

Building a Circular Economy

Design Qualities to Guide and Inspire
Building Designers and Clients



LE BATI
BRUXELLOIS
SOURCE DE
NOUVEAUX
MATERIAUX

VUB



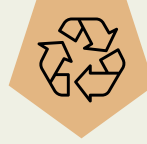
ARCHITECTURAL
ENGINEERING

Circular Des



Reused

Use building parts and components already present on site or reclaimed elsewhere



Recycled

Look for building components made of low-value by-products or waste materials



Safe and Healthy

Use components that do not harm the environment or humans during their use, reuse or recycling



Pure

Prefer components that consist of a single material instead of a blend



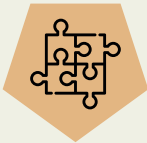
Manageable

Design building components that can be grabbed, moved and handled easily



Accessible

Integrate components so they can be reached and recovered without much effort or damage



Compatible

Use building components that can be interchanged and (re)combined



Multi-Purpose

Design buildings and spaces that support changing needs and requirements without alterations

Circular design qualities enable more effective reuse, re

Walk through them and set your am

Design Qualities



Use materials that are replenished continuously by responsible agriculture and forestry

Renewed



Choose materials that can be degraded into natural substances biologically

Compostable



Use components that resist the wear and tear of use and reuse

Durable



Go for low-tech, legible solutions rather than complicated ones

Simple



Make it possible to undo connections without damage to the components they join

Reversible



Assemble components so they are structurally, functionally and geometrically separated

Independent



Introduce diversity rather than a one-fit-all solution

Varied



Recognise and develop the qualities of a place responsibly

Location and Site

Recycling or renewal of buildings and building components.

Decisions from the start of the project.

More and more buildings and building products are branded as 'circular'.

Lighting fixtures or interior finishing for example are offered through leasing, or buildings are marketed together with maintenance services and material passports. But do these products cycle effectively and more efficiently in closed material loops than their conventional alternatives?

This question is hard to answer and illustrates that the transition of the construction industry from a linear take-make-waste model towards a circular practice is a challenge. Knowing that the service life of a building product is spread in time and space with responsibilities handed over regularly, it is difficult to guarantee that a product will never end as waste. Many changes in our economy, legislation and behaviour are necessary to warrant that – most of them lying beyond the power of an architectural designer or engineer. Nevertheless, through well-thought and informed design choices closing material loops can be enabled and even encouraged. So, let's design out waste!

Building a Circular Economy

Design Qualities to Guide and Inspire
Building Designers and Clients



LE BATI
BRUXELLOIS
SOURCE DE
NOUVEAUX
MATERIAUX



ARCHITECTURAL
ENGINEERING

Table of Contents

A Booklet to Guide and Inspire p. 5

What's in It for Me?
What Is a 'Circular' Building?

1. Approaches p. 7

Design for Longevity
Design for Disassembly and Deconstruction
Design for Reuse

2. Qualities p. 9

- | | |
|---------------------|-----------------------|
| 1. Reused | 9. Manageable |
| 2. Recycled | 10. Accessible |
| 3. Renewed | 11. Reversible |
| 4. Compostable | 12. Independent |
| 5. Safe and Healthy | 13. Compatible |
| 6. Pure | 14. Multi-Purpose |
| 7. Durable | 15. Varied |
| 8. Simple | 16. Location and Site |

3. Concepts p. 43

Between Pace-Layering and Support and Infill
Between Kit-of-Parts and Open Building Systems
Between Buildings as Material Banks and Urban Mining

4. More Actions and Opportunities p. 47

References p. 50

In heritage projects new interventions are frequently independent from, and connected in a reversible way to, the existing structure to preserve the latter's value. Pavilion at the Great Butcher's Hall in Ghent (BE), arch. Coussée & Goris (photo: Wim Van Nueten)



**Rather than permanent solutions for
changing needs, we need dynamic
assets that can evolve together with
new user demands.**

A Booklet to Guide and Inspire

Specific design choices, extending the service life of buildings and closing material loops, are considered key instruments in the transition towards a circular construction economy. This booklet brings together the insights and experience of design practitioners, researchers and other organisations from Brussels and beyond on designing buildings prepared for change and circularity.

Presenting complementary design approaches, qualities and concepts, this publication offers guidance to designers and clients to develop a suitable building concept and make well-thought and informed choices. It includes a series of actions too, allowing designers and clients to bring circularity into practice and explore the benefits and opportunities of a circular economy further.

