The technical restrictions and solutions of
Prefab, Space-in-Space, Plug & Play

TRANSFORMABLE LIVING UNITS

for flexible conversion of vacant office space without investments

Leon Zondervan

An exploratory catalogue;

The technical restrictions and solutions of Prefab, Space-in-Space, Plug & Play Transformable Living Units for flexible conversion of vacant office space without investments.

Master Thesis January 2014

Architectural Engineering

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Abstract

A big amount of office space is structurally vacant in the Netherlands, these buildings (mostly offices, but also outdated schools for example) deteriorate and surrounding areas become desolated. Despite this surplus of office space, there is still a shortage of housing space. An obvious solution seems to be transforming these offices into housing. However, in practise many financial, technical and legal obstacles arise. A flexible transformation strategy that does not require investment, but still results in comfortable housing, is not yet available. Therefore, such a method is proposed in this paper by eliminating the need of permanent structural changes in the offices, and designing a leasable Living Unit, which are placed inside vacant buildings. This Unit is a small temporary house, and reusable in other buildings. This asks for a generic, transportable system. A way to realize this is using a prefab and modular structure. A space-in-space, plug-and-play apartment that instantly creates a comfortable house in any building.

This concept is similar to the already existing sanitary units for building transformation, or the demountable prefab wall systems by Faay Prefab. The innovation of the Living Units is in the combination of these two; instant leasable housing for building transformation.

The technical restrictions of these units are formed by the physical properties of the vacant offices and regulations on the areas of building conversion, building quality and safety.

There are three types of building conversions: permanent, temporary (maximum 5 years) and anti-squatting, and they have all different regulations. Temporary conversion has fewer regulations than permanent, and anti-squatting has the least of all. The stricter the chosen regulations, the more generic the Living Unit will be, but the higher quality it needs to have, and so the more expensive it will be. Therefore the Living Unit is most suitable for temporary conversion, because it requires a quality of ‘existing buildings’ in the Bouwbesluit, which is relatively low. This has some significant advantages; a floor height of only 2.4 meters is required, the ventilation air does not have to come directly from outside and outdoors space is not required. Also the Law of noise nuisance is not applicable for temporary housing.

When the Living Unit is maximum 4.7 meters wide and 2.8 meters high, it can fit in around 38% of the vacant offices in Amsterdam. After removing ceilings this percentage will be much higher. To create a comfortable home in such a small space a transformable interior can be used. This creates multifunctional spaces, so that relatively more comfortably can be lived on the same amount of square meters. Vertical elements that move horizontally are the most suitable way to make this possible. This method is in practise often formed by sliding walls, but they are expensive, so for the Living Unit it would be better to only use transformable furniture, such as a Murphy Bed.

The Living Units can have their input of ventilation air via the vacant office space. The office space is then an in-between climate space that forms a buffer in temperature, wind and rain between the Units and outside. This solution is generic and requires no structural changes. This office space can be ventilated naturally, so it is

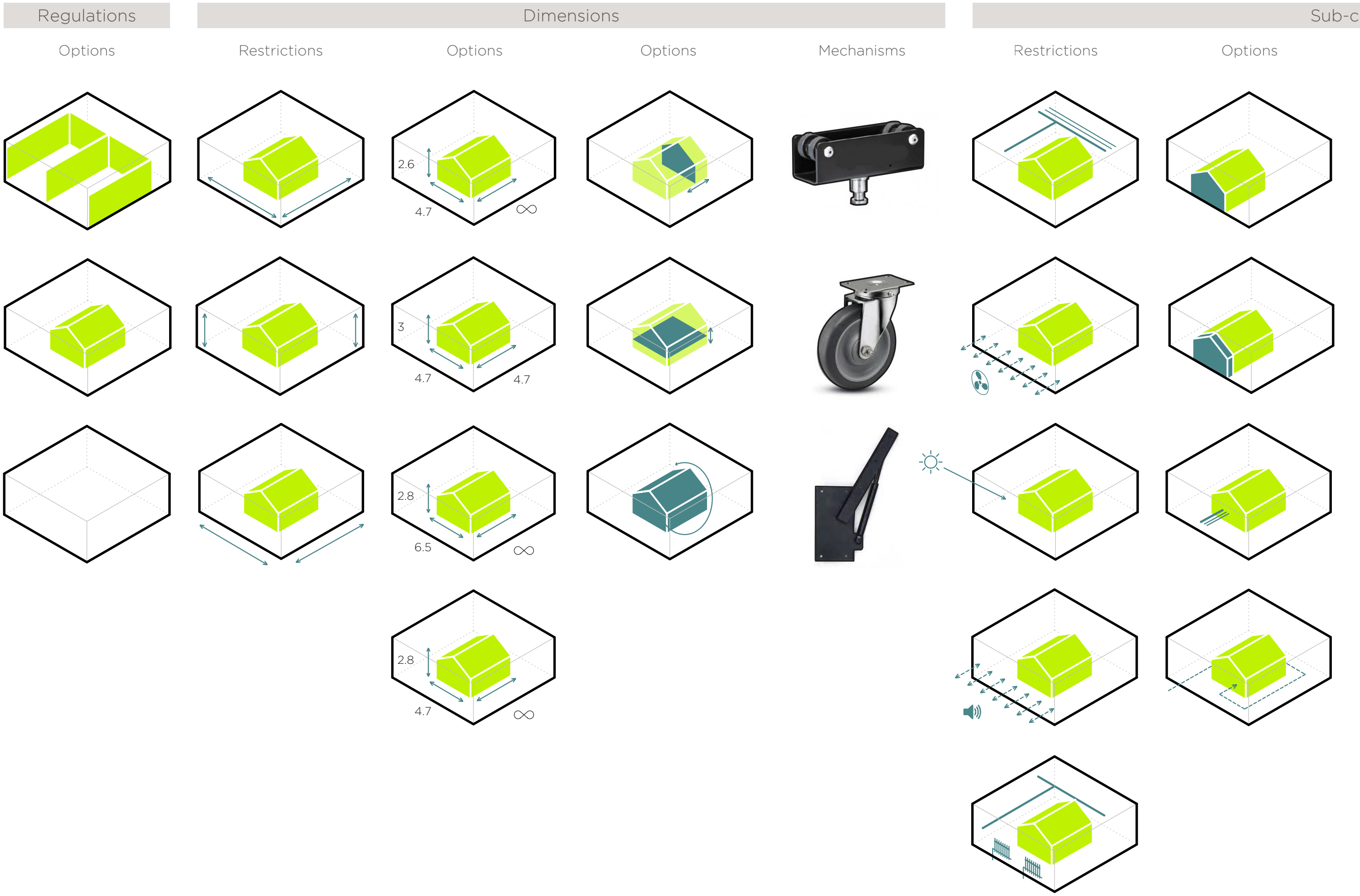
necessary that a window is open or removed. The air flow of this natural ventilation could be generated by the mechanical extraction of air in the individual Living Units, which will be emitted outside, via flexible air ducts. It can enter the Unit via sound absorbing ventilation boxes. To prevent polluted air going from one Unit to another by operable windows, the suction of the extraction needs to be strong. An alternative is an air filter at the input of ventilation. An air conditioning can provide heat, cooling, air purification and humidification, but if mechanical cooling is not necessary heating can also be done by electrical convectors.

The limited capacity of the water, sewer or electricity network in vacant offices can generally be solved by additional installations which connect the new utilities to the existing networks. The Units need to be able to work individually, so a local electric boiler can be used for heating water. The cold water can be brough to the Units by a new temporary network of pipes hanging on the ceiling. Measures has to be taken to prevent heating of these pipes, to prevent legionella. When the new taps of the Units lower the water pressure of the overall network too much, a pump can solve this. When the maximum allowable pressure is reached but the volume flow is not sufficient, possibilities for a buffer system with water tanks should be researched. The connection with the sewer system always have to be sloped, which is probably many times not possible. Therefore a disposer with a lifting station (in Dutch an opvoerinstallatie) is necessary. This installation has to be below the sanitary appliances, generally under a raised floor in the bathroom. It collects the waste water, grinds it, and when full it pumps the waste through a relatively thin pipe, towards the main sewer network. These solutions for utilities are relatively expensive and they can´t expand the capacity of the existing networks infinitely. Therefore the properties of the specific location (and the budget) can limit the possible amount of sanitary units. It won’t always be possible that every living unit has its own sanitary facilities.

Many kinds of construction methods, systems and mechanisms are possible to use in the Living Unit; monolithic structures of cardboard or polystyrene, sandwich panels, wood panels systems or frame structures of steel, wood or aluminium. All of them have their pro’s and con’s and there is not a method that already can be chosen as the most suitable for the Units. A technique that definitely creates big opportunities for the Units is CNC milling, which allows large design flexibility and a cheap and quick production process. This can be used in a wood frame or panel construction, possibly in combination with sandwich panels.

Floors and roofs have different requirements than walls, and therefore might require another structural system. For the floors it is important to find a solution which doesn’t need a load bearing frame. The roof should be made out of single spanning elements, as long as it is possible to transport such long elements.

A general conclusion is that the technical and legal restrictions are limiting, but certainly don’t make realisation of Living Units unfeasible or unprofitable. A more detailed design of the Living Units is necessary to specify the limits and possibilities. Help of experts or advisers will be needed on the areas of micro-climate, utilities and fire safety. With a location, developers and sponsors the Living Units can become reality, starting with a first prototype.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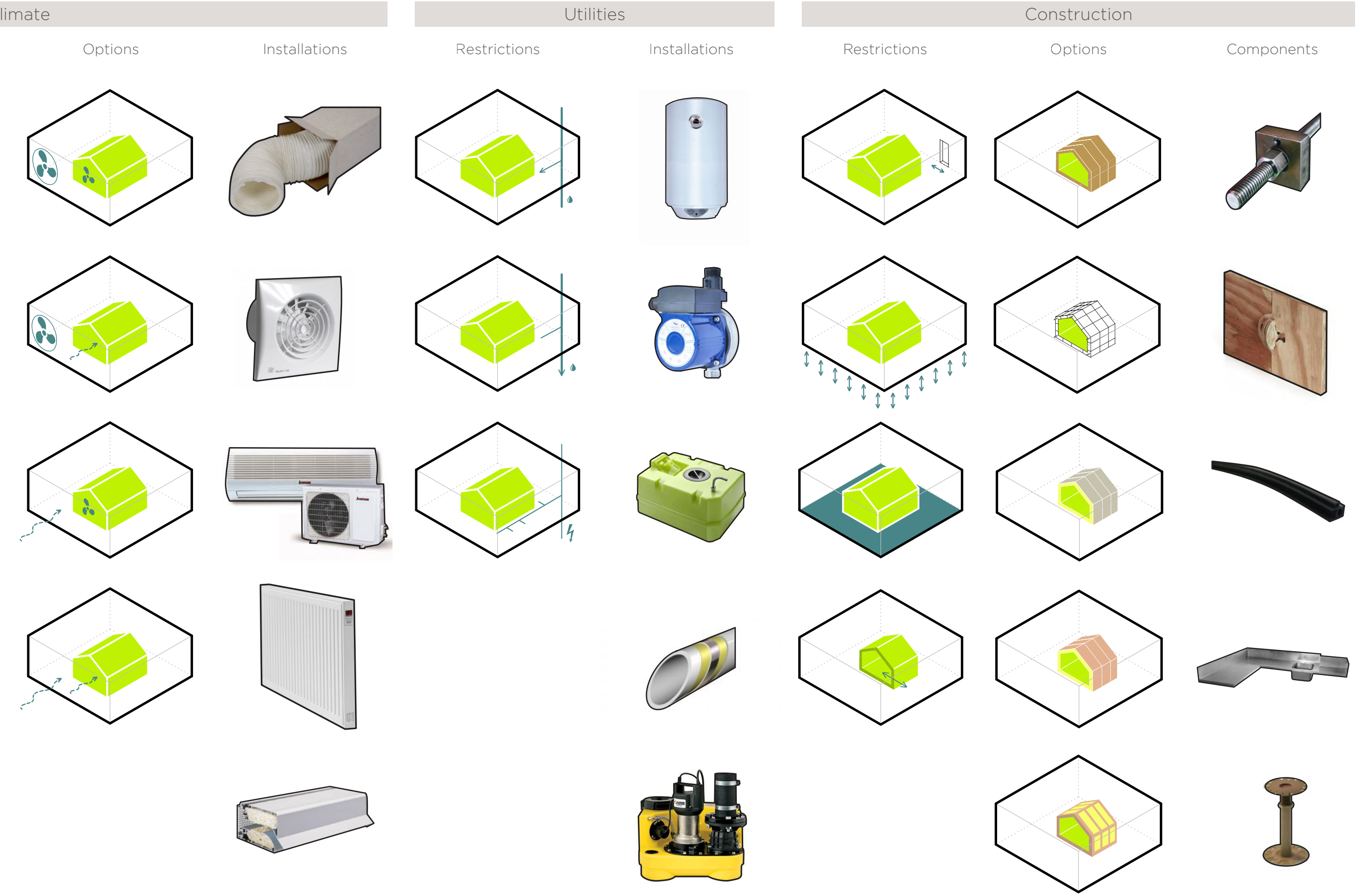
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Components

Background

Problem statement

A big amount of office space is structurally vacant in the Netherlands, these buildings (mostly offices, but also outdated schools for example) deteriorate and surrounding areas become desolated. Despite this surplus of office space, there is still a shortage of housing space. An obvious solution seems to be transforming these offices into housing. However, in practise many financial, technical and legal obstacles arise. Therefore owners like investment funds and housing associations have to overcome great financial and psychological barriers. Also, developers and investors are since the financial crisis more reluctant to start such expensive building project. Finally also many municipalities lack the commitment, means and experience to start such projects (Benraad, 2011, p. 5).
Even though anti-squatting and temporary housing have relatively easy regulations and therefore are sometimes more accessible, the anti-squatting mostly does not result in comfortable housing, and the business plans for temporary transformation is in many times not able to be conclusive in the maximum term of five years (H-team, 2013).
A non-commital flexible transformation strategy that does not require investment but still results in comfortable housing is lacking.

Objective

Facilitate more spacious, luxurious and comfortable living space for a wide public, without the current high costs, by making building transformation easier and eliminate the need for investment, using a smart architectural (product)design.
The solution has to be implementable in a short term, which has to be illustrated by a tested and working prototype, providing a possible product for a venture.

