other. If people want to drive the upper car, they have to move the under car first.

This way may be sufficient for storage, is this suitable for human-scale space?

Fortunately there is an example of apartment that uses similar design approach to gain more usable space. The project is for a young couple in Beijing, who need to renovate their small apartment. This is a very small room with limited height and space which has no any further extension. The ventilation and daylight condition is terrible.

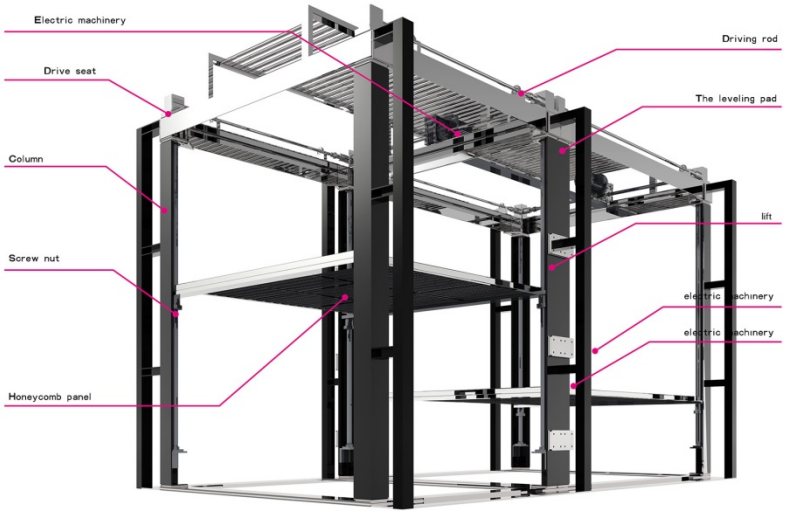


Fig.10. Illustration of flexible floor with lifting structure

Source: https://www.gooood.cn/renovation-by-zhang-haiao.htm

Fig.11. Layout with different height

Source: https://www.gooood.cn/renovation-by-zhang-haiao.htm

Such design proves that it is possible to use lift structure to form flexible floor for normal room, and it does make same floor space be used during whole day with different functions. The height of space is 3.4m, which is not enough to have two normal floors. Original height of living space under bed space is only 1.9m, while height of sleep space leaves 1.5m. These conditions provide uncomfortable environment. All different kinds of function are missing from the space. New design creates different height by involving movable mechanics floor plate. Folding furniture is designed and they could be transformed to different functions, which are living room, gym, movie theaters, bedroom, multiple living and study room. One can transfer the layout according to different functions.

On the other hand, although the space makes a small room possible to be used during whole day, the character of the room (apartment) ties its user and it cannot be used by other people.

3. Conclusion

All approaches have their merits and demerits. Increasing users in same space and increasing using time in same space seems to have huge different between each other.

Can these explorations suitable for a flexible building in limited space with work and live?

Reducing personal space consume can effectively make a building occupy less space than a normal one or provide more rooms or facilities in same dimension**.** Both Compression and Simplification increase space efficiency by include more users in limited space. Normally they still meet people‘s basic need for different kind of functions. Architecture with limited space will able to contain more users, which makes its rent price lower if it is designed with this way.

On the other hand, by the increase of space efficiency, such way weakens space comfort and versatility. Normal hotel room supply enough and comfortable space for possible use, people can not only sleep, rest but also work or meet others in same room. A standard hotel room provide this by occupy enough space. To increase space efficiency exploration compresses or cut these dispensable functions. Main space become basic and pure, then it is more likely to be used for simple objective like sleep, rest or formal work. As a result, space is vacant when its main function does not work. During day time most of rooms with bed in capsule hotel will be useless.

All space with these ways has narrower and clearer target population than common space. All explorations of compression and simplification aim to provide smaller but more affordable space in good location, which is attractive and reasonable for young population.

If these ways are used in new building with flexible function, its drawbacks should be remedied.

Increasing the time of use in architecture design goes to another way to improve space efficiency. When combine these approaches with research problem “how to make flexible space with both work and live” a series of periodical conclusion can be established.

Attempts that focus on using both vertical and horizontal potentials are able to make space be fully used during whole day. By using flexible furniture or floor same space start to hold multiple functions.

Users in space remain unchanged than space without such design. All two approaches aim to increase using time rather than change the scale of functions.

These two approaches increase space comfort. By hiding furniture or floor that for night functions during day while hiding day functions during night, users get more space for both day and night.

The characters of two main aspects are complementary to each other, which mean there are possibilities to make better options by combining them together.

4. Future vision

For main research proposal, both live and work can have certain period by defining the detailed type. Of course there are always examples that cannot be arranged like this, but for further exploration and low rent price in context, the future vision will choose suitable type that adapt research proposal. All case studies that are showed above just achieve one of two main aspects(Reduce personal space consumption or increase the time of use).

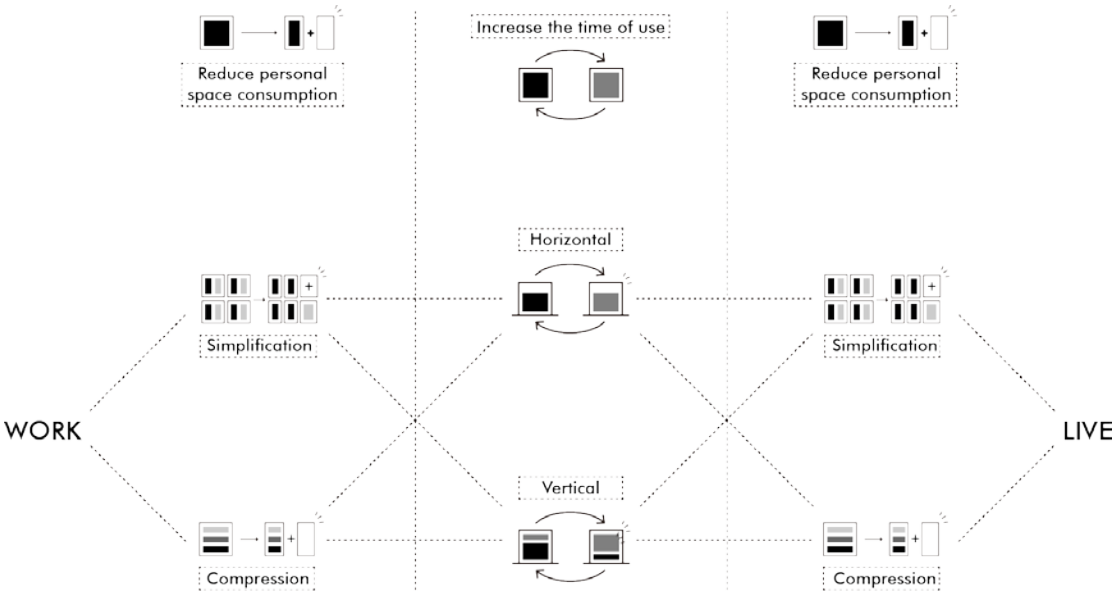


Fig.12. Illustration: new connection between different elements

As a result, there is possibility that combines two aspects to create space that can be used as two functions and can transfer from one to the other. The character of Compression and Simplification make space contains more users, while Horizontal and Vertical make space able to change function that adapts different users.