1. Approaches

To shift the built environment and construction sector towards a circular

practice, designers and clients can take some basic approaches. Do you design for longevity, disassembly and reuse?

2. Qualities

Circular design qualities enable more effective reuse, recycling or renewal of buildings and building components. Walk through them and set your ambitions from the start of the project.

3. Concepts

In past and present design practices, a variety of design concepts combine circular design qualities, tailored to a specific project context. Make yourself familiar with the most typical ones.

4. More actions

Finally, a series of strategic actions brings the implementation of each design quality that last step closer. Find opportunities or create for yourself the right conditions for a successful 'circular' building.

This booklet is the result of an extensive review of practices and studies on building design and circularity, without the intention to be complete. It proposes a coherent framework and must advance together with the knowledge in the field; an advancement that will require rigorous testing and validation of each design approach and quality, in addition to more proof-of-concepts and exemplary practices.

This document also needs your input. Share your insights on our website where you can also find recent findings: www.vub.be/arch/circulardesign.

What's in It for Me?

For architectural designers and advising engineers, circular design qualities challenge their choices. They do so in favour of a futureproof building stock and circular economy while assisting designers in communicating clearly about it with their clients.

For product developers and manufacturers, circular design qualities offer an opportunity to review the use and reuse potential of their products and rethink their design and development in favour of a transition from a linear towards a circular business.

For private and public construction clients, circular design qualities offer a set of principles and criteria that help specifying the design ambitions and

needs, bringing building adaptability and circular material flows into the project brief and at the table from the initial design discussions onwards.

What Is a 'Circular' Building?

To align with the idea of a sustainable circular economy, a building must be created with components that are reused, remanufactured, recycled or regenerated in an efficient and effective way and will continue to follow these loops. This way, buildings and building components are never wasted but remain useful assets and valuable resources.

Acknowledging that buildings and their components are never in an end state but part of a process, and that this is one of the reasons why the construction sector has a vast share in our environmental footprint, requires us to rethink not only how we build, but also what we build. Rather than permanent solutions for temporary and changing needs, we need dynamic assets that can evolve together with new technical developments and user demands.

1. Approaches

To reduce the consumption of virgin, non-renewable resources, reclaimed building components can be used again, repaired, remanufactured or recycled.

Designers and clients can support a circular building practice in different ways. On the one hand, it is possible to optimise the capacity of every building to accommodate the evolving demands and needs of its users effectively, increasing its utility, extending its service life and thus maximising its value over time. On the other hand, it is possible to optimise the resource efficient management of all building-related material flows, avoiding the depletion of natural resources and the production of waste and thus minimising buildings' environmental impact.

Design for Longevity

In a circular design and construction practice, one can avoid new construction and review and revalue, upgrade and refurbish what already

exists. Several architectural qualities keep a building's value up over time, facilitating maintenance and repair, while enabling current and future service life extensions. They include strategic qualities, for example the asset's location, but also spatial qualities such as a multi-purpose lay-out.

Design for Disassembly and Deconstruction

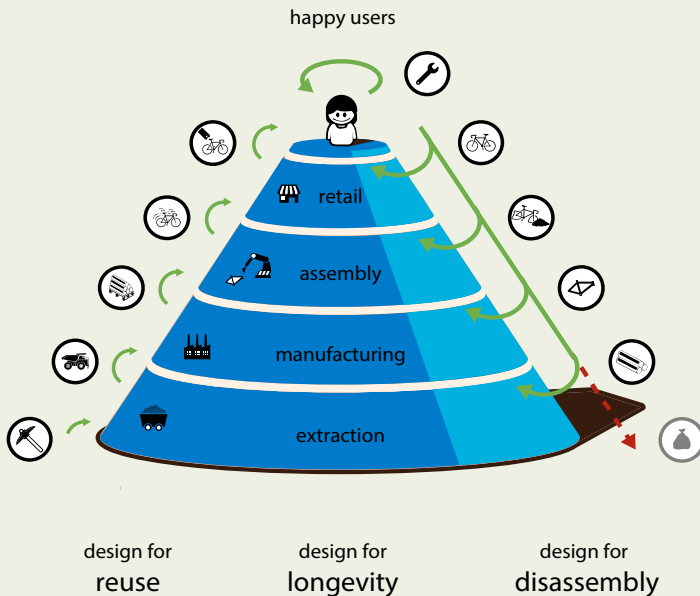
Complementary, to close material flows, components and materials must be reclaimed without damage to maintain their value, facilitate their processing and minimise waste. Therefore, various technical design qualities are key factors. They relate to design choices about, for example, the durability of components, their independent assembly and the reversibility of their connection.