Overall design question

How can flexible and transformable architecture increase the flexibility of a building transformation to provide relatively cheap but comfortable housing in vacant offices?

Technical Fascination

My technical fascination is transformable architecture. This is a non-static form of architecture, which is intended to respond to a changing environment, for example to a desired change of function of a space.
This is a very broad subject, and therefore the subject itself had to be analysed and categorized first, so that a selection could be made of a specific form of

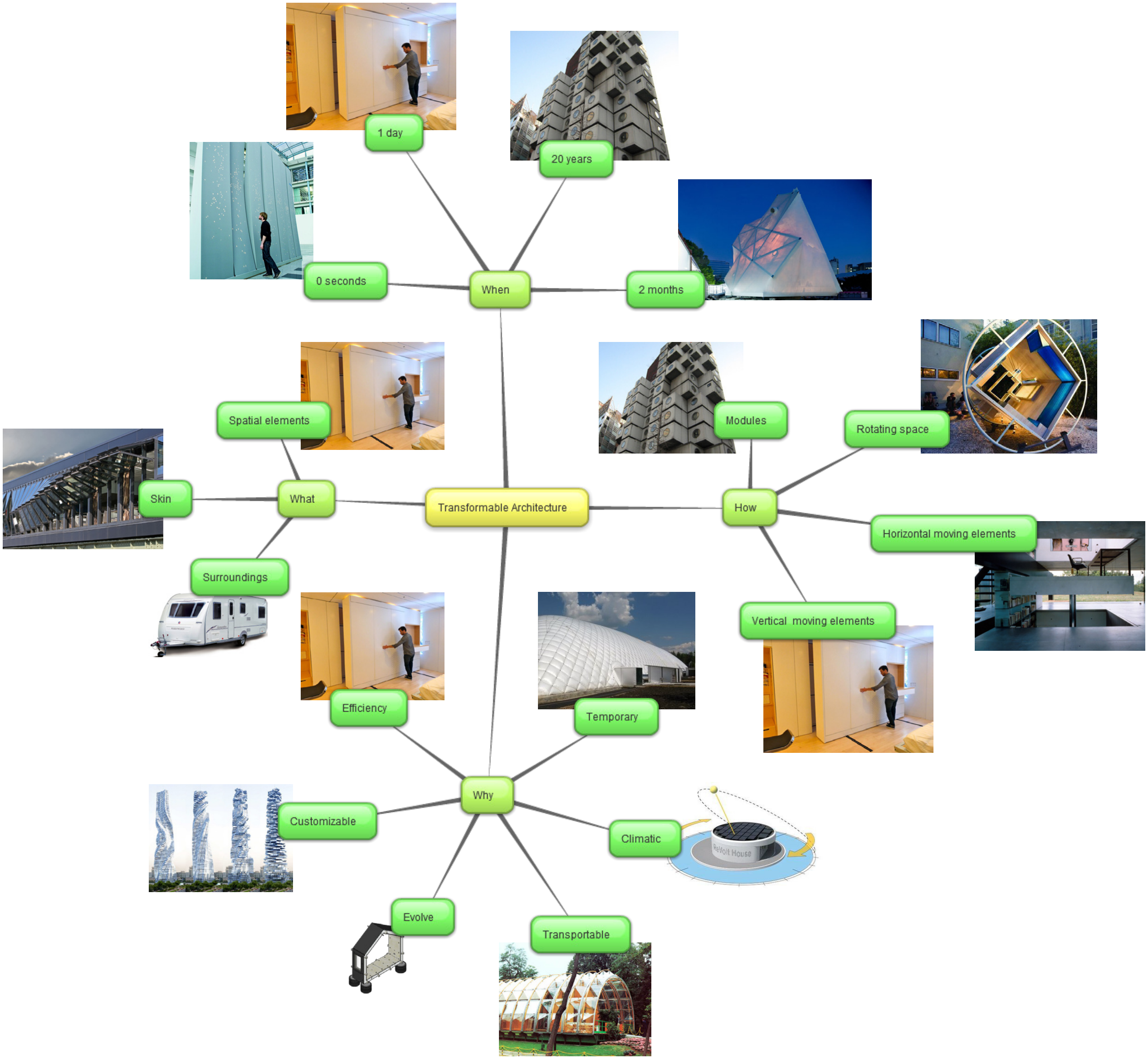


Fig. 1. Categories of transformation (own illustration)

transformation which is most suitable for the technical research, in context of the design question. In the literature many overlapping definition of forms of transformable architecture are discussed. Such as transportable, flexible, adaptive, dynamic, metamorphic, adaptable, deployable, temporary, modular, movable, convertible, kinetic, robotic and interactive. Since this categorization didn't help focusing, I analysed around 50 examples of transformable architecture and categorized them myself by the 'when', 'what', 'how' and 'why' of transformation. A short summary of the results is given here.

The reason for transformation turned out to be the most useful categorization, because it determines the what and when, and ultimately how. The question that it raised was 'Why does the design has to be transformable'? The answer, which is specified by the concept is: It has to be temporary or transportable, since it is for a flexible, temporary change of a building. And to make this more easy it has to be as small as possible so space has to be used efficient. The conclusion: a living unit with transformable configuration of space to facilitate transportability and space efficiency, to allow an easy reuse of an office.

Concept

To prevent the need for investment and make the transformation more accessible two requirements are set. First of all, no permanent structural change in the offices is allowed, since this normally requires investment. Second, the new structure inside the vacant buildings has to be able to be temporary, and reusable in other buildings. This asks for a generic, transportable system. A way to do this is by a prefab, transportable, modular Living Unit. A space-in-space plug-and-play apartment that can be placed inside the vacant building, creating a comfortable house. If these Units are generic and fit in many locations, they can be leased, eliminating the need for big investments.

Technical Research Question

What are the technical and legal restrictions, opportunities and solutions for the design of a cheap, generic, portable living unit that facilitates a comfortable micro-climate and -environment in vacant buildings that are in poor condition?

Relevance

With the current urge for (temporary) transformation of vacant buildings, more and more products are especially developed for this, such as plug-and-play sanitairy facilities (Place2Live) and prefab wall systems (e.g. Vaay Prefab). The concept what this research paper focuses on could shape the next innovative product in this sector.

Fig. 2. Impression Living Unit (own illustration)

Method

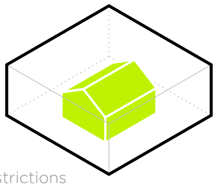
Way of working

The technical research is divided by the topics size, climate, utilities and construction. Every topic contains two main parts: first the restrictions, and finally the solutions.

Restrictions: Requirements from concept

First of all the requirements that are given by the concept of the Living Unit are defined, such as generic, cheap and comfortable.

Restrictions: Existing offices



Restrictions
offices

Living Units are placed in existing building (mainly offices) and therefore the properties of these buildings must be defined, since they form a restriction for the possible technical solutions. Always first is tried to find general data about buildings, for example the average floor height. Then the minimum is searched, for example the minimum floor height. Mostly two sources are used for this:

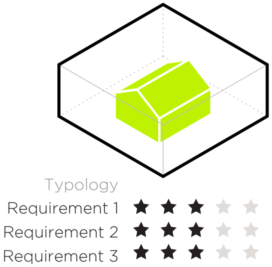
- Doctoral thesis: Remøy, H. (2010). Out of Office; a Study on the Cause of Office Vacancy and Transformation as a Means to Cope and Prevent. Delft: IOS Press.
- Master thesis: Koornneef, F. (2012). TU Delft Msc Thesis: Converting office space: Using modular prefab architecture to convert vacant office building.

These sources use a TU Delft database of 200 vacant offices in Amsterdam. These offices are used as a representative.
However, for many properties of buildings there is no data available. In these cases the regulations are used as representative, for example Bouwbesluit 1992.

Restrictions: Regulations

The regulations for housing and building transformation set requirements for the Living Unit, for example the minimum allowed floor height. Most regulations are from Bouwbesluit 2012.
There are different regulations for temporary transformation, permanent transformation and anti-squad housing. In the first chapter all these different regulations are researched and one type of transformation is chosen, so that the regulation that apply for this specific form of transformation is used in the restrictions of the following chapters.

Requirements	Requirements Concept & Design	Restriction Context: existing offices	Restriction Use: housing regulation	Research question?
Dimensions	Fit in most offices Small but comfortable	Floor height Grid size Floor size	Regulation minimal living space Regulation transformable interior	Maximum size? How to make the interior transformable? What is the floor plan?
Sub-climate	Ventilation Heat Acoustics Light Insulation	Existing climate systems Open-able windows disturbance from surroundings (Sound, airpolution) Light entry	Regulation for ventilation, heat, acoustics and light	How does a sub-climate work? How to climate the sub-climate (which interventions)? What climate is the office (semi-outside)? Can we use the existing systems? How to get contact with outside?
Utilities	Electricity Water Sewer	Existing networks Maximum capacity	Regulation for extending piping Regulation for unplugged facilities	What can we make unplugged? How to connect to existing utilities and piping? Can we make it self-sufficient?
Construction	Transportable: Modular Lightweight	Door size Elevator size Construction strength Floor	Fireproof Insulation	How to make a modular constructions? How to make a lightweight constructions?



System or installation

Solutions: Typologies or general options

In context of the requirements and restrictions, solutions are discussed. This research paper is intended to work like a catalogue for the following design process and therefore many possible solutions are discussed and evaluated. In general first parameters are defined, which generate different solutions in the form of typologies (for example climatization concepts), which are illustrated as much as possible by case studies. They are ranked using the earlier defined requirements.

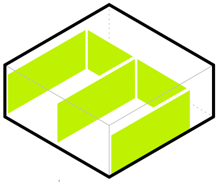
Systems & Installations

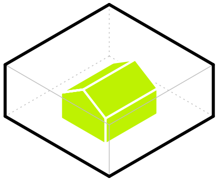
The most suitable one is then researched further, and the Jellema series, Handboek Installatietechniek and Handbook Constructing Architecture are used to define systems. These systems are usually build up out of different materials or installations, to get an idea of the capacity and price of these products online retailers are consulted. These prices are only a very rough indication.
When possible a best final options is chosen, but sometimes more research is needed, or the best option depends on the chosen construction method in the design phase.

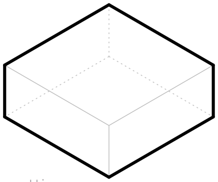
Circumstances & Limits

In general this research paper is supposed to work as an exploratory catalogue for prefab space-in-space plug-and-play constructions. The regulations that are researched and discussed in this paper are indicational, experts or advisors should be consulted in case Living Units are going to be built in reality.
Regulations for fire safety are not elaborately discussed in this paper, because these are very comprehensive and specific for the location, for example the locations of fire compartments. In general the Living Units have to be fireproof in a certain extent. If they are and how to test and certificate this, should be researched when Living Units become reality.
The properties of offices are used as parameters for the design, in a way that a generic Living Unit can fit in as many as possible locations. However, there will be locations where the units simply won't be able to function, for example the floor height will be too low or the sewer system too small.
Finally, what exactly the market is for the concept of the Living Unit is not researched in this paper, only the technical restrictions and solutions.

Regulations







There are three types of building conversions: permanent, temporary (maximum 5 years) and anti-squatting, and they have all different regulations. In the following chapters restrictions formed by regulations for the Living Unit are going to be set out, therefore one conversion type has to be chosen which represents the regulations. An elaborately research on these regulations can be found in appendix 1.

Temporary conversion has less regulations than permanent, and anti-squatting has the least of all. The stricter the chosen regulations, the more generic the Living Unit will be. When the regulation of permanent conversion are chosen, the Living Unit will also be suitable for temporary conversion and anti-squatting. However, the regulations will be very strict, and in many cases of temporary conversion not necessary. Another disadvantage of the regulations for permanent conversion is the level of quality it needs: the 'rechtens verkregen niveau'. This is different for every building, and sometimes even for every floor in a building. This makes it difficult to set a general set of rules that the Living Unit has to meet. Also it is important to note that the concept of the Living Unit is flexibility and low budget, which suits best for temporary conversion and anti-kraak. That is why the regulation for temporary conversion will be used as starting point in the next chapters, which means the Bouwbesluit 2012 will be assessed by the level of 'temporary building', and when this is not specified, by the level of 'existing building'. Some advantages of this relatively low level compared to the higher level of 'new buildings' are:

- A minimum floor height of 2.1 or 2.4 meters (2.6 for new buildings) (Bouwbesluit 2012, article 4.7)
- Input ventilation air does not have to come directly from outside (for new buildings all the ventilation air has to come from outside, which would complicate the climate concept of Space-in-space) (Overveld, 2011, p. 136)
- Outdoor space is not required (it is required for new buildings) (Bouwbesluit 2012, article 4.34)

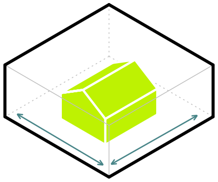
Besides this, a big advantage is that the law of noise nuisance is not applicable for temporary building (it is for permanent buildings).

Dimensions

REQUIREMENTS

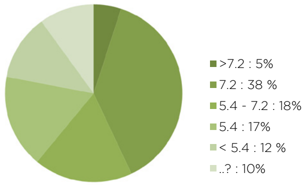
Fit in the existing structure: Since the Living Unit is a secondary structure standing in existing (office) spaces, it simply needs to be made to fit. The size of the existing load bearing structure and possibly installations will determine the allowable maximum size of the unit.
No structural changes: To minimize or eliminate the need of investment, structural and constructional changes in the building should be prevented as much as possible. This means that for example the removal of obstructing lowered ceilings or piping is not always an option .
Generic: The Living Unit has to be generic. This means its size and weight has to be suitable for as many buildings as possible.
Comfortable: The Living Unit has to comfortable, more comfortable than the average student house. Therefore it can not be too small or have a very low ceiling.

RESTRICTIONS

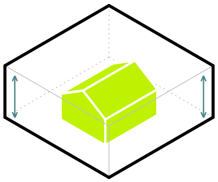


Grid size

The position of the columns determine how wide and deep the living unit can be, so that it can fit in between the columns.
There is not a known average grid size for all the offices in the Netherlands. However, there has been research by the TU Delft using a database of 200 vacant offices in Amsterdam, which can be used as a representative. A study on this database by Koornneef shows (graph on the right) in which amount the different grid sizes occur (Koornneef, 2012 p. 70). The grid sizes are mostly rectangular, and the most common one is 7.2 meters.