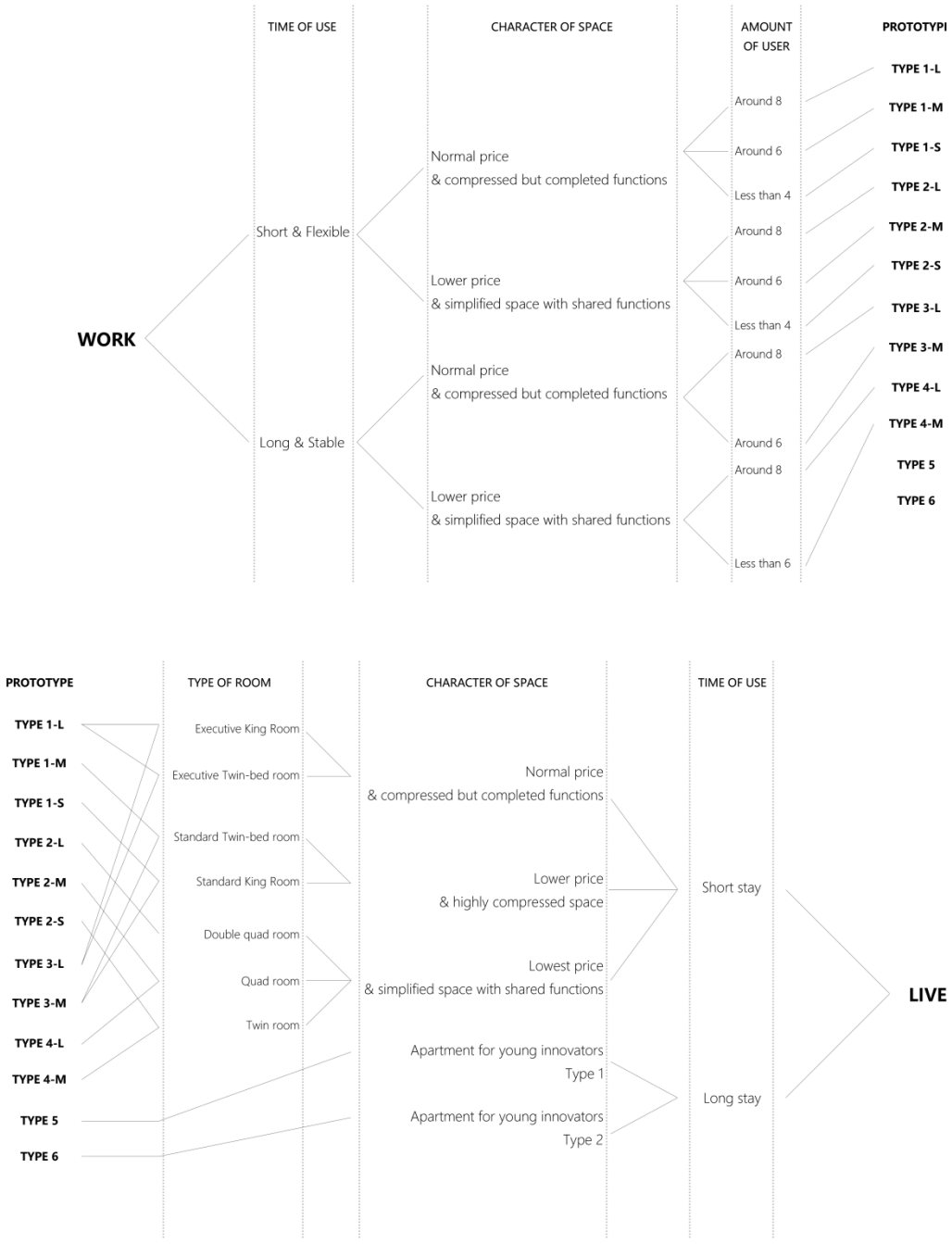


Fig.13. Illustration: suitable connections between different type of work and live

On the other hand, not every type of work or live space can be easily transferred from one to the other. It is necessary to define certain kinds of work and live space with similar special characters and connects them together.

According to these two main aspects, 12 prototypes that are suitable for different conditions are established. All these prototypes are not only smaller than normal space but also able to be used during whole day. These prototypes are then reach higher space efficiency than architecture nowadays and can be suitable solutions to fix the problem with high price and

low supply in central metropolis. The plan and axonometric drawing of all 12 prototypes are showed in appendix.

A criteria system is also needed to compare every prototype and make them suitable for certain kind of users. The criteria contains four parts, which are private dimension per people, price (of rent and live), private functions, using hours.

Appendix: Six prototypes

Prototype 1-L

Combination:

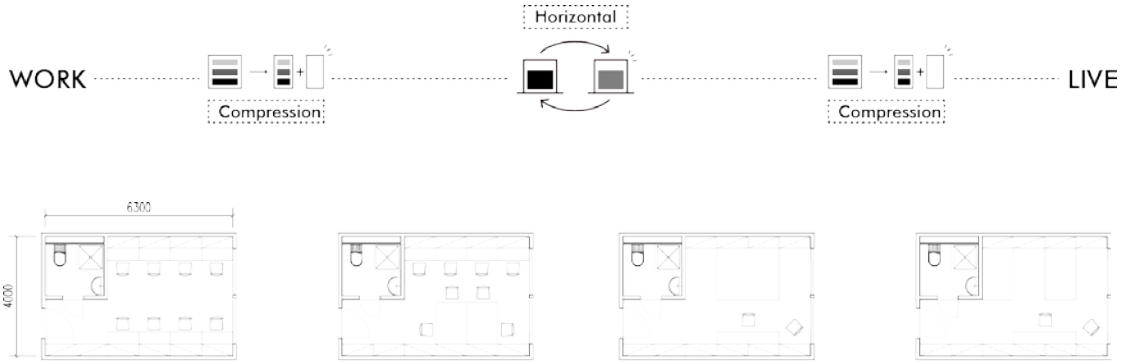


Fig.14. Illustration: plans with different functions of prototype 1

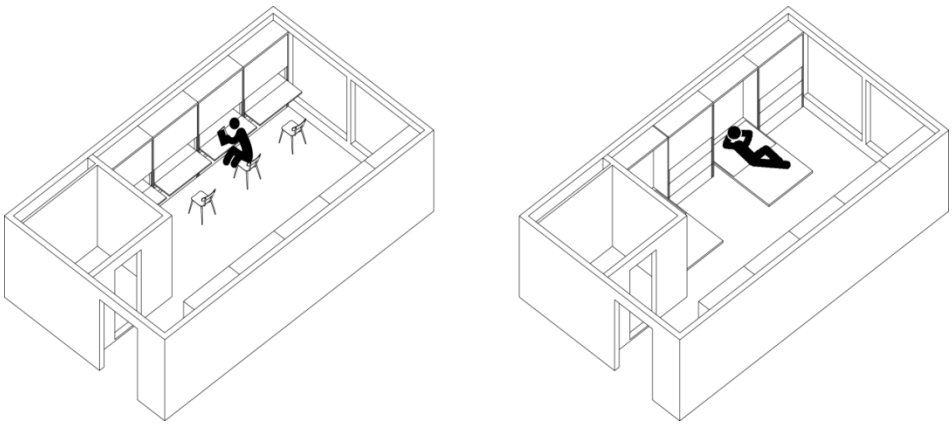


Fig.15. Illustration: axonometric drawings of prototype 1

Criteria:

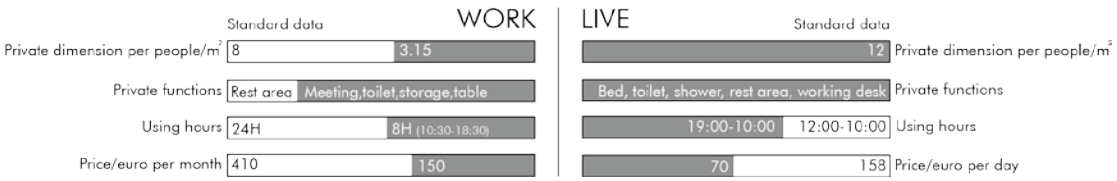


Fig.16. Illustration: character of prototype 1_6

Target groups:

Work: Companies that have **flexible working time** or rent with **short period**. They want **completed function** and **enough privacy**. The number of staff is around **8**.

Live: People that stay for **short time** (business people or tourists). They want **completed function** and enough **privacy**. They want **best space comfort**.

Prototype 1-M

Combination:

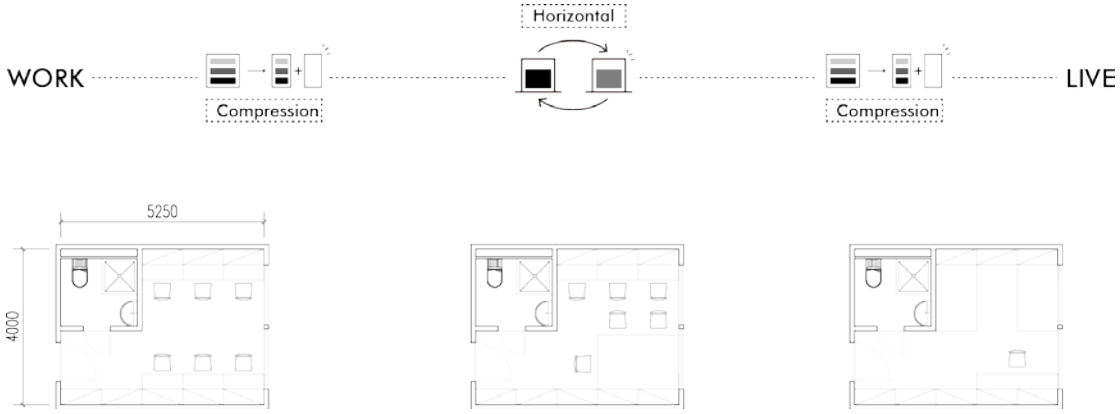


Fig.17. Illustration: plans with different functions of prototype 2

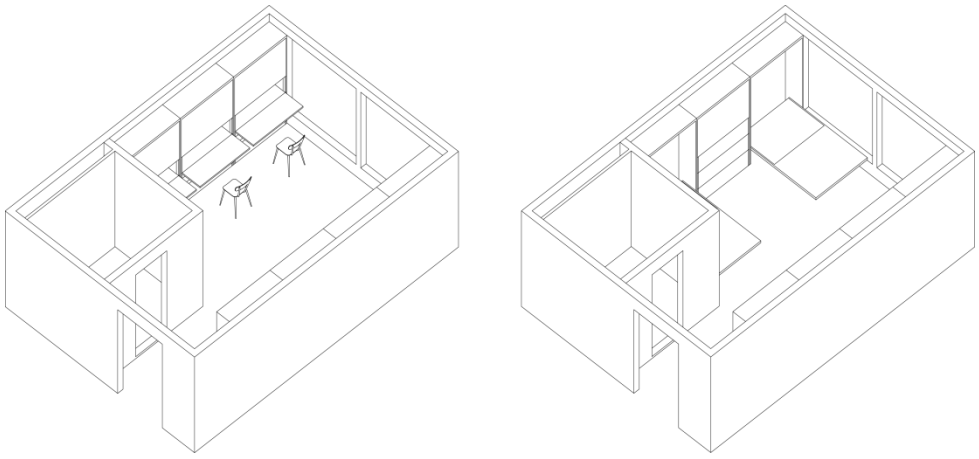


Fig.18. Illustration: axonometric drawings of prototype 2

Criteria:

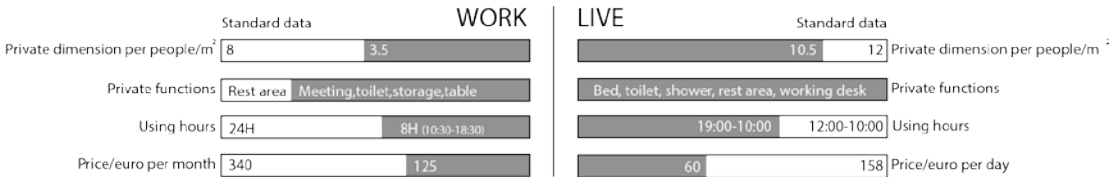


Fig.19. Illustration: character of prototype 2

Target groups:

Work: Companies that have **flexible working time** or rent with **short period**. They want **completed function** and enough **privacy**. The number of staff is around **6**.

Live: People that stay for **short time** (business people or tourists). They want **completed function** and enough **privacy**. They want **high cost efficient**.

Prototype 1-S

Combination:

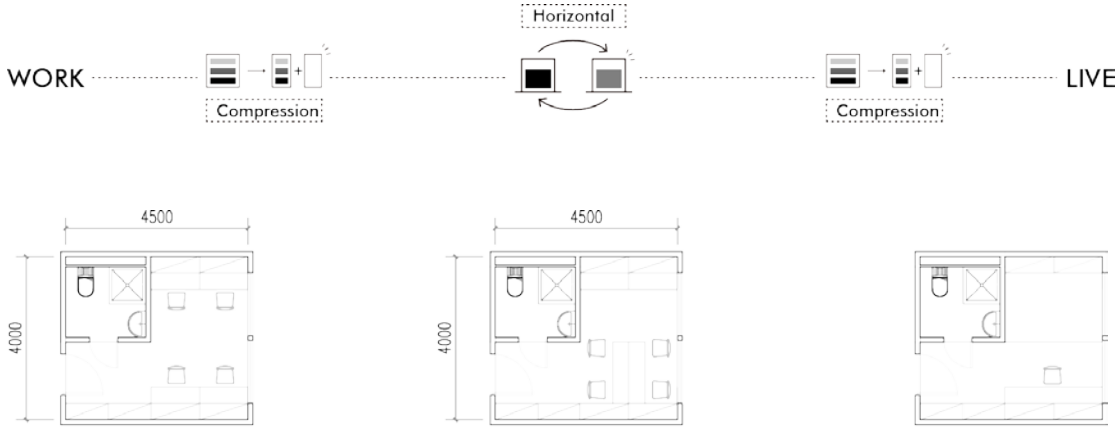


Fig.20. Illustration: plans with different functions of prototype 3

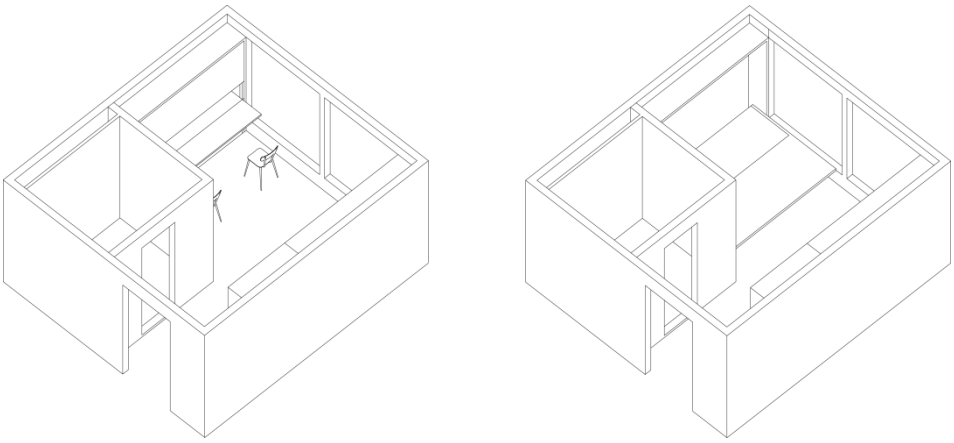


Fig.21. Illustration: axonometric drawings of prototype 3

Criteria:

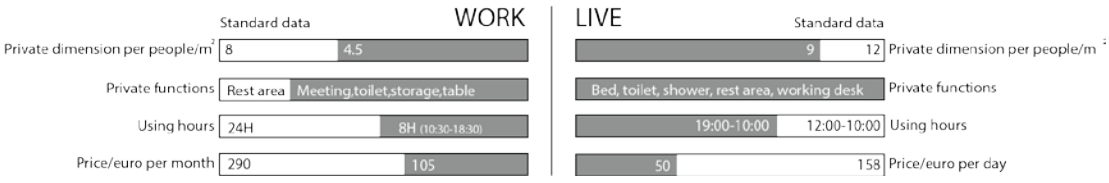


Fig.22. Illustration: character of prototype 3

Target groups:

Work: Companies that have **flexible working time** or rent with **short period**. They want **completed function** and enough **privacy**. The number of staff is less than **4**.

Live: People that stay for **short time** (business people or tourists). They want **completed function** and enough **privacy**. They want **high cost efficient**.

Prototype 2-L

Combination:

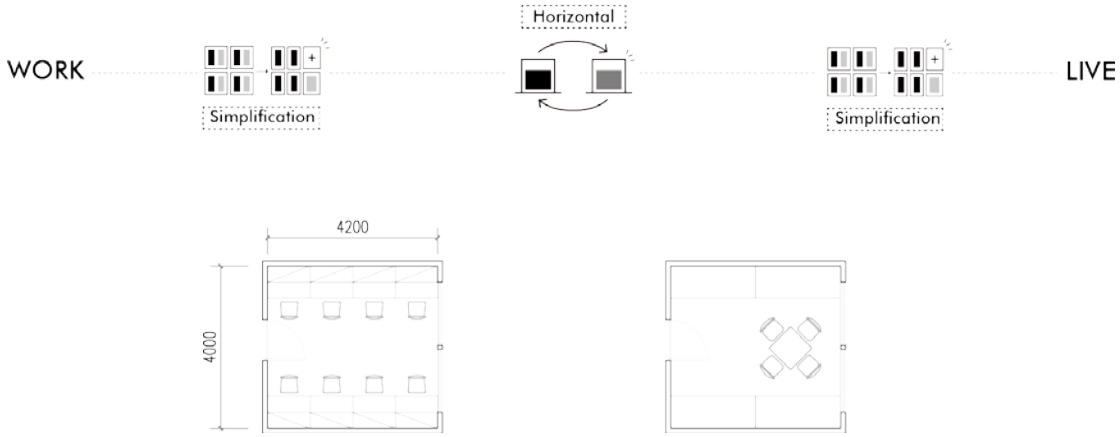


Fig.23. Illustration: plans with different functions of prototype 4

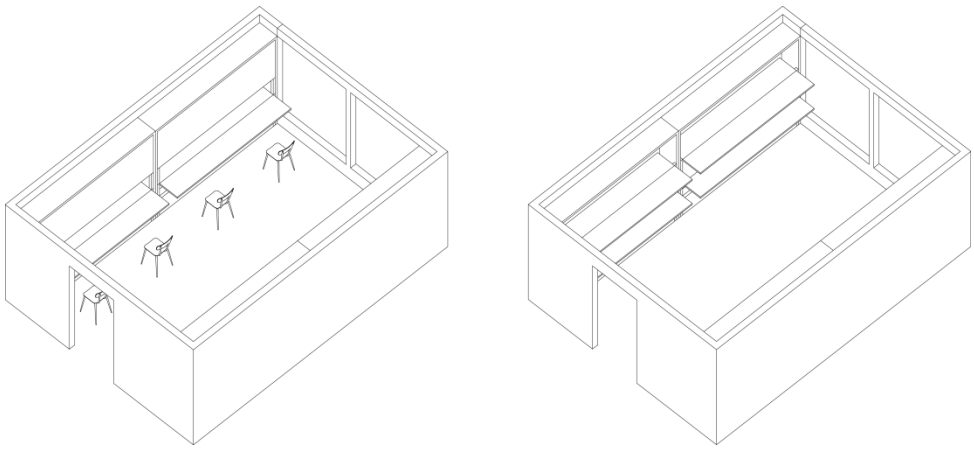


Fig.24. Illustration: axonometric drawings of prototype 4

Criteria:

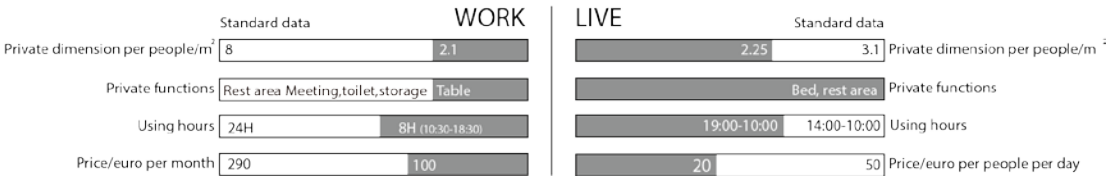


Fig.25. Illustration: character of prototype 4

Target groups:

Work: Companies that have **flexible working time** or rent with **short period**. They want **lower price** with **shared functions**. The number of staff is around **8**.

Live: **Tourists** that stay for **short time**. They want **low price** with **shared facilities**. They want **highest cost efficient** by choosing room with **8** people.