Design for Reuse

To reduce the consumption of virgin, non-renewable resources, reclaimed building components and materials can be used again, repaired, remanufactured or recycled. Building components and materials should for example be safe and healthy to reuse or pure to recycle.

Aside the environmental savings of closed material loops and the economic benefit of enduring asset value, the design qualities that are collected in

this booklet offer other advantages and opportunities too. In literature these benefits are often presented as an added value of a 'circular' building, although they are not necessarily related to closed material loops. That does however not mean these advantages are not valuable. Think for example of facilitated inspection, maintenance and small repairs of easily adaptable structures, or imagine the reduced hindrance and nuisance during their refurbishment.



The value hill for building a circular economy (interpreted after Achterberg, E., Hinfelaar, J. & Bocken, N.)

2. Qualities

Aspire a unique equilibrium balancing
the set of qualities within the specific
context of a project.

Before you start reading the following pages, a few words on how to use the design qualities. They collect some insights that were acquired during the earlier adoption of the qualities in practice.

First, **use design qualities as qualities**. Set them as ambitions or walk through them when comparing design alternatives. The qualities have demonstrated their added value as a review framework from the start of the design process onwards, regardless whether that process takes a conventional programming, a scenario planning or a co-creation approach.

Second, **don't expect black or white choices**, neither red, orange or green solutions, but aspire a unique equilibrium balancing the whole set of qualities within the project's specific context. What is important, is that design choices

are made based on the awareness of their long-term consequences. Here lays a crucial role and responsibility for the designer and client. Understanding that the future is uncertain, it seems in the interest of all stakeholders to retain those options that are the most resilient or robust.

Third, **avoid cherry picking of individual qualities**, although it is not always possible to review and fulfil all of them. Some are very specific and some may even be contradictory. Therefore, communicate clearly about which aspects have been considered, which not, and why. Furthermore, in those situations where it is only possible to evaluate building products because there is no building design yet, the assessor should know that choices at one scale level might jeopardise the qualities' benefits at another level.



(photo: Allard van der Hoek)

VILLA WELPELOO

2012 Architecten, now Superuse Studios

Enschede (NL), 2009

Built with steel beams reclaimed from obsolete textile machinery and covered with wood sidings once part of cable reels, Villa Welpeloo by Superuse Studios demonstrates that it is possible to reuse existing objects. The materials provided incentives to develop and refine the design. "New shapes and innovative methods were needed to incorporate the reclaimed materials," the designers state.



(photo: Allard van der Hoek)

01

REUSED

Use building parts and components already present on site or reclaimed elsewhere.



Benefits

Reusing building parts and components extends their service life, avoids them to be wasted and reduces resource consumption. On-site reuse could also diminish transport and local nuisance.

Related design concept

Buildings as material banks

Actions and advice

Make an overview of existing parts and components. Include accurate descriptions to assure their traceability.

Consider repairing or remanufacturing components to comply with the same or another function.

Reserve time and budget for surveys and feasibility studies, and provide temporary storage space on site.

Rely on skilled resellers and engage from the start a contractor to ensure the reclaimed components' quality.

Set priorities if the reuse of whole parts is not feasible. Look for high-value items, on-site or off-site.



(photo: Lendager UP)

COPENHAGEN TOWERS II: PET FELT ACOUSTIC PANELS

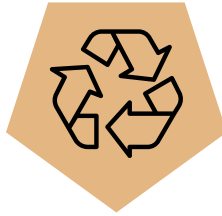
Lendager Group

Copenhagen (DK), 2016

For the Copenhagen Towers II project in Ørestad, Lendager Group designed acoustic ceiling panels from recycled PET bottles. These bottles were washed, sorted and granulated, heated and extruded to raw PET fibres. Using PET-felt as an acoustic element adds value to plastic waste. And compared to new plastic, “every kilogram of recycled plastic, spares the environment 1.5 kilograms CO₂,” the developers claim.

RECYCLED

Look for building components made of low-value by-products or waste materials.



Benefits

Recycling supports the reduction of construction's impact on the environment by reducing the use of virgin resources and decreasing waste incineration and landfill.