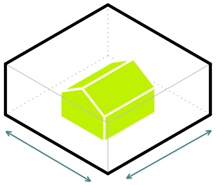
Grid size vacant offices (Koornneef, 2012 p. 70)



Floor height

To determine the average or most common floor height, the same research and methods are used as in the previous paragraph.
For the buildings in the database, the free floor height is mostly between 2.6 and 2.8 meters, which is the total floor height minus the construction height, minus the height needed for installations (Remøy, 2010, p. 67).

When lowered ceilings and (computer)floors are removed with the conversion, there will be more height available. The lowered ceilings are the most significant one, they can have heights more than 0.5 meters. For exactly how much buildings this is possible is not known.
Another influence on the floor height is the type of construction. When concrete flab slabs are used, normally load bearing beams define the maximum floor height. Around 34% of the vacant offices are built with this method (Koornneef, 2012, p. 70)
Bouwbesluit 2012 article 4.7 prescribes a minimum usable floor height for 'existing buildings' of 2.4 meters, and in some situations 2.1 (for new buildings this is 2.6 meters).



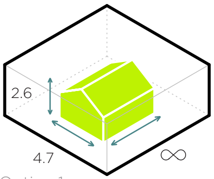
Floor size

The floor size of offices limits the maximum allowable size of the living unit. The layout of office buildings is very diverse, and in contrary to the grid size and floor height there is no statistically data for this property. The minimum size of a single office space is generally around 8-13 m^2, bases on the ARBO rules (Koornneef, 2012, p. 48), but this doesn't determine the size of the whole office floor since many offices have open office plans.
Sketches of the offices layout of the database discussed in 'grid size' and 'floor height' by Koornneef show a large variety of layouts, but it can be concluded that in many buildings there are at least two modules in the grids. This makes spaces around 10.8 (grid size of 5.4) or 14.4 (grid size of 7.2) meters deep.
Spaces that are made for residence, like the living room, dining room, kitchen or bedroom have a minimum floor surface of $7.5m^2$ and a width of 2.4 meters (Bouwbesluit 2012, article 4.7). In total a living space should be at least $10m^2$ (Bouwbesluit 2012, article 4.6).

OPTIONS & SOLUTIONS

Maximum size

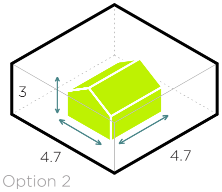
The size of the Living Unit will determine on how many locations it would fit. The smaller it is, the more locations it will be suitable for, which means its more generic but probably less comfortable. Therefore a balance should be sought between size and comfort.
There are three parameters that generate options for the maximum size of the Living Units: the height of the Living Unit, the grid size of the office and the position of the Units relative to the load bearing structure. When the units are smaller than a single grid size, it can fit in between the load-bearing beams where there is a higher floor height. This will not work for every building since many construction types have no load bearing beams (only 34%), and only when the lowered ceilings and possibly installations are removed this is possible.



Option 1
No structural changes ★ ★ ★ ★ ★
Generic ★ ★ ★ ★ ★
Comfortable ☆ ☆ ☆ ☆ ☆

Option 1

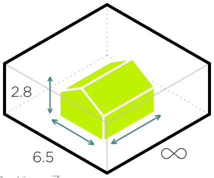
Floor height: 2.6
Grid size: 5.2
Position: Under beams
When a height of 2.6 meters is chosen , it will fit in 100% of the buildings regarding floor height. But then only 0.2 meters is available for the construction height, and the free floor height in the unit will be just 2.4 meters, which can be uncomfortable. Removing old lowered ceilings won't be necessary.
With a width of maximum 4.7 meters it will fit in a grid size of 5.2 meters or more, which is 78% of the buildings. The units will be under the load bearing beams and therefore it can have a length longer than 4.7 meters.
This option will fit in around 78% (78% * 100%) of the vacant offices.



Option 2
No structural changes ☆ ☆ ☆ ☆ ☆
Generic ★ ★ ☆ ☆ ☆
Comfortable ★ ★ ★ ★ ☆

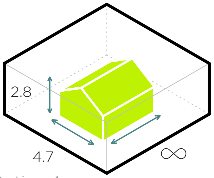
Option 2

Floor height: 2.6
Grid size: 5.2
Position: In between beams
When again a floor height of 2.6 meters is chosen, but now the lowered ceilings and installations are removed and the unit is placed in between the load bearing beams, the height of Units can be bigger, maybe 2.9 or 3 meters. Only around 34% of the buildings have these load bearing beams, so this option will fit in around 26% (34% * 78%) of the vacant offices.



Option 3

No structural changes ★★★☆☆
Generic ★☆☆☆☆
Comfortable ★★★★☆



Option 4

No structural changes ★★★☆☆
Generic ★★★☆☆
Comfortable ★★★☆☆

Option 3

Floor height: 2.8

Grid size: 7.2

Position: Under beams

It is not known how much buildings have a free floor height of 2.8 meters, but since 2.6-.28 is the general size, for now it will be assumed that around 50% of the buildings have a free height of 2.8 meters. When a grid size of 7.2 meters is chosen, the Units can be wider, which could increase comfort. Only 43% of the buildings have this or a bigger grid size. So this options will fit in around 21% (50% * 43%) of the vacant offices. This percentage could be bigger when the lower ceilings are removed in case the free floor height is lower than 2.8.

Option 4

Floor height: 2.8

Grid size: 5.2

Position: Under beams

Again a free floor height of 2.8 meters is chosen as restriction, now with a grid size of minimum 5.2 meters. This option will fit in around 38% (50% * 78%) of the vacant offices. Like option 3, this percentage can be increased when lower ceilings are removed.

Evaluation

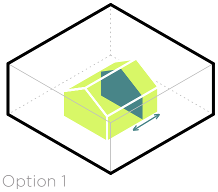
Option 1 is suitable for 78% of the vacant offices, and therefore the most generic option. The size is very limited though, which can have negative consequences for the living comfort of the unit. Therefore option 4 is better, even though it only fits in 38% of the buildings. After removing ceilings the percentage will be much higher. However, if the Unit is still a relatively small space with maximum width of just 4.7 meters and a free floor height of 2.6 (if the construction height is just 0.2 meters). To facilitate a comfortable house in such a small space, transformable interior could be used, which is discussed in the next chapter.

Transformable interior

To ensure comfort in the small Living Unit, a transformable interior can be used to allow multiple use of space. As concluded in the paragraph ‘Technical fascination’, there are many types of transformable architecture. In this chapter the reason for transfomability is spatial efficiency.

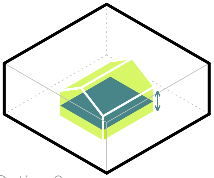
Many rooms in a house are used only a part of the day, after that they are just empty. This is because most rooms only have one function, for example bedroom, kitchen or living room. It is more space efficient and therefore cheaper when rooms have more functions. For example, many students live like this, they have a single room with a bed, a desk, a couch and sometimes even a kitchen. In these

cases the multifunctional room is used because of lack of money and space, however, a multifunctional room can also be created to facilitate comfort and luxury. Research by MIT for a project 'MIT Cityhome' researched what people really want from their homes. They documented wishes and dreams like 'I wish my home was a theatre' or 'I wish my home made exercise trilling'. The conclusion of the researchers was that a transformable interior could offer this kind of living, in a small space, without compromise (Rose, 2012).
Analysing many examples of transformable interior have led to three very distinctive but general typologies. These options differ from each other by how elements move relative to the space. This is taken as parameter, illustrated by short case studies. These options are evaluated by how space efficient, compact and cheap/easy they are.



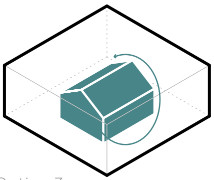
Option 1

Space efficiency	★★☆☆☆
Compact	★★★★☆
Cheap and simple	★★★★★



Option 2

Space efficiency	★★★★☆
Compact	★★☆☆☆
Cheap and simple	★★☆☆☆



Option 3

Space efficiency	★★★★★
Compact	☆☆☆☆☆
Cheap and simple	☆☆☆☆☆

Option 1
Transforming elements: vertical

Vertical element that can move and consist furniture which creates functions. Often these element can also function as room divider or inner wall.
This elements can slide vertically, rotate or fold out.

Option 2
Transforming elements: horizontal

Horizontal element of furniture coming down from the ceiling or from below the floor. In this way more floors can be created, without the height needed for conventional floors.

Option 3
Transforming elements: the whole house

The space itself moves, often rotates, so that the walls and ceiling can offer furniture.

Evaluation

Option 1 with its vertical elements that move horizontally is the most simple solution, and therefore probably the cheapest. This is supported by the fact this technique is the most used one in the case studies. Option 2 and 3 might even lead to a higher efficiency than options one, but the system needed for this is not compact, and regarding the limited floor height of the offices it is not possible.

The examples of option 1 consist mostly two important elements, sliding walls and retractable furniture, which is partly in the sliding walls. The walls are able to create temporary rooms.

Vertical elements


Fig. 3. Life Edited 1 apartment, slidable wall (Dirksen, 2012)


Fig. 4. Rotor House by Luigi Colani (Designboom, 2010)


Fig. 5. Drawer house by Nendo (Nacasa, 2003)

Horizontal elements


Fig. 6. Didomestic by Elii architects (Guzman, 2013)


Fig. 7. Suitcase House by Gary Chang (Edge-design-Institute, 2013)

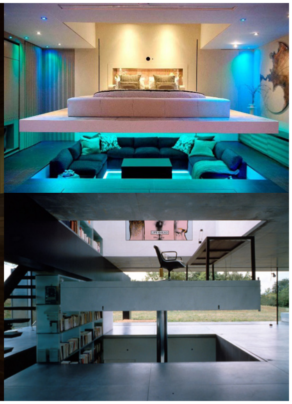


Fig. 8. YO! Home by Simon Woodroffe (Harry, 2012)

Whole house transforms


Fig. 9. Rotating house by Bureau Spectacular (Hipstomp, 2008)


Fig. 10. Roll it by University of Karlsruhe (Omkar, 2011)

Fig. 11. Rail carriage (fotostudiopro)

Sliding walls on rails

Innovative examples of micro-apartments that contains sliding walls are the Domestic Transformer by Gary Chang and the Life Edited 1 apartment for Graham Hill. In the first example, the sliding walls have a ceiling track system as well as rollers along the base (Chang, 2008, p. 102), which is necessary since the wall is quite heavy, carrying furniture and media installations. The second one only has a floor track and it doesn't have heavy furniture folding out of it (Alter, 2013).
These walls are not designed to be sound-proof, and therefore have a relatively simple detailing. The railing system have to prevent the walls from tilting and should make them easy movable. It is not (yet) possible to find off-the-shelf products. In the Life Edited 1 apartment the rails were custom made by Modern Office System, which is a company specialized in making large file storage systems for places like libraries and law offices. They supplied two steel tracks and a welded-steel carriage. Additional reinforcements were added to support the concentrated weight of the moving wall. The track and carriage cost around $4800. The cabinet (wall unit itself) was $18000, which the designer say is due to the complexity of its design and levelling and reinforcing the floor. They explain: 'There are definitely ways making the design less expensive. For example, both using casters instead of the tracks, and making a less complex cabinet would make the wall simpler and cheaper. Expenses you probably shouldn't avoid are making the floor level and having tight tolerances since both of these things make the wall seem like an integral part of the space. Nevertheless, spending $23K for a feature that adds a ton of storage, a desk, a projection screen and an additional bedroom–in a city where a 100 sq ft space can easily fetch $100K–might make a lot of sense for many (Friedlander, 2013).' Their last remark might be true in cities like New York, in the context of the Living Unit for the vacant offices this is definitely not the case.

Fig. 12. Caster (Accesscasters)

Sliding walls on casters

In the Barcode Room by Studio 1 sliding walls are built up using the cheaper technique that is proposed by Friedlander; the walls are placed on casters (Knezo, 2012). A video on their blog shows the movement of the walls, which is strikingly less smooth than the walls on rails in the Domestic Transformer and Life Edited 1.

Robotic sliding walls

The Changing Places Lab of MIT reseraches the technical solutions for robotic sliding walls in their project 'City Home'. Kent Larson states that their prototype, an automatically movable frame with sensors could become a standardized system to build robotic slidable walls and be used on a large scale (Larson, 2012). It has slot connections which automatically are made when the wall is in the desired position.

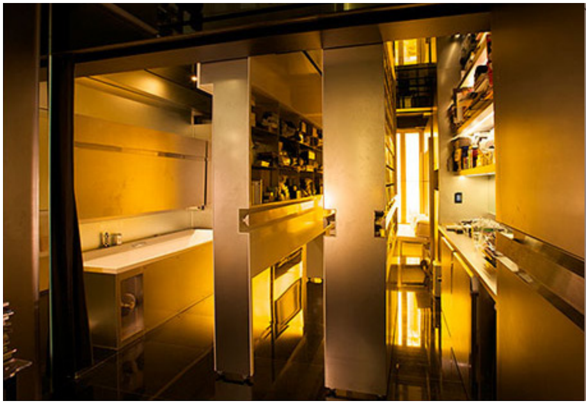


Fig. 13. Domestic transformer by Gary Chang (Dowd, 2010)

Fig. 14. Life Edited 1 apartment, slidable wall (Williams, 2013)


Fig. 15. Barcode Room by Studio_01 (Alter, 2012)


Fig. 16. Barcode Room by Studio_01 (Alter, 2012)


Fig. 17. Robotic sliding wall by MIT, frame on wheels (Larson, 2012)


Fig. 18. Robotic sliding wall by MIT, temporary connection to ceiling (Larson, 2012)

Fig. 19. Murphy Bed mechanism (Rockler)

Foldable furniture

Contrary to the sliding walls, there are many product available in the range of foldable furniture. Just a few popular examples will be discussed to explore its potential for the Living Unit and get an idea of the type of mechanisms used.