Prototype 2-M

Combination:

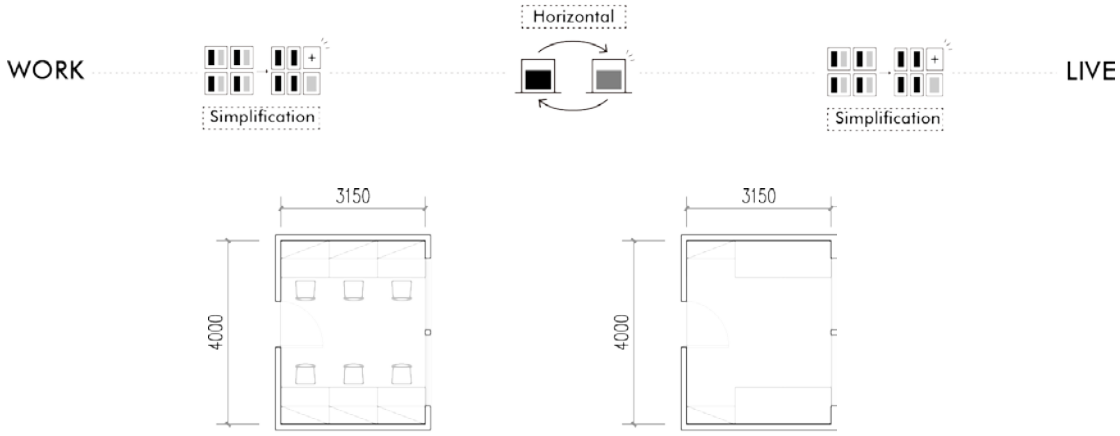


Fig.26. Illustration: plans with different functions of prototype 5

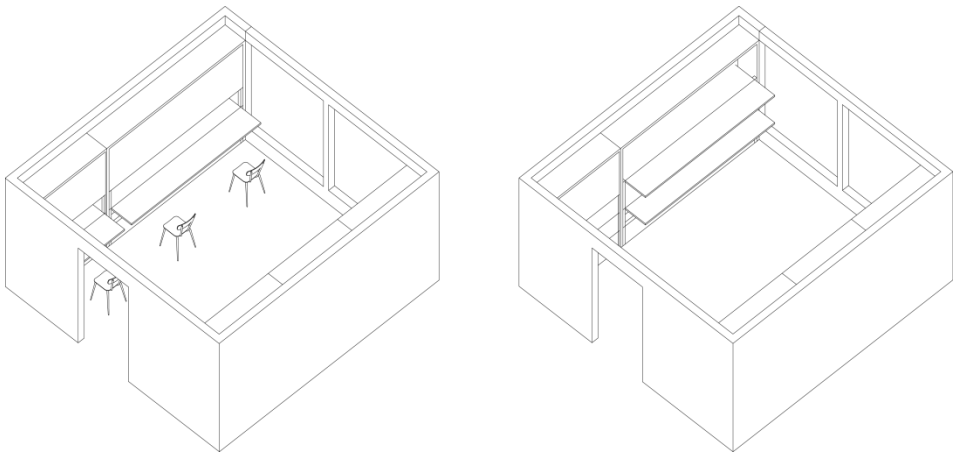


Fig.27. Illustration: axonometric drawings of prototype 5

Criteria:

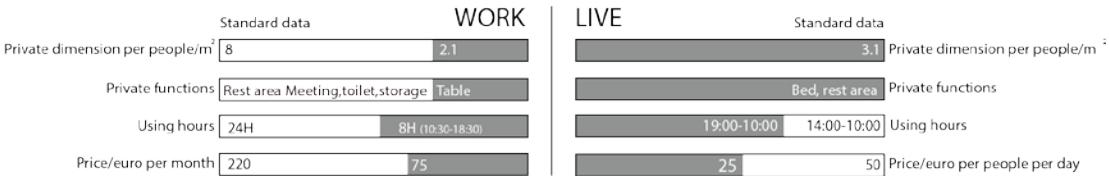


Fig.28. Illustration: character of prototype 5

Target groups:

Work: Companies that have **flexible working time** or rent with **short period**. They want **lower price** with **shared functions**. The number of staff is around **6**.

Live: **Tourists** that stay for **short time**. They want **low price** with **shared facilities**. They want **medium cost efficient** by choosing room with **4** people.

Prototype 2-S

Combination:

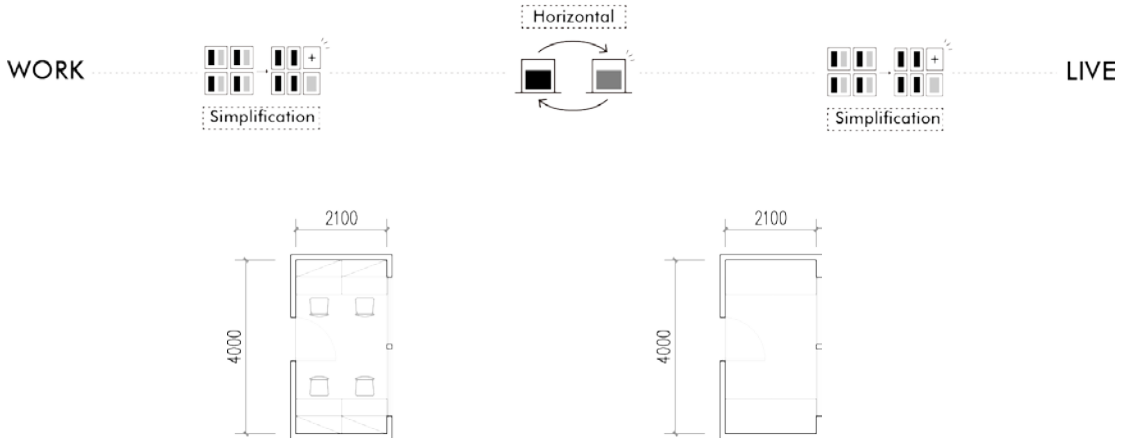


Fig.29. Illustration: plans with different functions of prototype 6

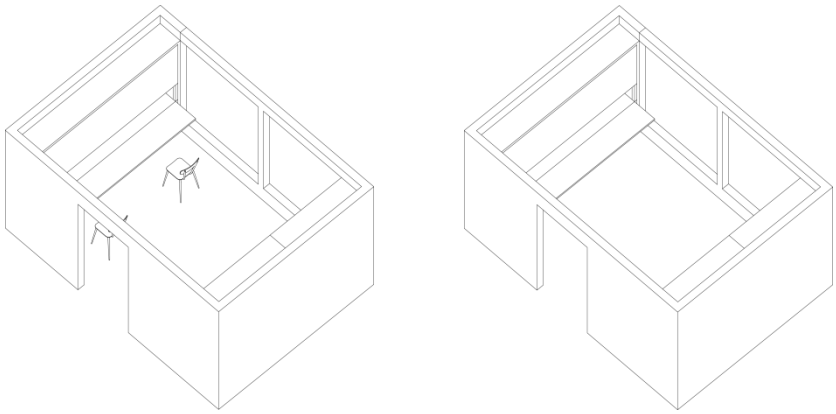


Fig.30. Illustration: axonometric drawings of prototype 6

Criteria:

Fig.31. Illustration: character of prototype 6

Target groups:

Work: Companies that have **flexible working time** or rent with **short period**. They want **lower price** with **shared functions**. The number of staff is less than **4**.