A classic example is the Murphy bed, which is a bed hinged at one side so it can be stored vertically in a wall or a cabinet. This bed was invented already around 1900 by W. L. Murphy, but is still often used in contemporary micro apartments (Murphy, 1911). Nowadays there are many variants on this model, complete cabinets are available but it also possible to buy just a frame. Prices start around 500 or 1000 euros for a simple double bed, to over 2000 for ones where a dining table or couch appears when the bed is folded in (Haags Beddenbedrijf). The core mechanism is a rotating system including a pressuring mechanism making lifting up the bed easier, which can be a gas piston or high tension balancing strings. These mechanism are separately available for around 200 euros, making it possible to build your own Murphy Bed relatively easily (Rockler). A heavy duty bed frame is needed to make it strong enough to lift, which sets high requirements for the frame.

Another solution for the bed is a sleeping couch. Many types are sold by Ikea from around 300 euros to 1000 euros. Transforming this bed to a couch and visa versa is in general quite a time consuming job compared to the folding up of Murphy bed.

Besides the example of the Murphy bed consisting a table, many options are possible for transformable tables. They often have legs that can be folded in, after which the table is just a flat surface and can be stored easily. This is a physically intensive operation though, which is a disadvantage of this system. Besides the folding in, also the placing of the chairs has to be done by hand. Except for the foldable pick-nick table, which has a very limited comfort since the chairs can't move.

Evaluation

There is not much documented about the technical solutions for sliding walls and its financial consequences. However, for now it seems making a smooth sliding wall unit is quite expensive since it requires a high quality rail system. These difficulties will even increase when a wall like this has to move in a temporary, deployable modular construction.

Transformable furniture is much easier since there are many products available. The bed transforming into a table or a couch seems the most simple and effective option, since its transforming process doesn't require a lot of strength or time. Besides this it saves relatively a lot of space .

CONCLUSION

When the Living Unit is maximum 4.7 meters wide and 2.8 meters high, it can fit in around 38% of the vacant offices in Amsterdam. After removing ceilings this percentage will be much higher. To create a comfortable home in such a small space a transformable interior can be used. This creates multifunctional spaces, so that relatively more comfortably can be lived on the same amount of square meters. Vertical elements that move horizontally are the most suitable way to make this possible. This method is in practise often formed by sliding walls, but they are expensive and complicated so for the Living Unit it would be better to only use transformable furniture, such as a Murphy Bed.

Fig. 20. Folded in bed with table (Haags Beddenbedrijf)

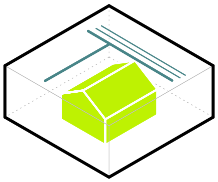
Fig. 20. Bed folded out over table (Haags Beddenbedrijf)

Micro-climate

REQUIREMENTS

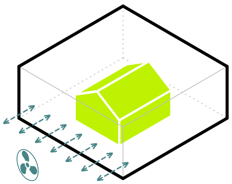
No structural changes: To minimize or eliminate the need of investment, structural and constructional changes in the building should be prevented as much as possible. This means that for example that big improvements of the facade are not possible.
Generic: The Living Unit has to be generic and needs to be able to work in a group, but also individually.
Complete sub-climate: The Living Unit needs to have a complete and fully controllable comfortable sub-climate. It needs air treatment (ventilation, purification, humidification), heating, cooling, good acoustics and lighting.

RESTRICTIONS



Installations

Offices usually have a complete installation for ventilation and heating (HVAC), while dwellings have individual installations (Zeiler, 2007, p. 258).



Cooling and ventilation

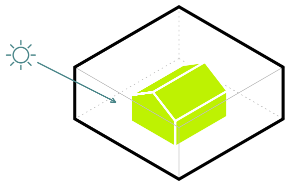
Cooling is sometimes done mechanically by a HVAC system with/or operable windows. However, the windows in offices developed in the end of the 1970's and beginning of the 80's often cannot be opened, which caused a rise of the 'Sick Building Syndrome' halfway the 80's. The operable windows where then reintroduced, in combination with individually adjustable heating, ventilation and sunscreens (Remøy, 2010, p. 96).
In Bouwbesluit 2012 there are no regulations stating that it is obligatory to have operable windows for office or housing.
The minimum ventilation capacity for existing buildings are (Bouwbesluit 2012, article 3.38 and specified by NEN8087):

- User area: at least 0.7 $dm^3/s/m^2$ of floor area, with a minimum of 7 dm^3
- User area with a cooker (nominal heat input more than 15 kW) or an open combustion unit: 21 dm^3/s
- Toilet: 7 dm^3/s
- Bathroom: 14 dm^3/s

In contrary with the regulations for new buildings, the input of the ventilation air does not have to come directly from outside (Overveld, 2011, p. 136)

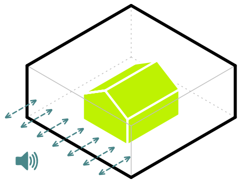
Regulations for output of ventilation air are: (Bouwbesluit 2012, article 3.40):

- At least of 21 dm^3/s of the output of ventilation air from a user space with a cooker has to be disposed directly to the outside.
- The output of ventilation air of a toilet and bathroom is disposed directly to the outside.



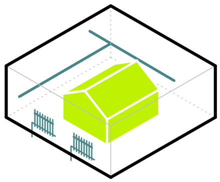
Daylight

The amount of day light entering the office is dependent on the size and the type of glass. Sometimes a reflective glass is used, limiting the light entrance. Offices have at least 5% of the floor space as daylight surface (windows), since this has been prescribed by regulation (Remøy, 2010, p. 96).
A user space of housing for existing building has a minimal daylight surface of 0.5 m^2. This is much easier than the regulations for new buildings which require 10% of the floor surface for housing, and 5% for offices (Bouwbesluit 2012, article 3.78, specified by NEN2057).



Acoustics

A lot of offices are positioned near roads, which causes sound nuisance. Sound proofing regulations for offices are easier than for housing, which means that many offices have more sound nuisance then a general house (Kennisbank-Herbestemming, 2012).
The minimal characteristic soundproofing is 20 dB for new buildings, and 10 dB less for existing buildings (Bouwbesluit 2012, article 3.2 en 3.6).
Bouwbesluit has more regulations about sound nuisance for areas around industries and roads, but these are based on the law of noise nuisance which does not apply to temporary surroundings permits, which means they don't apply for temporary buildings (IenM, 2012).



Heating

As explained in the paragraph 'Installations', heating is mostly done by a HVAC system, which is not always individually controllable.

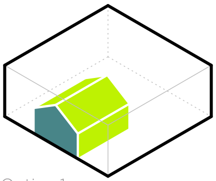
OPTIONS & SOLUTIONS

Climatization concept

The main typology of the Units in the office is a space-in-space. To further specify this typology, the connection between the living Unit, the office space and outside is researched. The living Unit is a space that is inside another space, but it can have a connection with the outside though. This connection can have different reasons and different routes. For example, outside is the source of fresh air needed to ventilate the Living Units. This fresh air can be brought directly into the Units, or via the office space. Another example is the output of ventilation space, regulations require that a part of the air is brought directly outside.
The type of connection between the living Unit, the office space and outside is a parameter which can generate different climatization typologies. These will be discussed and evaluated using the requirements for the living Unit.

1. Direct physical connection between Unit and outside

The Living Units will be positioned against the existing facade, connected directly to it.
+ Comfortable: The physical connection has the advantage that you can experience the connection with outside, which is normal in the current Dutch architecture and is comfortable for many, and perhaps even a prerequisite. It will therefore greatly enhance the quality of space in the Unit.
- Specific: each facade is different, and the connection between the wall and the Unit will either have to be specific, or there must be a generic solution found that can make the connection despite the constructional differences between the buildings.
- Operable windows: the windows needs to be operable on the place the Living Unit is connected.
This typology is in practise a conventional single facade, like used in the Bunny Lane house by Adam Kalkin (Herbers, 2006, p 50).

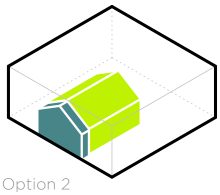


Option 1

No structural changes	☆☆☆☆☆
Generic	☆☆☆☆☆
Comfortable	★★★★★
Energy efficient	☆☆☆☆☆

2. Physical connection between Unit and outside via double facade

The Living Units will be positioned near the existing facade, and connected via an in-between climate space.
+ Energy efficient: Greenhouse effect can be used to heat up the Units
+ Comfortable: There is close connection to the outside for the users
- Specific: every building needs a different connection with the facade.
- Operable windows: the windows needs to be operable where the Living Unit is.
This typology is used in the conversion of the van Nelle fabriek. The original facades have single glass and due to this historical importance this could not be changed. A second facade with double glazing is therefore placed 1 meter or 2.5



Option 2

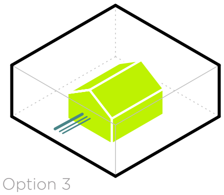
No structural changes	☆☆☆☆☆
Generic	☆☆☆☆☆
Comfortable	★★★★☆
Energy efficient	★★★★★


Fig. 21. Bunny Lane house by Adam Kalkin (Herbers, 2006, p 50)


Fig. 22. Bunny Lane house by Adam Kalkin, interior (Herbers, 2006, p 50)


Fig. 23. Van Nelle fabriek, climate facade with ducts under floor (Wilschut, 2001, p. 43).

meters behind the original facade, creating a climate space in between. Air is heated up by the green house effect, and mechanically sucked into the offices. To prevent overheating or rain entering the climate space, the windows of the outside facade can mechanically open and close, controlled by rain and temperature sensors (Wilschut, 2001, p. 43).



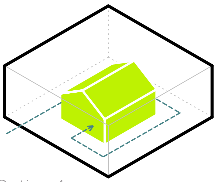
Option 3

No structural changes	★★☆☆☆
Generic	☆☆☆☆☆
Comfortable	★★★☆☆
Energy efficient	★★★☆☆

3. Connection between Unit and outside via ventilation pipes

The Units can stand individually in the office space, but are connected to the outside by pipes, for input and output of ventilation air.
+ Easy natural ventilation: less greenhouse effect, always enough oxygen
- Specific and needs investment: Holes in the facade for piping are necessary

This method is used in the administration offices of the RDM Campus (Crone, 2010, p. 47).



Option 4

No structural changes	★★★★★
Generic	★★★★★
Comfortable	★★★☆☆
Energy efficient	★★☆☆☆

4. Connection between Unit and outside via vacant office space:

The office space is an in-between space between the outside and the Unit. The Unit is completely separate from the facade. The office will be a climate space, used to heat and ventilate the Units.
+ No structural change in the office: The facade does not need to be adjusted.
+ With minimal resources (e.g. door and one window out) a ventilated opening can be created.
+ A climate space (similar to a double skin facade) is created: which is semi-outdoor. No rain, but with ventilation.
- Outside climate in office: The offices space needs to be ventilated a lot, because the air from the office will ventilate all the Units. This means that this office space will be cold in the winter (unless a heat recovery system is used, which is quite expensive). Also noise nuisance can be a problem due to the openings needed for the ventilation.

This typology is used in cases where the big space (where units are placed in) is in such a bad shape or so big that it functions as an outside space, like the NDSM Kunststad Amsterdam (Damme, 2008). Or in situations where the primary space is functioning as a greenhouse like in the Mont-Cenis Akademie (Pasquay, 2000, p.1). In both examples the house-in-house spaces are mechanically ventilated.

Evaluation

Option 4 has the best overall ranking, since it is very generic and there are no structural changes necessary in the facade. Besides this, there is no piping necessary (expect for some ventilation output, due to regulation). The office space will be an in-between climate space, creating a buffer for heating and cooling. This typology could be specifically suitable for offices where the windows are not possible to open. With some minor structural changes the openings for the ventilation could be created, for example by removing some windows. This has

Fig. 24. RDM Campus, greenhouses inside a large climatized space (Crone, 2010, p. 47).

Fig 25. NDSM Kunststad Amsterdam (Damme, 2008)

Fig 26. NDSM Kunststad Amsterdam, exterior (Theurbangeographer, 2013)

Fig 27. Mont-Cenis Akademie, interior (Eurofotograf)

Fig 28. Mont-Cenis Akademie (Pasquay, 2000, p.1

some risks though: rain could enter, and in the winter the office space could get very cold. Despite these risk, this typology will be researched further in the next paragraphs, and possible solutions will be discussed.

Ventilation concept

Minimal amount

The minimum ventilation for the individual Units is prescribed by regulations. Taking the concept design of the Living Unit as principle and assuming it has two rooms, the minimum is 14 dm^3/s for a bathroom, and 11.2 $dm^3/s/m^2$ ($16m^2$ X 0,7 dm3/s/m^2) for a multifunctional living room. During complete utilization of all functions, these ventilation needs can be added up to a total of 25.2 dm^3/s (25 l/s, or 90 m^3/h). If there are hypothetically speaking five Living Units in a vacant office space, 450 m^3/h (5 x 90m^3/h) is needed.
The relationship between this total ventilation need for the Living Units and the ventilation need for the offices depend on the airflow and the possible pollution of this air inside the office, which both are dependent on the type of output of the ventilation air of the Units:

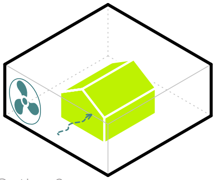
- Destination output: If the output is sent outside (so not in the office space) internal air pollution is prevented, and the 450 m^3/h in the office space should be enough for the 450 m^3/h of the Units.
- Airflow: If the office space has 450 m^3/h ventilation air, can all this air reach the Units? If the airflow from office into Unit is strong enough, theoretically this should be possible.

Concluding, the relationship between the amount of ventilation needed in the office relatively to the Units is dependent on the type of ventilation system of the individual Units and the office space.

Using the type of ventilation (natural or mechanical) as parameters, different solutions can be generated, which are evaluated on the effectiveness of airflow and energy.

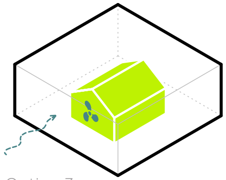
1. Office mechanical – Units mechanical

When both office and Units are ventilated mechanical, a sufficient airflow is ensured. The advantage is that the climate in the office can be regulated, and only the necessary air will enter, preventing heat loss by an excess of ventilation in the winter. In the summer ventilation can be higher, so that a greenhouse effect in the office is prevented. However, fans, sensors and a regulation system is necessary, which requires specific solutions and investment.