Live: **Tourists** that stay for **short time**. They want **low price** with **shared facilities**. They want **space comfort** by choosing room with **2** people.

Prototype 3-L

Combination:

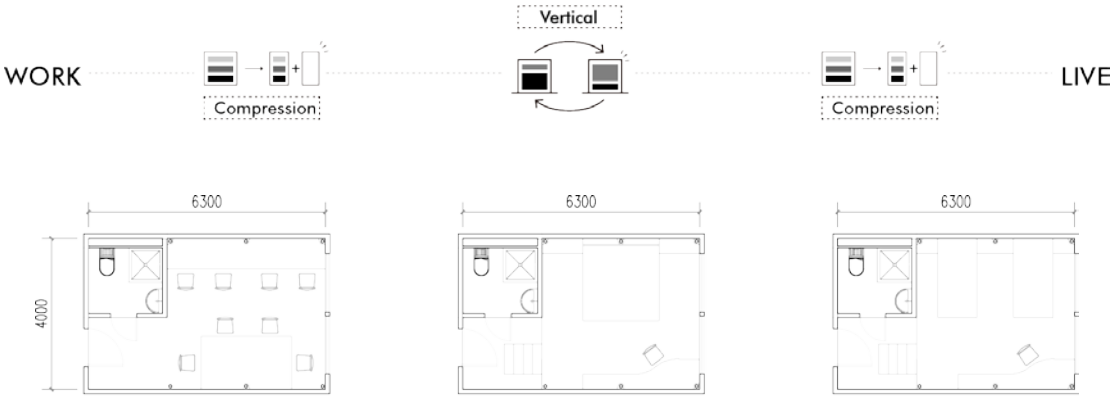


Fig.32. Illustration: plans with different functions of prototype 7

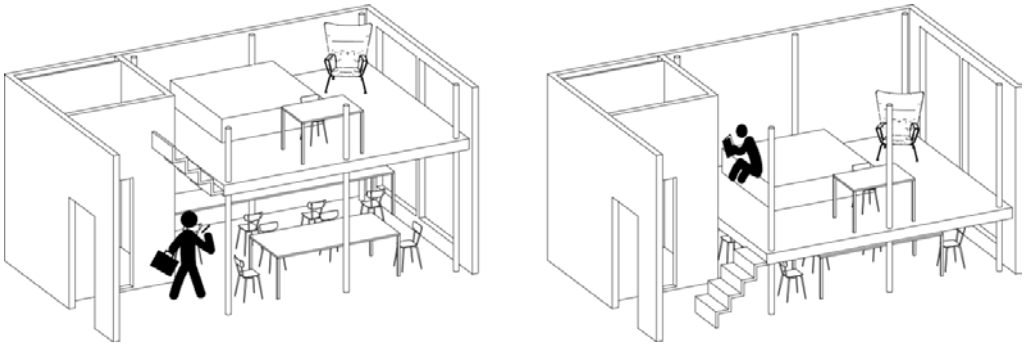


Fig.33. Illustration: axonometric drawings of prototype 7

Criteria:

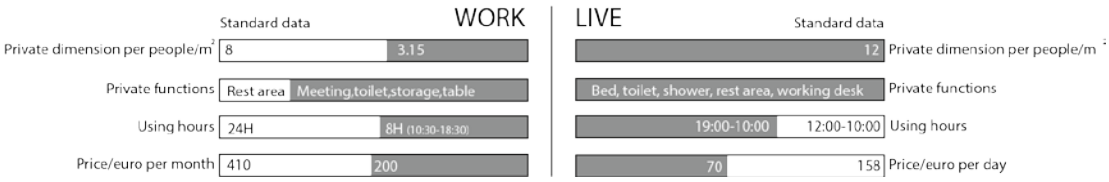


Fig.34. Illustration: character of prototype 7

Target groups:

Work: Companies that have **stable working time** or rent with **long period**. They want enough **privacy** with **completed function**. The number of staff is around **8**.

Live: People that stay for **short time** (business people or tourists). They want **completed function** and enough **privacy**. They want **best space comfort**.

Prototype 3-M

Combination:

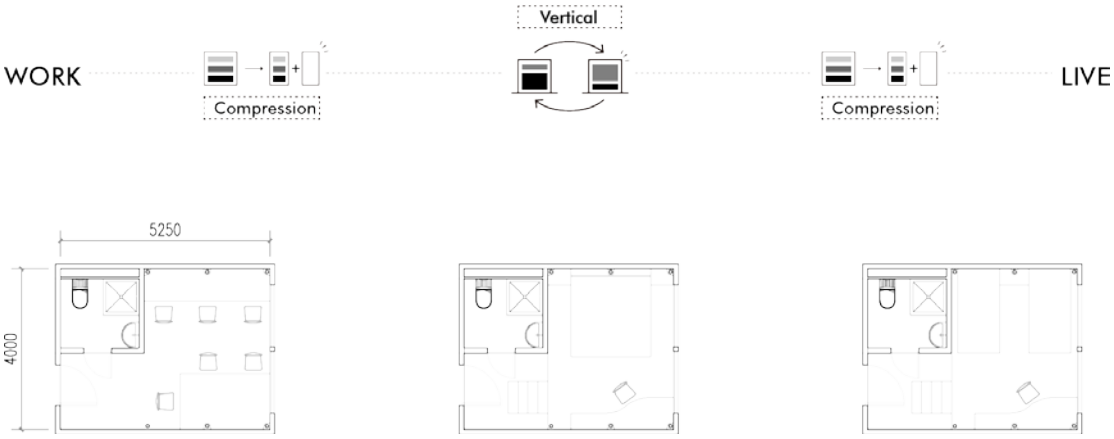


Fig.35. Illustration: plans with different functions of prototype 8

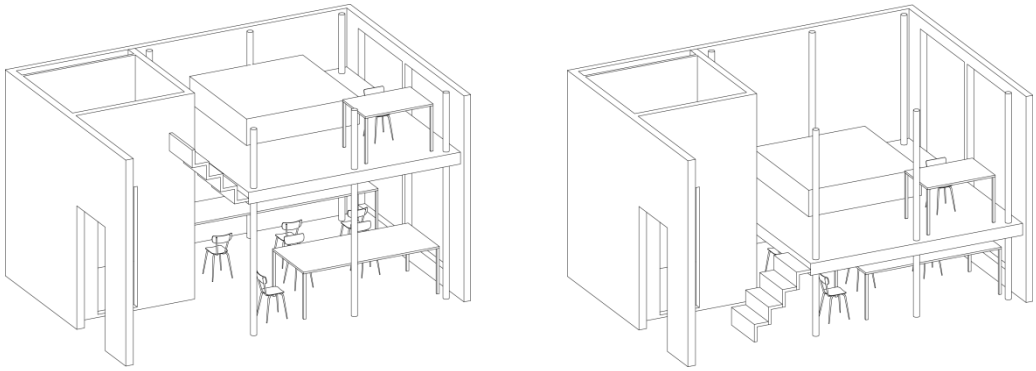


Fig.36. Illustration: axonometric drawings of prototype 8

Criteria:

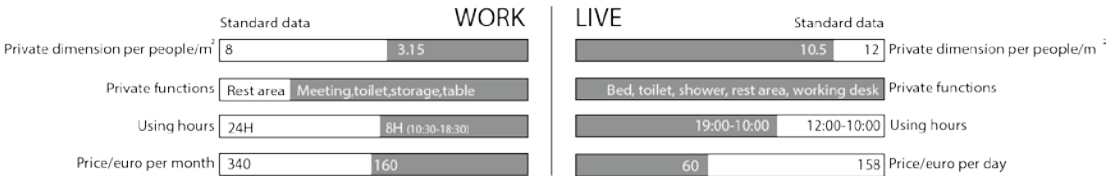


Fig.37. Illustration: character of prototype 8

Target groups:

Work: Companies that have **stable working time** or rent with **long period**. They want enough **privacy** with **completed function**. The number of staff is around **6**.

Live: People that stay for **short time** (business people or tourists). They want **completed function** and enough **privacy**. They want **high cost efficient**.

Prototype 4-L

Combination:

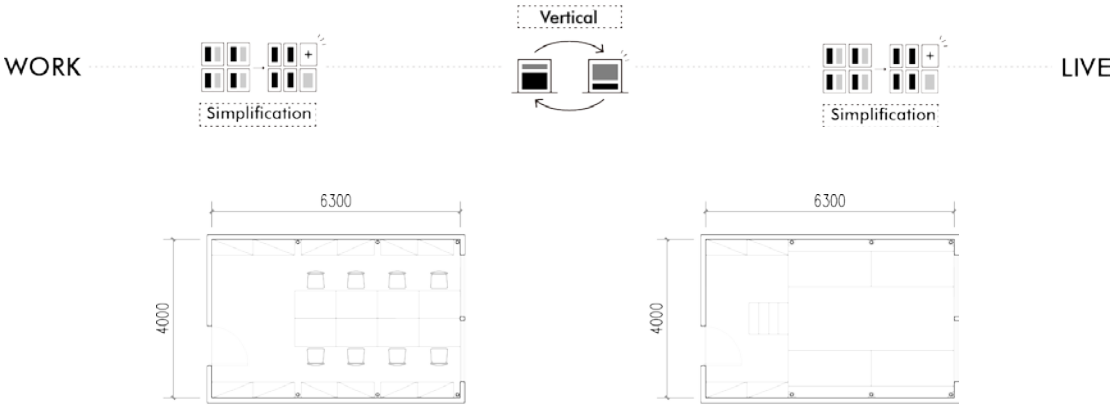


Fig.38. Illustration: plans with different functions of prototype 9

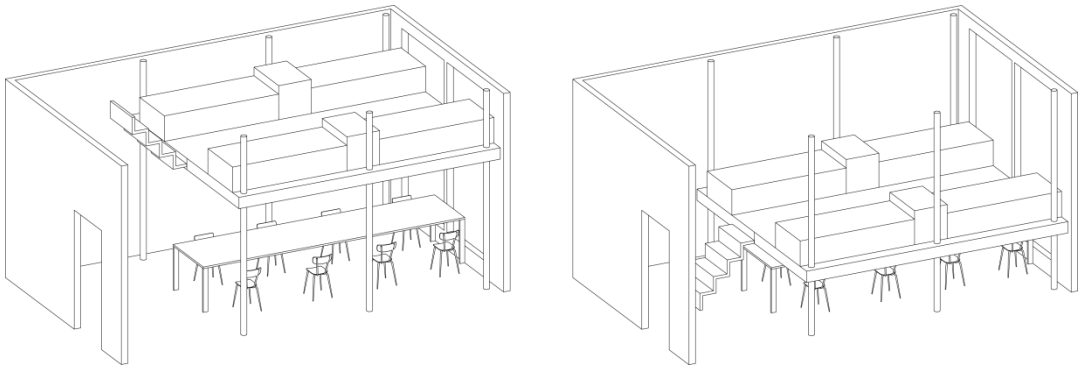


Fig.39. Illustration: axonometric drawings of prototype 9

Criteria:

Fig.40. Illustration: character of prototype 9

Target groups:

Work: Companies that have **stable working time** or rent with **long period**. They want **lower price** with **shared functions**. The number of staff is around **8**.

Live: **Tourists** that stay for **short time**. They want **low price** with **shared facilities**. They want **medium cost efficient** by choosing room with **4** people.

Prototype 4-M

Combination:

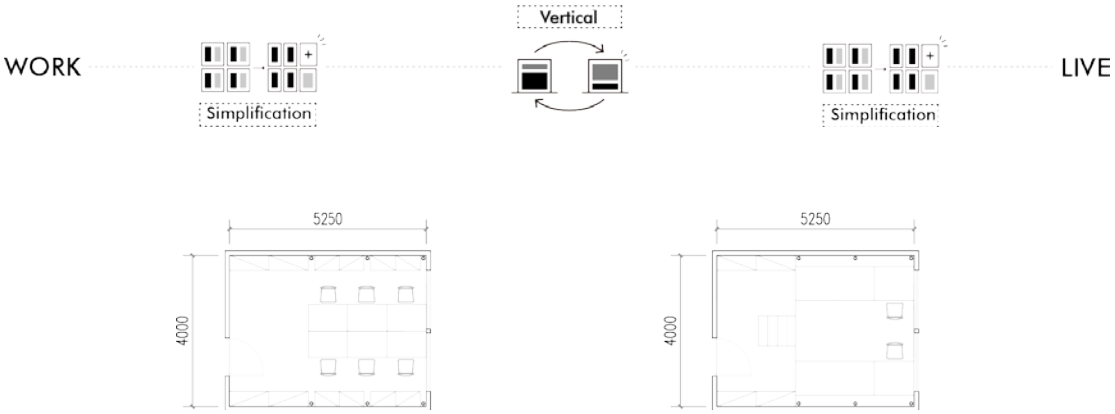


Fig.41. Illustration: plans with different functions of prototype 10

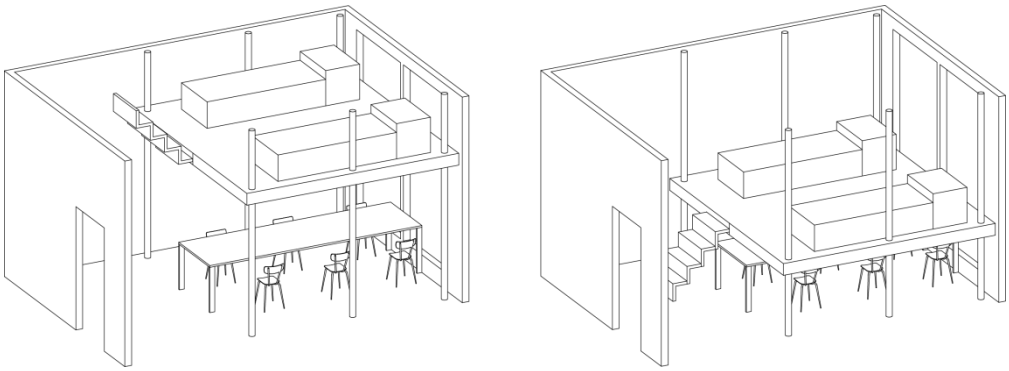


Fig.42. Illustration: axonometric drawings of prototype 10

Criteria:

Fig.43. Illustration: character of prototype 10

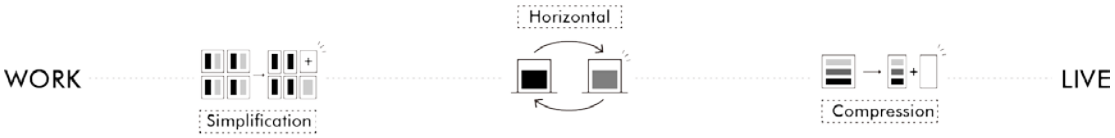
Target groups:

Work: Companies that have **stable working time** or rent with **long period**. They want **lower price** with **shared functions**. The number of staff is less than **6**.