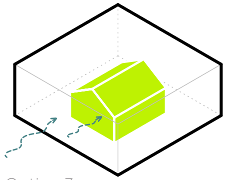
Option 2

Cheap	★★☆☆☆
Generic	☆☆☆☆☆
Effective airflow	★★★★★
Energy efficient	★★★★★



Option 3

Cheap	★★★☆☆
Generic	★★★★★
Effective airflow	★★★★★
Energy efficient	★★★☆☆



Option 3

Cheap	★★★★★
Generic	☆☆☆☆☆
Effective airflow	☆☆☆☆☆
Energy efficient	☆☆☆☆☆

2. Office mechanical – Units natural

When the office is mechanically ventilated, a sufficient airflow in the office is ensured, which then could naturally flow into the Units. However, the natural ventilation of the Units will then be completely dependent on the amount of airflow in the office, which has to be regulated so that its ventilation can be adjusted to the current ventilation needs of the Units. Like option 1, fans, sensors and a regulation system are necessary. Unless the ventilation flow of the office is not regulated, but in this case a lot of heat will be lost by the excess of ventilation.

3. Office natural – Units mechanical

When the Units are mechanically ventilated using fans for extraction, an airflow will be generated that sucks air from the office into the Units. This results in a low pressure in the office space, ensuring a natural ventilation from outside. The big advantage is that the Units are individually controllable, and the natural ventilation in the offices will be naturally adjusted to its airflow. However, if the natural ventilation in the office is not controlled, there can be an excess of ventilation caused by already existing pressure differences and heat will be lost.

4. Office natural – Units natural

With offices and Units both naturally ventilated, the airflow can not be enforced, having the risk that sometimes the airflow is not strong enough, resulting in insufficient ventilation. This could be minimized be by optimizing the location providing cross ventilation, however, these possibilities are completely dependent on the location and therefore very specific.

Evaluation

Option 3 with natural ventilation of the office and mechanical ventilation in the Living Units has the highest ranking. The energy efficiency is not optimal, unless controlled ventilation is used in the offices, preventing heat loss by an excess of ventilation. This would require investment and makes it less generic though. Technical solutions and products for this ventilation principle will be discussed in the next chapters. Wether all the natural ventilation air from the offices can be mechanically brought into the units, has to be researched more detailed when the design is in a further stage.

Ventilation Installations

In the previous chapter the generation of airflow was discussed, now the installations that can generate this will air flow will be explained. Beside airflow, air purification, cooling and control will be discussed.

Airflow generator

The mechanical ventilation of a Unit can be created using fans extracting air from the Unit, or suppling air to it. Either way, regulations state that the ventilation air from the bathroom and toilet has to be brought outside, which means piping is necessary to bring it outside, with fans for the airflow. So a fan extracting air will be there anyway if the Living Units contain a bathroom or toilet. To prevent output air from one living Unit being used again by another living Unit, it would be best to have all output air directly brought outside. So for now it will be assumed that all ventilation output is brought outside. This means that there is no need to have another installations that sucks in the air into the Unit, since this is already done by the fans for the output.

Fig. 28. Flexible PVC duct (Ventilatieshop 1)

Output duct

The duct for the output of a single Unit, if round, need to have a diameter of around 125 mm, with a ventilation rate of 90 m^3/h and a airspeed of 0.2 m/s (which is the maximum airspeed in a room for new buildings prescribed by bouwbesluit 2012, article 3.30) (calculated with digitale luchtschijf 2013). A flexible PVC duct could be used, which are available for around 2 euros a meter (Ventilatieshop 1). A conventional bathroom fan can be used, for around 70 euros (Ventilatieshop 2). However, to be more energy efficient a regulation system is desirable.

Fig. 29. Ventilation fan (Ventilatieshop 2)

Prevent air pollution in office

Even though the basic principle is mechanical ventilation of the Living Units, if for comfort the windows are operable (and of course the door), polluted (smelly) air could still go from one Unit, into the office space, and then into another Unit.
A way to prevent this it to make sure the fan for ventilation output is working (maximum), so that the pressure in the Unit is lower than in the office, creating an airflow from office to Unit. If this really works is dependent on the pressure in the office, and so very dependent on the location, such as the position of the building, the natural air flow and the temperature.
Another way to eliminate this problem is to purify the air before it enters the Units. This could be done by a specialized air purifier or as a part of a more integrated system; the air conditioning. When a split Unit airco would be used, the air will be sucked in, cleaned, dehumidified, heated and cooled. For a space of 20m^2 these are available for around 700 euros (Aircokopenonline). This would

eliminate the need for other heating systems. A disadvantage of the airco is that the airflow will be generated by two points, by the airco and by the output fan. These should be balanced, and therefore maybe communicate with each other, which requires more expensive control systems.

Fig. 30. Split unit airco (Aircokopenonline)

Evaluation

The most important choice is to use an airco or not. The advantages is that it purifies the air which could be good in areas near highways, and also heats, cools and humidifies it. The disadvantage is that this is an extra energy using machine that generates airflow and it is relatively expensive.

A more detailed research is necessary to determine if without airco and only output fans enough pressure difference can be created so that air won't go from the Unit into the offices. If it does, this is the cheapest and most simple options.

Heating

Heat demand

Various online heat demand caclulators (Mercatron and Laurens Radiatoren) show that a room as in the Living Unit (more or less 4*4*2.6 meters) has a heat demand of around 2500-3000 watt. When the design of the Unit is in a further state this can be calculated more exact. Also the effect of the office space as greenhouse should be researched then, since this possibly lowers the heat demand.

The heating of the Unit can be done by an airco or heating elements such as radiators, floor heating and heated furniture. Since completely only conventional systems can be used, the discussion on this topic is kept short. Some interesting examples of heating systems will be discussed, all electrical since the need of gas in the living Unit should be prevented.

Fig. 31. Electrical radiator (Vasco & Radson)

Airco

An airco of around 600 euros can have a heat demand of around 2800 watt (aircoshop).

Electrical radiator

Electrical radiators are on the market on many sizes, prices and heating capacities. For around 500 euros it is possible to get one that heats up around 1500 watt (Vasco & Radson).

Fig. 32. Convector (Megapool)

Electrical stove with oil (convector)

Electrical stoves (kachels) are much cheaper than radiators. For around 60 euros it is possible to have a capacity 2000 watt (Megapool).

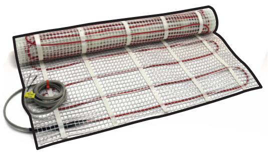


Fig. 33. Electrical heating mat (Quickheat)

Electrical heating mat

To have floor heating in the Unit is difficult since the floor has to be demountable. A solution are electrical heating mats (Quickheat). For around 500 euros a mat of 2 by 2.85 meters is available, providing 750 watt heating, which is relatively more expensive than the electrical heaters.

Evaluation

It is difficult to evaluate the options on comfort, but it is clear that the electrical convectors are by far the cheapest options. Therefore this is probably the best heating system for the living Unit.

Cooling

Cooling can be done by an airco or a air cooler. The need for an active cooling system is different for every location, since it is dependent on the temperature of the office space, which is dependent on the amount of airflow caused by natural ventilation and the entering heat by sun radiation. One option is to implement an airco, to be sure that in every location there is no overheating. Another options is to make sure the office does not get too hot, using sun shading and making sure the amount of ventilation can be high enough, using cross ventilation and large openings. This last solution is not generic since it is different for every location, but adding sun reflecting curtains or panels inside could already be enough. These could be used at every location so they are quite generic. Generally curtains and panels can be expensive, so a cheap solution has to be sought, which could be second hand curtains, or using cheap materials as cardboard.

Acoustics

Except for a regulation for minimum sound proof of the walls there are no other regulations. However, since many offices are near big roads reduction of sounds nuisance should be considered.

The openings that are necessary to allow air for ventilation coming in the Units could transport sound and cause nuisance. Therefore a sound-absorbing ventilation box (suskast) is necessary. The principle of this boxes is very simple, it is an opening with sound insulating material. Since there is no rain in the office, the requirements regarding the construction of this product is not very high, and therefore it should be considered to design and build the box integrated in the construction, avoiding the need of buying an expensive off-the-shelve box.

Fig. 34. Suskast (NBD online)

Light

A half of square meters window is obligatory by Bouwbesluit 2012. However, the Unit is standing inside the office, and its window is not directly outside. Besides that some offices have reflective glass, so to make sure the Units have enough light more windows are necessary. The amount of daylight entering the Unit can also be controlled by placing the Unit closer or more far away from the window, but only once, when the Units are placed.

CONCLUSION

The Living Units can have their input of ventilation air via the vacant office space. The office space is then a in-between climate space that forms a buffer in temperature, wind and rain between the Units and outside. This solution is generic and require no structural changes. This office space can be ventilated naturally, so it is necessary that a window or door is open. This air flow of this natural ventilation is generated by the mechanical extraction of air in the individual Living Units, which will be emitted outside, via flexible air ducts. It can enter the Unit via sound absorbing ventilation boxes.

To prevent polluted air going from one Unit to another by operable windows the suction of the extraction needs to be strong. An alternative is an air filter at the input of ventilation can be used.

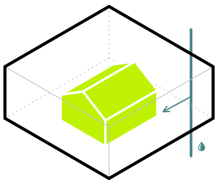
An air conditioning can provide heat, cooling, air purification and humidification, but if mechanical cooling is not necessary heating can also be done by electrical convectors.

Utilities

REQUIREMENTS

Complete house: The living units should be a complete house, with all utilities a normal house has: a kitchen, shower, toilet, washing machine. This means water, electricity and drain is necessary.
Generic: Connecting utilities can be expensive, which should be prevented.
Individual: One unit should be able to function completely, but also as a group.
Generic: The unit should fit almost everywhere, and so the utilities should be able to connect on any location.
Temporary: The connection of the utilities are temporary, which means they should be connected and later disconnected from the permanent water supply and sewage

RESTRICTIONS



Water supply

Water supply by external distribution net

The available volume of cold water coming in from the water company is unlimited. However, the pressure can be different at every location and determines the water flow (q_v in l/s). This pressure depends on many factors like height difference in the area, the place of the connection with the distribution system and the load on this system.
Water supply companies are required by law to offer water with an amount and pressure as is required in the interest of public health, there is no prescribed minimal though (Hofkes, 2004, p. 144).

Internal water distribution

The volume and pressure of water is dependent on the supply by the water company, but also on the types and amount of taps and connections for appliances and the length and direction of the piping.
In general offices have very little or no shower or bathing facilities, and much less sanitary facilities per person compared to dwelling. Therefor the capacity of the internal water supply is also relatively small and possibly not sufficient for the larger amount of waters supply (Zeiler, 2007, p. 258)
Nen 1006 require that a water system must be designed so that for the intended purpose planned volume flow and pressure for taps and connections for appliances are available. Again no specific minimal is required (Hofkes, 2004, p. 142).

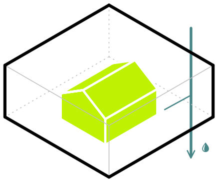
Warm water supply

Water can be locally heated by natural gas, electricity or additional sources as solar power, a heat pump, or district heating. Temperature of the warm water and the waiting time depends on the type and capacity of machine, the volume flow and the temperature of the cold water (Hofkes, 2004, p. 142). This is all very dependent on the specific location, and therefore it is not possible to say in general how much warm water is available for the new facilities. New installations might be required, especially since it can be difficult to transport the warm water from existing installations to the new Living units. In general the warm tap water installations has to be as close as possible to the taps to prevent energy loss and waiting times (Hofkes, 2004, p. 145).

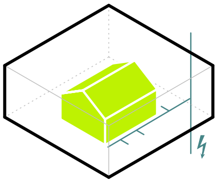
Regulations

To prevent Legionella bacteria NEN 1006 require that the temperature of the tap water in piping areas of cold water installations must not exceed 25 ° C and is not lower than 4 ° C to prevent freezing. Water supply companies are also not allowed to deliver water warmer dan 25 ° C, in practice it is between 5-20° C.
Warm tap water is at least 55 ° C when tapped (Hofkes, 2004, p. 143).
Overall, the new water network has to meet requirements set by NEN 1006 (Bouwbesluit 2013, article 6.12).

Sewer system



Because of the relatively small amount of sanitary facilities in an office, the capacity of the internal sewer system is also relatively small (Zeiler, 2007, p. 258). For example, in an office transformation to student housing in Middelburg by Woongood Middelburg, originally only 4 toilets per floor where present, which had to be increased to 30 to 40 toilets per floor. The already existing internal sewer system was not calculated on this amount (Benraad, 2011, p. 10). This means that the standpipe might be too small, which is the vertical connection bringing all waste to the house connection pipe.
An important regulation for when adding new facilities that needs a connection to the sewer system, is that the collector pipe (which is the horizontal connection between the appliance and the standpipe), always have to be sloped, 5 to 20 mm/m (1:200 tot 1:50) and is required to prevent congestion. Besides this there are many regulations in detail about the how to connect and make curves in piping (Hofkes, 2004, p. 241)
Finally, a new sewer system has to meet requirements set by NEN 3215 (Bouwbesluit 2013, article 6.16).



Electricity

The electrical power and the amount and distribution of electrical outlets is for housing completely different compared to offices. In general, with the conventional transformation of offices (making fixed inner walls) the complete electricity network connected to the central main distribution in technical space has to be remade. (Zeiler, 2007; p. 259).
Wether this is necessary when Living Units are used, depends on how many electricity one unit uses, how many units will be installed and the amount of available power where the units are placed in the office. If the units should be able to be connected using one electricity cable, a requirement is that the maximum used by this unit is not higher then what the end group that supplies this power can supply. Since the unit will not be connected to gas, it will use relatively a lot of electricity, especially with appliances like a boiler, microwave, washing machine and induction cooker (and maybe even an airco). In a conventional house some of these appliances get their own electricity end groups (Hofkes, 2004, p. 54). In an office this won't be always possible, simply because there won't be enough groups.
The electrical network has to meet the requirements set by v1041 (Bouwbesluit 2012, article 6.8)

OPTIONS & SOLUTIONS

For the connection to utilities discussed in the next chapters, the (green) alternatives like solar power and rain water collection will be left aside because first of all a generic, conventional decentralized installation has to be found.