Live: **Tourists** that stay for **short time**. They want **low price** with **shared facilities**. They want **space comfort** by choosing room with **2** people.

Prototype 5

Combination:



Target groups:

Apartment for **young innovators.** This apartment provides both **co-working space** for young innovators to start their enterprise with their partners and **comfortable living space** in **affordable price.**

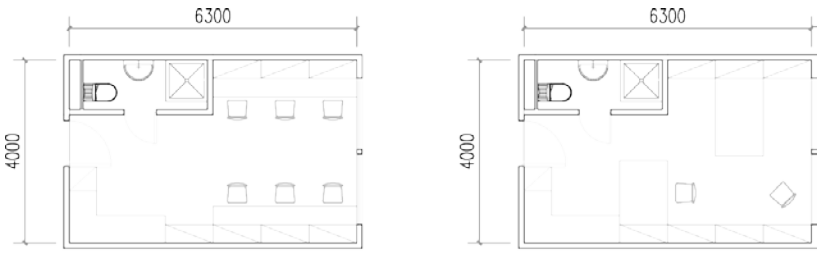


Fig.44. Illustration: plans with different functions of prototype 11

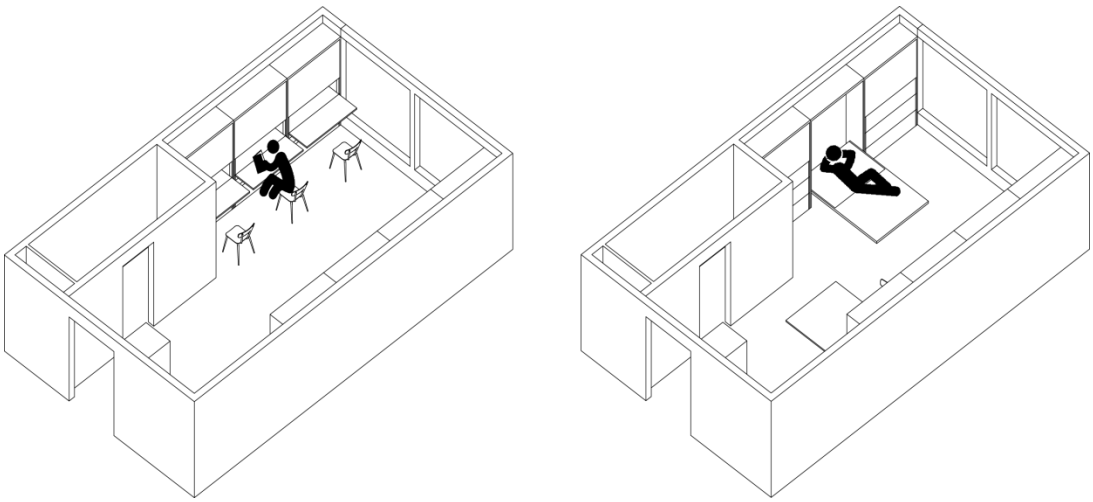
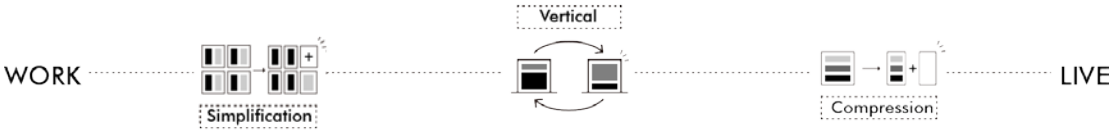


Fig.45. Illustration: axonometric drawings of prototype 11

Prototype 6

Combination:



Target groups:

Apartment for **young innovators.** This apartment provides both **co-working space** for young innovators to start their enterprise with their partners and **comfortable living space** in **affordable price.**

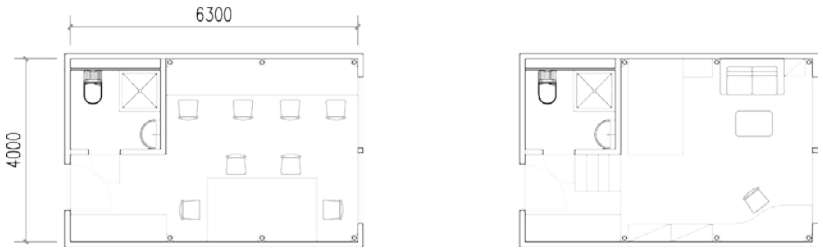


Fig.46. Illustration: plans with different functions of prototype 11

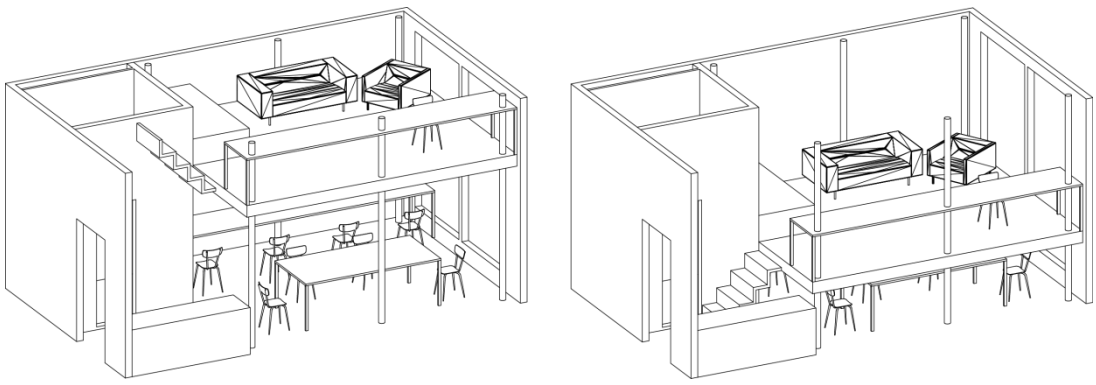


Fig.47. Illustration: axonometric drawings of prototype 12

Note：

1. The data is from Sprekende Cijfers Kantorenmarkten medio 2018.
2. The paper refers the third edition of Atchitects' Data.
3. Source:
https://www.parool.nl/amsterdam/defensie-wil-toch-op-het-marineterrein-blijven~a4600872/
4-5. The data is from P16 of Architects' Data, which shows universal standard human scale.
6. The standard data of dimension and function are from the Architects' Data; The standard data of price of office is from Kantoren in cijfers 2017; The standard data of price of hotel is from PwC;

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