Reference

With the transformation of not-housing buildings to housing, in general sanitary facilities needs to be added. Sanitary units are available as products, which are mostly used for temporary transformation, such as the Smartcube, Cubi, Woonmachine en Place2Live. These units have toilets and washing facilities, and optionally cooking, sleeping or storage space. They are made up out of elements which are demountable and transportable and cost around 5.000 to 10.000 euros, and are in general cheaper (producers claim 30%) than a conventional built in bathroom.
The concept of Place2Live is similar to that of the Living Unit; it consists of modules that are connected on location. The individual elements are able to be moved by a lift and fit through doors. It is intended that the Place2Live forms a turnkey solution for creating profitable rentable vacant offices and it will be offered as a lease, for 350 - 500 a month. Electricity, water and drainage are integrated

Fig. 35. Place2Live Sanitary unit (Worobiej, 2011, p. 21)

and linked per module. The sewer system has a disposer with a pumping station, which pumps the waste through a small pipe (diameter 32 or 40 mm.). Shower and toilet are connected to mechanical ventilation. Optional are biofermentation and rainwater toilet flushing (Worobiej, 2011, p. 21).

Warm water supply

Connecting to existing warm water supply

Connection to the already existing warm water supply in this office will in most cases not be possible, because of the limited power of the existing heating system. Besides that, the warm water will have to be transported from the central heater to the units which requires insulating (expensive) piping and heat loss will occur anyway.

Electrical boiler

Fig. 35. Electrical boiler (Elektrische Boiler Shop).

Since there is no gas connection the water heater has to be powered electrical: an electrical boiler. The power of an electric boiler is limited, because otherwise (expensive) facilities for three phase electricity (krachtstroom) is required. Stock units from 50 to 200 litre are suitable as the central water heater, the size of the device must be adjusted to the daily consumption (Hofkes, 2004, p. 147).
An individual boiler is probably most suitable for the units, since the units have to be able to function individually. Also, the conventional home boiler is made to heat up water for a single household, and there won't be need for an extensive insulated piping system. A stock unit of 50 litres will probably be big enough for the Living Unit (for 1 or 2 persons) and are available for around 200 euro (Elektrische Boiler Shop).

Cold water supply

The existing water supply of the office can be connected to the Living Units. But its supply will not always be sufficient for the larger demand of water, therefore some installations need to be added to increase pressure and water volume.

Pressure

Fig. 36. Water pump (Wildkamp)

When more taps like a sink, toilet or washing machine are added to the internal water distribution net, pressure decreases. To solve this a pressure boosting system can be connected (Hofkes, 2004, p. 186). This is a pump, which in most cases is only active when the water pressure is too low (for example when more showers are used at once). Sometimes an expansion tank is connected (this system is called a hydrofoor).
The already present water pressure in the office and the amount of Living Units connected to this network, determines how strong the pump has to be. Most

likely a single pump can be used for more (or many) living units. Pumps that increase the pressure with 1 bar are available for around 500 euros (Wildkamp).

Volume

The volume of water supplied by the water company is in theory endless, however, the water network inside the office has a certain size (diameter of piping), and since there is a maximum pressure stated by regulations, there is also a maximum volume flow in this network. In some situation this volume per second is not enough for the demands of the Living Units. This depends on the location (capacity of water network) and the amount of Living Units.

To solve this and make sure there is always enough water, a buffer tank could be implemented. A collective one, or individual ones like in a camper or a boat. However, there are no examples where this is done in a temporary building transformation, and might require a relatively big investment.

Fig. 37. Water tank for buffer (Rs-Jachttechniek)

Piping

Water pipes are preferably placed where there is no chance of freezing, excessive heating (maximal temperature water is 25 degrees Celsius) and mechanical or other type of damaging. In addition, water pipes should be accessible for the purpose of repairing leakages or adjusting the installation (Hofkes, 2004, p. 159). This piping, from the water supply to the Living Units, could be placed on the ground, but then should be protected since they will be in a collective user space. Otherwise they could hang under the ceiling.

The biggest challenge is probably preventing the water in the pipes from getting to warm. They can warm up because of solar radiation, seasonal influences, heat sources (e.g. light) or nearby hot piping. In practise the near presence of hot piping or appliances is a big problem, therefore many rules existing like the minimum distance between warm and cold water piping. The insolation of water pipes is in general only used for warm water piping to prevent heat loss. The temperature of the office depends on the location, which means that this should be researched when a Living Unit is placed, to find out if measures against heating up are necessary.

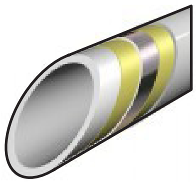


Fig. 38. PE-x piping for water (Pijp Universeel)

Many different materials are possible for the water pipes, but since the piping for the Living Units are temporary, flexible pipes are probably most suitable. Polythene (PE) or cross linked polythene (PE-x) is often used, and is available on big roles for around 80 cent per meter (Pijp Universeel).

Sewer system

After conversion, homes (or Units) normally need a new sewer network which connects this new facilities to the existing sewer system. Since this network always have to be sloped, special measures has to be taken for the horizontal net-

work. In general there are three options; pipes under the floor, through individual shafts or under raised floors. These options all require either a constructional change in the building (penetrating the floors) or need other expensive constructions, like a raised floor in the corridor. Besides that, the limited floor height of the offices can be a problem for a raised floor. Especially when the distance between the Living Units and the connection with the existing vertical sewer pipe is big, these solutions are difficult.
An alternative is a disposer with a lifting station (in Dutch an opvoerinstallatie). This installation has to be below the sanitary appliances, generally under a raised floor in the bathroom. It collects the waste water, grinds it, and when full it pumps the waste through a relatively thin pipe, towards the main sewer network. A disadvantage of this system is that is susceptible to malfunction and needs maintenance. Products that have the capacity for toilets and showers are available for around 500 euro's (Saniship). This systems get used on for example (house) boats.
A big advantage is that it grinds and buffers the waste before it goes to the existing sewer system of the office, therefore the risk on a too low capacity of this existing sewer system is minimized.

Fig. 39. Sewer disposer with lifting station (Saniship)

Electricity
The most easy solution would be if the Living Unit had only one plug, which would power the whole unit. If this is possible, depends on the amount of power available and the location of this connection in the office, relatively to the Living Unit. If there is not enough, a new network has to connect the unit to the central power network of the office, possibly all the way to the technical space.

CONCLUSION

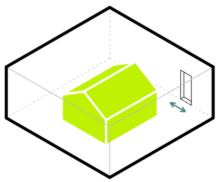
The modular unit concept for building transformation is getting explored in the sector of sanitary facilities by a variety of companies. Even though the prices for these units are lower than a conventional built-in bathroom, the price is still relatively high compared to the goal of the Living Unit.
The limited capacity of the water, sewer or electricity network can in general be solved by additional installations which connects the new utilities to the existing networks. However, these solutions are relatively expensive and they can´t expand the capacity of the existing networks infinitely. Therefore the properties of the specific location (and the budget) can limit the possible amount of sanitary units. It won't always be possible that every living unit has its own sanitary facilities.

Construction

REQUIREMENTS

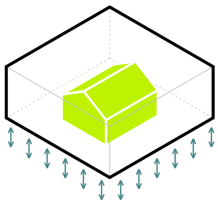
Transportable: The Living units has to be transportable through doors and elevators, so it needs to be modular, demountable and light weight.
Insulating: The Living Units facilitate a micro-climate, therefore the walls, floors and roof needs to be insulating.
Simple: When the construction is simple and doesn't require a lot of skills and time, it is more easy to build the Units in reality.
Cheap: The construction has to be as cheap as possible.
Comfortable: The Units needs to be as comfortable as a normal house. Therefore structures as tents or inflatables are not suitable.
Self buildable: When the designer can built the parts himself, at least for the prototype money can be saved. When a big number of Units should be produced, it is not a problem to use off-the-shelve construction systems.

RESTRICTIONS



Elevator and door size

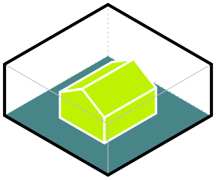
If the elements of the Living Unit should be transportable through doors and elevators, the maximum size must be determined. Since there is no data about the general door and elevator sizes in vacant offices, Bouwbesluit 1992 will be used as a representative. It states that doors are minimally 0.85 meters wide and 2.1 meters high (2.3 since bouwbesluit 2003 article 4.11). The size of elevators in bouwbesluit 1992 is only determined for housing, and are at least 1,05 by 1.35 m. (bouwbesluit 1992, article 42 and 43). Since bouwbesluit 2003 this minimum also counts for offices (bouwbesluit 2003, article 4.7).



Construction strength offices

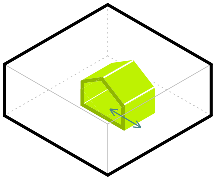
The strength of the construction is determined in the design process based on calculations using constructive loads. Permanent loads (weight of the buildings itself), variable loads (non-permant, e.g. persons, furniture) and special loads (external forces, e.g. rain, wind).
The Living Units will be a non-permanent object on the existing structure, and so it will be a variable load. Since 1972, NEN 3850 stated that the allowable variable loads in offices had to be minimally 2.0 kN/m^2. After 1990 this limit was increased to 2.5-3.5 kN/m^2 by NEN 6207. However, to allow flexible office or archives most offices are over-dimensioned, using loads of 5.0 or 10 kN/m2 as guideline (Koorn-

neef, 2012, p. 62).
Current regulations prescribe a minimal allowable variable load for housing of 1.75 kN/m^2 (Boveldt, 2004, p. 86). This means that if offices are converted to housing, a surplus of 0.75 kN/m^2 (for offices from 1990) or 0.25 kN/m2 (before 1990) is available for the semi-permanent weight of the Living Unit. In reality this is more due to the over-dimensioning.



Floor surface

Since the Living Units will be placed on the floor of the vacant offices, the condition of these floors are determining how this connection can be made.
Around 35% of the vacant office buildings (Database 200 vacant offices in Amsterdam) are constructed out of concrete flat slabs. Over time these are subject to deformation: the floor slabs will start 'hanging' between the columns (Koorneef, 2012, p. 62). Besides this, a floor can have an uneven surface because of the absence of a top floor (new buildings) or damages.



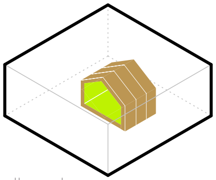
Insulation

The façade of a temporary building has a thermal resistance of at least 1,3 m2•K/W, and a maximum heat transfer coefficient of 4,2 W/m2•K (Bouwbesluit 2012, article 5.7). Doors and window(frames) have a maximum heat transfer coefficient of 2,2 W/m2•K. Two percent of the construction is not required to meet these standards. (Bouwbesluit 2012, article 5.3).

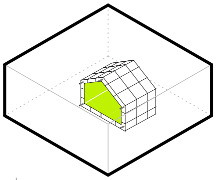
OPTIONS & SOLUTIONS

Construction system

There are countless methods, systems and materials for the construction. This chapter discusses a very limited selection of systems that could be suitable for the Living Unit. Since the goal of the Living Unit is to be a technically and financially feasible design and concept, construction methods and materials are required which are proven to work and used in reality. However, there are some innovative construction methods that are not used (much) yet but still could be suitable for the Living Unit, because of the fact that the construction will be inside another building, and therefore there won't be rain, snow, or much wind.
Portable structures like tents or inflatable structures will be left aside here, since only examples of structures that create a conventional house with rigid walls will be shown.



Monolith Cardboard	
Design freedom	☆☆☆☆☆
Self buildable	☆☆☆☆☆
Easy to montage	★★★★★
Generic	☆☆☆☆☆
Cheap	☆☆☆☆☆



Monolith Polystyrene	
Design freedom	★★★☆☆
Self buildable	★★★★☆
Easy to montage	★★★★★
Generic	★★★☆☆
Cheap	★★★★★

Monolith Cardboard

In monolith structures a single materials is both load bearing and insulating (Deplazes, 2008, p. 140)
Cardboard is getting more popular nowadays in architecture and design, because of its recyclability, light weight and insulating properties.
An example of a modular transportable cardboard structure is the W-House. Individual segments are connected with invisible links. The basis of the W-House is virgin fibre corrugated cardboard, with a patented method RS Developments, it is wrapped around a huge mold, while environmentally friendly glue is added. This creates a tough and insulating sandwich structure. By the winding process heat insulation and construction is integrated in a sustainable way. Then each segment sealed in a waterproof aluminum outer shell. The producers claim it is as much as three times more durable than traditional structures (FictionFactory, 2013).
Due to its production process with a mold, there is only one size possible. The height is around 3.3 meters, and therefore it will be too big for most offices.
Another problem is that the segments are too big to fit through doors and elevators. If the segments are made smaller, connecting it rigidly could become a problem. Therefore it is not a suitable option for most vacant offices, but it would be in specific cases where there is enough floor height and there is a possibility to move the modules inside.
More often used applications of cardboard in architecture are honeycomb panels, for example in doors and walls, columns (many buildings by Shigeru Ban) and cellulose insulation from recycled paper (Deplazes, 2008, p. 144)

Monolith Polystyrene

The polystyrene house (2003) by Ronan and Erwan Bouroullec is an interesting structure, because it is a relatively simple monolithic structure, made from cheap, light and very well insulating material; polystyrene. The precut blocks are slotted together, and connected by horizontal poles (Topham, 2004, p. 104). It is just a concept design though, and not build in reality. The biggest obstacle (rain) will not be a problem for the living units though.
An example of a real built polystyrene monolithic structure are prefab dome houses. House kits start at less than $30,000 (Frid, 2008).
An alternative for polystyrene is polyurethane, which can have a higher thermal resistance, but is more expensive (Deplazes, 2008, p. 144).

Sandwich panels

Sandwich panels consist a core of insulating material, covered on both sides by sheets, which work together to absorb loads (Hofkes, 2005, p. 87). There are many sizes, thicknesses, insulating materials (PIR, PUR, Rockwool) and sheet materials (steel, plastic, polymers, wood etc.) available. These are off-the-shelve

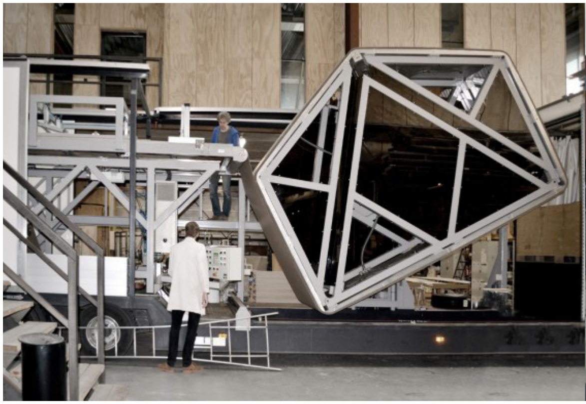


Fig 40. Production process of the W-house (FictionFactory, 2013)

Fig 41. Segments of the W-house (FictionFactory, 2013)

Fig 42. Polystyrene house by Bouroullec, segments (Topham, 2004, p. 104)

Fig 43. Polystyrene house by Bouroullec (Topham, 2004, p. 104)

Fig 44. Polystyrene prefab domes (Frid, 2008).

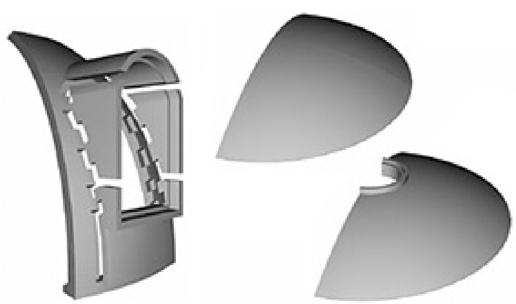
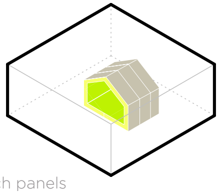


Fig 45. Segments of the polystyrene prefab domes (Frid, 2008).



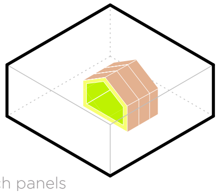
Sandwich panels

Design freedom	★☆☆☆☆
Self buildable	☆☆☆☆☆
Easy to montage	★★★★☆
Generic	★★★★★
Cheap	★★★★☆

panels, specially for walls or roofs.
In the flexible sanitary unit Place2Live PUR is used as a composite sandwich material with glass fibre polyester. It results in a durable, lightweight and very thin construction. The panels are specially made for this unit, and therefore only suitable for a relatively large production (Worobiej, 2011, p. 21)
Prices for off the shelve sandwich panels start around 15 euros per square meters, but can easily be 20 (Huisman Gemert).

Wood panels

A conventional way to make a relatively lightweight and insulating structure is by a timber panel construction, which is also possible to make prefab using sandwich panels. The Dutch company Faay is specialized in prefab insulated (inner) walls and ceilings, which can be ordered as customized package (Faay Isolatiewanden). The wall panels are standing on a wooden beam, and vertically connected to each other via a steel I-profile. Prices for the walls (calculated for the Living Unit, 5.5x7x2.6 meter) start around 2000 euros, which have a thermal insulation of 0.58 m^{2}K/W (appendix 2). The living unit probably requires a higher thermal insulation and therefore the price will be significantly higher. The maximum insulation they offer is 2.17 m^{2}K/W and a sound insulation of 50 dB. The system is demountable, as long as the walls are not glued together.
A method to make a timber panel (or a frame) more customized is using the digital production technique CNC-milling. This technique is used by Pieter Stoutjesdijk in houses for emergency areas, like Haiti. It allows a very fast production process and connection systems can be milled in the wood, which is applicable for temporary and modular structures like the Living Unit (DeArchitect.nl, 2013). Another advantage is that there is no need for secondary companies that produces the construction; the design can directly be milled in for example a Fab lab, which can reduces time and costs.



Sandwich panels

Design freedom	★★★★★
Self buildable	★★★★★
Easy to montage	★★★★★
Generic	★★★★★
Cheap	★★★★★

Frame construction

In frame constructions only the frame is load bearing. The dividing is made by sheets, which sometimes help to make the structure rigid (Hofkes, Jellema 3, 2004, p. 161)
A possibility which a timber frame gives is integration of furniture. In the Musashino Art University Library by Sou Fujimoto Architects shelving for books is integrated in a timber frame (in reality not all shelves are load bearing). (Frirson, 2013).
Besides the conventional wood and steel, aluminium could be used. For example, the Loftcube. It is a mobile house which can be transported in one piece by a helicopter, or it can be demounted. To make it light the whole load bearing frame is built from aluminium. It is covered by glass-fibre-reinforced plastic (GRP) panels,

Fig 46. Place2Live Sanitary unit (Worobiej, 2011, p. 21)

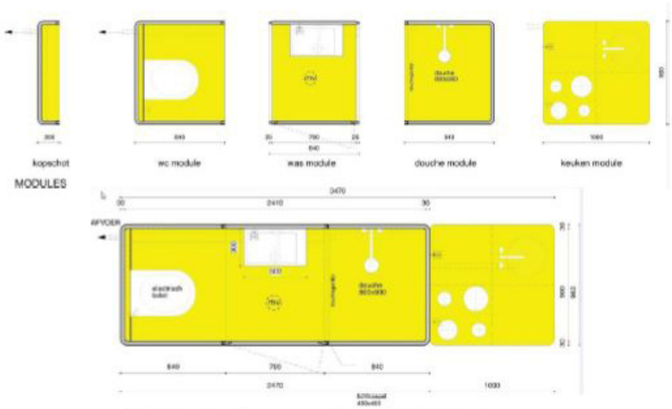


Fig 47. Segments of the Place2Live Sanitary unit (Worobiej, 2011, p. 21)

Fig 48. Sandwich panels as wall (Faay Isolatiewanden)

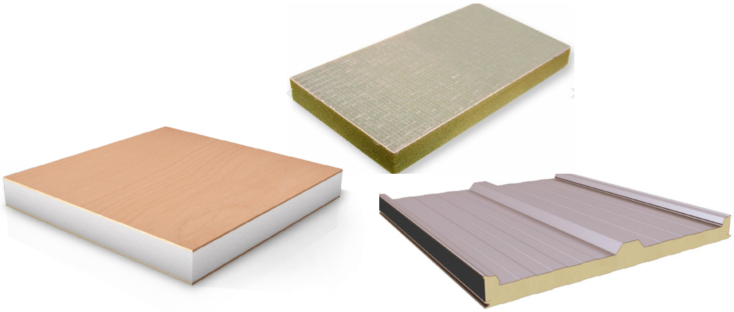


Fig 49. A variety of sandwich panels (own composition)

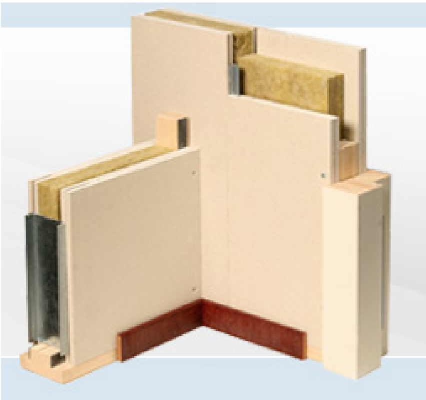
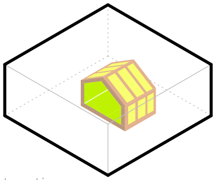


Fig 50. Insulating prefab wall (Faay Isolatiewanden)

Fig 51. CNC-milled house and segment connections by Soutjesdijk (DeArchitect.nl, 2013)



Frame construction

Design freedom	★ ★ ★ ★ ★
Self buildable	★ ★ ★ ★ ★
Easy to montage	★ ★ ★ ★ ★
Generic	★ ★ ★ ★ ★
Cheap	★ ★ ★ ★ ★

which are fixed to the structure by means of a quick-locking mechanism (Detail, 2004, p. 1443).

Roof

Ceilings systems of Faay (discussed in previous chapter) are build up by 10 cm high steel I-profile beams (maximum 4.2 meters span), resting on wood beams connected to the walls. The ceiling panels are double plasterboard, with a 2.5 mm thick chipboard in between. It has a thermal insulation of 1.98 m^2K/W and a sound insulation (Rw) of 55dB (Faay catalogue). Another options are the sandwich panels discussed earlier.

Evaluation

A disadvantage of a monolithic structures where one material is both load bearing and insulating, is that the property that makes it insulating (permeated with air-filled pores) make the structure less strong and brittle (Deplazes, 2008, p. 140). Therefore in general a monolithic structure needs to be thicker to have the same strength as a non-monolithic structure (very generally said). This is a big disadvantage regarding the limited floor size of the offices, it requires that the structure of the unit is as thin as possible. However, for the walls a monolithic structure could be suitable, even though the material probably has to be covered both in- and outside, for fire regulations, prevent damage, but also to create a more conventional wall, for example wood instead of cardboard or polystyrene.
Sandwich panels are in general more effective than the monolithic structures. A big advantage of off the shelve sandwich panels is that the products are fireproof (tested and certified) which makes it easier to get the Living Unit accepted as fireproof. Also they allow a quick montage of elements.
A frame construction gives more freedom in integrating for example furniture in the load bearing structure. By making shelves load bearing and insulating, material, weight and money could be saved. Like discussed in the chapter of sandwich panels, CNC milling makes it possible to built relatively cheap very specific timber frames with connections.
Alternatively aluminium could be used, but it is a relatively expensive material.
For roofs a simple frame of steel beams could be used. A disadvantage compared to the earlier discussed roof sandwich panel is that it is more difficult to make it modular.

Segments

Maximum size

The method to move the segments into the vacant building, determines the maximum size of the segments. It could be done by a temporary fork lift outside the

Fig 52. Musashino Art University Library by Sou Fujimoto Architects (Frirson, 2013).

Fig 53. Musashino Art University Library by Sou Fujimoto Architects, Interior (Frirson, 2013).

Fig 54. Loftcube (Detail, 2004, p. 1443).

Fig 55. Loftcube, interior (Detail, 2004, p. 1443).

Fig 56. Prefab ceiling system (Faay catalogue)

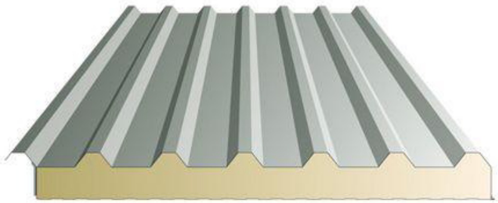


Fig 57. Sandwich panel for roof (Bouwproducten)

building, or simply using the existing elevators. When the segments of the Living Unit should be able to fit through every door and in every elevator possible, the minimum size of a door (0.85 x 2.1 m) and the minimum depth of an elevator (1.35m) is determining the maximum size of the module: 0.85 x 2.1 x 1.35 meters. But when the segments are supposed to be transported on a trolley or a pallet truck, the maximum height of the module is at least 0.1 meter lower.
For floor and wall modules this size is not a problem. However, for the roof a span needs to made of around 4.5 meters, which would be 3 modules. This requires a very strong connection between these segments. Therefore it is probably easier if single roof beams or panels (4.5 meters) are spanning the whole length, as long if these beams are transportable, for example via the stairs. If this is possible depends on the specific location.
The individual segments have to be connected to form one whole. This connection needs to fit exactly to prevent leaks that reduces insulation and moist problems.


Fig. 58. Pallet truck (Midlandpallettrucks)

Connection: Treaded tensioning cable or rod

The connection can be made pressurized, so that the segments are pushed against eachother by the connection system, minimizing the risk on leaks. However, too much pressure could deform the modules.
This pressure can be created by a treaded tensioning cable or bar. This bar could penetrate two or more modules. At the end are bolts, which move to eachother when rotated, pushing the segments against eachother other (Macalloy). Instead of bolts a cable tensioner can be used, which could be integrated in a segments.


Fig. 59. Treaded tensioning rod (Macalloy)

Connection: Slot connection

In a slot connection a protruding part of one segment slides in or over a notch in a adjacent segment. This is not a pressurizing connection, However, segments can be pushed against each other and then bolted together with a slot connection, which will maintain the pressure.
This type of connection is used in the wall systems of Faay (discussed in Sandwich Panels, Wood).


Fig. 60. Slot connection (DeArchitect.nl, 2013)

Even with a pressured connection between segments, the joints have to be made watertight in areas like the kitchen, toilet and bathroom. There are different options:

Joints: Sealants

The sanitary unit Smartcube consist out of six sandwich panels, which are connected on site, and the joints are made water tight with a sealant. This is a quick and simple method but with demounting the segments, this sealant has to be removed which is a time consuming task.

Fig. 61. Sealant (Binnenvaartwinkel)

Fig. 62. Rubber strip (Cncchinamq)

Fig. 63. Aluminum kitchen counter (Tevako)

Joints: Rubber

When the segments are pushed against each other by a pressurizing connection, a rubber in between the segments could seal it. This would make disassembly easy, but some disadvantage could be that it is difficult to connect two meeting rubbers (in x and z direction) and there could accumulate dirt in these joints. There is probably more risk on leaks compared to sealants.

Joints: Single elements

On places like the kitchen counter or the bathroom floor, a single watertight (floor) element could be placed on the segments. This would make a safe option, but it is only possible if elements of the required size can enter the building.

Evaluation

The type of construction system determines how the segments have to be design ed and connected. In general a combination of slot connections and pressurized connection could be suitable for the Living Unit. The floor segments probably need a pressurized connection, especially to make sure the joints can be made watertight. The connection of the wall on the floor segments have the pressure of the weight of itself and the roof, and therefore a slot connections with bolts might be enough. In the design phase the water tightness of the joints have to be taken in account, to determine what kind of sealant could be used.

Floor system

The floor segments are placed on the floors of the vacant building. These original floors sometimes don’t have a completely levelled and even surface. Since the new floor needs to be completely levelled, these differences needs to be levelled out by an adjustable floor system.

Self carrying segments

The floor segments can be a structure which is strong and rigid enough to transfer the loads (of it self and loads on the floor surface) to the floor through specific points, for example the corner points. In this case these segments could have an integrated adjustable lifting system that could make it levelled despite an uneven office floor. This principle is used in computer floors, where the floors rest on screw jacks.
A disadvantage is that the floor segments needs to be strong, which wouldn’t be necessary if the floor could rest directly on the office floor. Besides this, a lot of jack are necessary, at least four per floor segment. Extra floor height is needed, since jacks are minimally around 70 mm high (Biz computervloeren). With computer floors these jacks are glued on the original floor, which is probably not a suitable temporary option for the Living Units.

Fig. 64. Screw jack (Biz computervloeren)

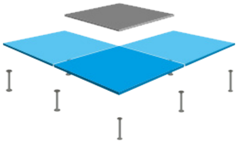


Fig. 65. Computer floor (Alteca)

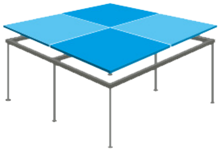


Fig. 66. Installation floor (Alteca)

Not-self carrying segments

When using for example polystyrene panels, these are probably not strong enough to make a span and carry the loads of the floor surface. Therefore they should be placed directly on the office floor, or in case of an uneven office floor on a secondary levelling structure.

This structure could be a frame like used in installations floors, with jacks like discussed in previous paragraph (Alteco). A frame could be made from steel, aluminium or wood. Alternatively to jacks adjusting blocks could be used.

An alternative cheaper method is to smoothen the floor by using sand. By making a very shallow sandpit, a flat surface can be created where the floor segments can rest on. A requirement is that the sand is prevented to be displaced while and after placing the floor segments. This would be the easiest when the whole floor is placed as one piece on the sand. Wether this is possible depends on the type of floor segments. Since this method is not a conventional or practised one, it should be tested if this actually works in reality.

Evaluation

A floor segment that can rest directly on the office floor needs to be less strong and rigid, and therefore in general less (expensive) material is needed. But this advantage is not valid when a secondary frame is necessary. Therefore a floor levelled by sand is the cheapest option. However, if this is really a possible solution should be researched and tested further in the design phase.

CONCLUSION

Many kinds of construction methods, systems and mechanisms are possible to use in the Living Unit,; monolithic structures of cardboard or polystyrene, sandwich panels, wood panels systems or frame structures of steel, wood or aluminium. All of them have their pro's and con's and there is not a method that already can be chosen as the most suitable for the Units.

A technique that definitely creates big opportunities for the Units is CNC milling, which allows a large design flexibility and a cheap and quick production process. This can be used in a wood frame or panel construction, possibly in combination with sandwich panels.

Floors and roofs have different requirements than walls, and therefore might require another structural system. For the floors it is important to find a solution which doesn't need a load bearing frame. The roof should be made out of single spanning elements, as long as it is possible to transport such long elements.

Conclusion

What are the technical and legal restrictions, opportunities and solutions for the design of a cheap, generic, portable living unit that facilitates a comfortable micro-climate and -environment in vacant buildings that are in poor condition?

Detailed answers on this question are given in the concluding paragraphs of the chapters Regulations, Dimension, Micro-climate, Utilities and Construction.
A general conclusion is that the technical and legal restrictions are limiting, but certainly don't make realisation of Living Units unfeasible or unprofitable. A more detailed design of the Living Units is necessary to specify the limits and possibilities. Help of experts or advisers will be needed on the areas of micro-climate, utilities and fire safety. With a location, developers and sponsors the Living Units can become reality, starting with a first prototype.

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Online calculation software

Digitale luchtschijf: http://www.itpeters.nl/software.htm

Laurens Radiatoren: http://www.laurens-radiatoren.eu/warmtebehoefte-berekenen

Mercatron: http://www.mercatron.be/vasco/nl/getpage.asp?i=124

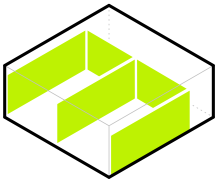
APPENDIX 1: REGULATIONS

There are 3 different types of conversion methods; permanent, temporary and anti-kraak. These 3 methods all have their pros and cons, and all have different regulations.

Laws

Laws and regulations are constantly changing. The most important for the conversion of buildings are summorized here (Benraad, 2011):

- With the introduction of the Spatial Planning Act (Wro, July 1, 2008), the Crisis and Recovery on (Crisis- en herstelwet , March 31 2010) and the Wabo (1 October 2010) the formal procedure time of the zoning and the surroundings are shortened.
- Bouwbesluit 2012 made big changes (relative to Bouwbesluit 2003) in the building regulations for the temporary and permanent conversion, which will be discussed in the next paragraphs.
- The squatting and vacancy act (Wet kraken en leegstand, October 2010) offers both opportunities and threats for temporary use. Squatting is now illegal, but buildings are still not allowed to be vacant for an indefinite period of time. The new law requires municipalities to keep a vacancy register. Assumed is that the owner comes up with an alternative function in 12 months. If they fail to do this, the owner is expected to show some initiative to have the building temporary used, and if necessary, to convert the building.



Permanent

The permanent conversion of a building means that it is planned to keep the new function as long as the building lasts. In practise this is at least more than 5 years, since regulations state that temporary conversion is maximum 5 years.

Deviation Zoning Plan

When converting a building the function normally changes. This is in violation of the zoning plan, which can be solved by following one of the next two procedures:

- Establish a new (stamp) zoning plan (WRO)
- Deviate on the basis of Wabo with a project decision / surroundings permit

Both Wabo project decision and the zoning plan have a decision period of 26 weeks. The new zoning plan offers more flexibility, but also takes more time.
(handleiding transformeren)

Level of quality in Bouwbesluit

Before the Bouwbesluit 2012 buildings that are permanent converted had to meet the requirements of ‘new buildings’. This is the highest level of requirements. To make the reuse of vacant buildings easier and cheaper, the Bouwbesluit 2012

lowered the requirements. For the biggest part of the quality aspects of buildings, they now have to meet the second highest level of requirements: 'rechtens verkregen niveau'. This is 'the current quality (before conversion) of the structure as far as that level is lawful and is not below the minimum level of ‘Existing building (which is the lowest level of quality)’. This means that a renovation plan can maintain the current quality, provided that the level is higher than ‘existing buildings’ (the absolute minimum). After the conversion the level should not be lower than the quality of the building before conversion.
More information:

- http://www.kennisbankherbestemming.nu/kennisdossiers/wet-en-regelgeving/bouwbesluit-2012
- http://www.kennisbankherbestemming.nu/kennisdossiers/wet-en-regelgeving/bouwbesluit-2012/wat-betekent-rechtens-verkregen-niveau-in-depraktijk

Law noise nuisance (Wet geluidshinder)

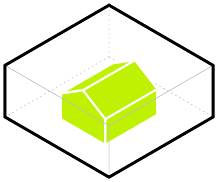
One of the laws that causes problems for the converison of offices into housing, is the wet geluidshinder (law noise nuisance). Many office buildings are in busy locations, highways, railways and airports. These locations are often ideal for offices because they are easily accessible to employees and customers.
Houses are ‘geluidsgevoelige objecten’ (Noise-sensitive objects), for who regulations allow less noise nuisance than for not noise-sensitive objects as offices. When these houses arise in an office which had lower noise nuisance requirements, this can be a problem. Measures to meet these requirements may increase significantly the costs of the conversion. When this is not possible, then a higher maximum value can be discusses. This must then be well argumented, and the value can not exceed the maximum limit laid down in the law.
More information:

- http://www.kennisbankherbestemming.nu/kennisdossiers/wet-en-regelgeving/geluidhinder
- http://www.kennisbankherbestemming.nu/kennisdossiers/wet-en-regelgeving/geluidhinder-inleiding/implicaties-voor-herbestemming

Air quality

Rules on air quality are found in the Air Quality Act (Wet Luchtkwaliteit). It is about maximum allowable concentrations of particulate matter (PM10) and stikstofdioxide (N02). It is expected that most of the air quality in the cases is not a problem in transformation of offices to living quarters. The air quality requirements can become significant when there is a conversion of big spatial developments, for example the construction of more than 1,500 homes and 10,000 m^2 of office.

More information:
- http://www.breda.nl/system/files/artikelen/wonen_in_kantoren.pdf



Temporary

Temporary use in general means that a building is temporarily offered by its owner, in anticipation of an other more permanent function. The maximum allowed time is prescribed by Wro and is now 5 years.
More information:
- http://www.kennisbankherbestemming.nu/kennisdossiers/tijdelijk-gebruik/wat-is-tijdelijk-gebruik

At the moment there are plans to extend this time to a maximum of 10 years, which has the advantage that the investments for the temporary conversion can be earned back more easily.
More infomation:
- http://www.herbestemming.nu/actueel/nieuws/h-team-en-nrp-positief-over-voorstel-permanente-crisis-en-herstelwet

Deviation Zoning Plan

The Wabo has two types of procedures : the regular procedure of 8 weeks and the extensive process of 26 weeks. A standard procedure is discussed in light, relatively simple projects that do not conflict with or slightly deviate from the zoning plan. Is a project called contrary to the zoning provisions, the extensive procedure of 26 weeks is needed. Usually, also for temporary, the extensive procedure is done by a Wabo project decision, which is a temporary deviation from the zoning plan, specified for the project in question (Benraad, 2011, p.23)

Level of quality in Bouwbesluit

The Bouwbesluit 2012 and also the one before of 2003, imposes less stringent requirements on temporary structures than permanent structures Structures intended to be temporary structures must be at least meet the requirements of existing buildings, which is the lowest level.
In practice, municipalities suggest or sometimes set some safety requirements higher than those for existing buildings, which is allowed by the Building Act.
If the building is a work and / or combination of function, also an occupancy permit (gebruiksvergunning) is needed which can bring additional requirements. For dwelling alone, no occupancy permit is needed.
More information:
- http://www.kennisbankherbestemming.nu/kennisdossiers/tijdelijk-gebruik/wet-en-regelgeving/toetsing-aan-bouwbesluit-en-gebruiksbesluit

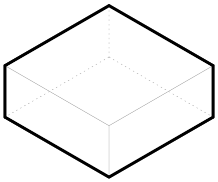
Law noise nuisance (Wet geluidshinder)

The law of noise nuisance does not apply to temporary surroundings permits, which are used with the temporary conversion of buildings. This means that if for example an office is temporary converted to housing, the maximum value of noise nuisance of office will continue to apply.

Yet, government states that in the context of proper spatial planning a (limited) acoustic assessment should take place.

More information:

- http://www.infomil.nl/onderwerpen/hinder-gezondheid/geluid/geluid-wabo/afwijken/



Antikraak

Anti-squatting is a form of temporary use of vacant property which is specifically intended to prevent squatting, vandalism and impoverishment. It is different from temporary renting, which is offered on the basis of the Leegstandswet, which requires a minimum period of 6 months and may not last longer than 5 years. Besides that it needs a municipal permit. All these rules do not acquire to anti-squatting living.

There are no national rules for anti-squatting. The rights and obligations of an anti-squatting resident vary by agency. Residents usually live very cheap and pay a fee between 75.00 and 500.00, depending on the object which is given on loan. Working toilets and a shower are In general always guaranteed.

The residents do not rent the property, but use it temporary. There is a loan agreement and not a rent agreement. A big difference, because tenants have more legal rights than anti-squatters. For example, a tenant can not simply be put out of its premises. Owners of anti squats also reserve the right to visit the house .

More information:

- http://www.woonbond.nl/pages/dossier_kraakAntikraak/downloads/rapport_renooy_november_2008.pdf

Keurmerk leegstandbeheer

There is a non-mandatory certification for anti-squat organizations. Regarding building quality, it requires that the premises must comply with minimal requirements, which could include being wind- and waterproof, adequate provisions in the field of electricity, water and sanitation.

More information:

- http://www.keurmerkleegstandbeheer.nl/library/files/1180320115_KLB%20Inspectielijst%201%20januari%202011.pdf

No clear regulation

There is no clear policy for anti-squat organisation, regarding the (fire)safety. Besides this there is no action taken against conflicting zone plans no and in general it is passively tolerated.

Decentraal beleid

Further regulation for anti-squatting is decentralized. For example, the Municipality of Zwolle is trying to solve the lack of general regulations through its own rules, especially in the field of fire safety.
More information:
http://decentrale.regelgeving.overheid.nl/cvdr/XHTMLoutput/Actueel/Zwolle/34965.html

Conclusion

Summarized, temporary conversion has less regulations than permanent, and anti-kraak has the least of all. In the following chapters restrictions formed by rthe regulations for the living unit are going be set out, and therefore 1 conversion type has to be chosen which reperesent the regulations.
The stricter the chosen regulations, the more generic the Living Unit will be. When the regulation of permanent conversion are chosen, it means the Living Unit will also be suitable for temporary conversion and anti-kraak. However, the regulations will be very high, and in many cases of temporary conversion not neccesarry. Another disadvantage of the regulations for permanent conversion, is the level of quality it needs, the 'rechtens verkregen niveau' is different for every building, and sometimes even for every floor in a building. This makes it difficult to set a general set of rules that the Living Unit has to meet.
Also it is important to note that the concept of the Living Unit is flexibility and low budget, which suits best for temporary conversion and anti-kraak. That is why the regulation for temporary converison will be used as starting points in the next chapters, which means the Bouwbesluit 2012 will be assessed by the level of 'temporary building', and when this is not specified by the level of 'existing building'. Some advantages of this relatively low level compared to the higher level of 'new buildings' are:

- A minimum floor height of 2.1 or 2.4 meters (2.6 for new buildings) (Bouwbesluit 2012, article 4.7),
- Input ventilation air does not have to come directly from outside (for new buildings all the ventilation air has to come from oustide, which would complicate the climate concept of room-in-room) (Praktijkboek bouwbesluit 2012, p. 136)
- Outdoor space is not required (it is required for new buildings). (Bouwbesluit 2012, article 4.34)

Besides this, a big advantage is the fact that the law of noice nuissance is not applicable for temporary building (it is for permanent buildings).

APPENDIX 2: COST CALCULATIONS WALLS

FAAY 40 JAAR
WANDEN | PLAFONDS

Kostenindicatie op basis van tekening

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Dank u wel voor uw aanvraag via de Wandcalculator op onze website. Hierbij ontvangt u de kostenindicatie van uw tekening. Mocht u meer informatie wensen of een offerte van onderstaande zaken, neem dan contact met ons op!

Omschrijving	Artikelcode	Prijs	Eenheid	Aantal (st)	Subtotaal
Vol Paneel 70mm Light 2605x400	VP7026040	31,25	per m2	55	1.787,50
Stellat 20x70mm, 5 stuks a 330cm	STEL2070	16,75	pak	3	50,25
Halve houtenveer, 10 stuks a 300cm	HAHOVE300	13,50	pak	1	13,50
Spaanplaatveer, 25 stuks a 100cm	SPAVE100	9,95	pak	6	59,70
Grenen Kozijn Set Opdek VP70 83x211,5	GREKOZSETOP7083X211,5	67,30	stuk	1	67,30
Kozijnpaneel VP70	KP70	22,95	stuk	1	22,95
Faay-Fix 310ml (PU-Ultra) per pak van 6 koker	FAAYFIX	28,50	pak	1	28,50

Totaal: 2.029,70

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