Related design concept

Urban mining

Actions and advice

To limit the use of virgin resources, set minimum recycled content percentages for different products.

Give priority to recycled products that are sourced locally and processed in an energy efficient way.

Ensure the compliance with durability, health and other requirements to avoid undesirable side-effects.



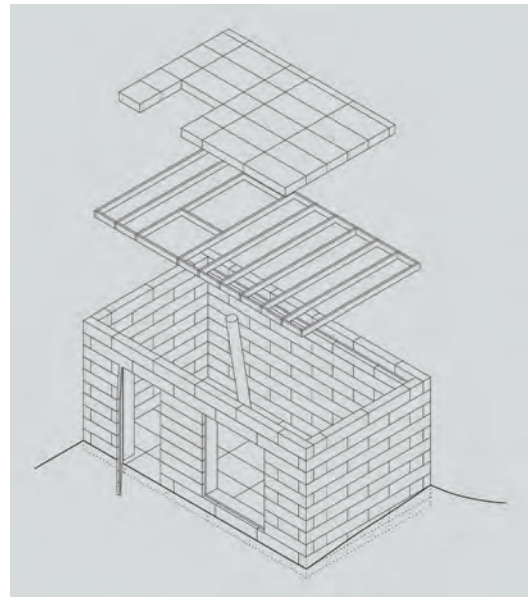
(photo: Lenny Codd)

CORK STUDIO

Studio Bark

London (GB), 2018

The Cork Studio, a garden building, is made almost entirely out of cork, the bark of the cork oak tree (*Quercus suber*). Discarded cork granules from a wine cork manufacturer were turned into solid blocks through a heating process which triggers them to release a natural resin. The blocks were cut into desired sizes and joined on site. Water, fire and degradation tests demonstrated the material's potential. "We built this to prove it," the designers report.



(drawing: Studio Bark)

RENEWED

Use materials that are replenished continuously by responsible agriculture and forestry.



Benefits

Through biological reproduction some materials are almost infinitely available. Many renewed materials also act as a temporary storage of the greenhouse gas carbon dioxide and could be biodegraded.

Actions and advice

Rely on well-documented labels that certify the responsible cultivation and resourcing of the material.

Select rapidly renewable materials; materials that grow at least as fast as their functional service life.

Use materials that are locally resourced to minimise the cost and environmental impact of transport.



(photo: architectengroep Barchi, Woonder cvba)

STRAW

Architectengroep Barchi and Woonder cvba

Multiple applications

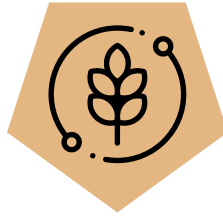
Since centuries straw has been used in construction as an insulation material or roof cover. Straw bales can be used as the infill of a supporting frame too or can be stacked to form the building's load bearing structure. If the correct conditions are provided, this renewable material is also fully compostable after its functional use.



(photo: architectengroep Barchi, Woonder cvba)

COMPOSTABLE

Choose materials that can be degraded into natural substances biologically.



Benefits

At their end-of-life, building components of compostable materials are not wasted but can be converted again into water, carbon dioxide and biomass. The organic material can then be reused or disposed responsibly.

Actions and advice

Prefer materials that are already sorted and collected for biodegradation.

Select materials that, under known composting conditions, biodegrade quickly and completely.

Verify if the composted material can be used as mulch or compost.



(photo: Arnaud Bouissou - Terra)

DENIM INSULATION

Denim insulation consists of fibres from jeans and sweaters we have been wearing day in and out without concern. Tests evaluating the emission of volatile organic compounds also confirm the expectations: these materials are safe and can be installed without wearing a mask. Some denim insulation products are not only composed of post-consumer cotton but are treated with a flame retardant or mixed with polyester.

SAFE AND HEALTHY

Use components that do not harm the environment or humans during their use, reuse or recycling.



Benefits

Select components that are safe and healthy throughout their use and end-of-life processing facilitates their future reuse, remanufacturing and recycling, effectively closing the related loops.

Related design concepts

Buildings as material banks
Urban mining

Actions and advice

Verify materials' compliance with standing norms and regulations on environmental and human toxicity.

Avoid materials emitting volatile organic compounds or particulate matter with adverse health effects.

Do not opt for materials that put labourers' health and well-being at risk during disassembly and processing.

Minimise the use of materials whose safety is under discussion or that are subject to future restrictions.

Strive for transparency about component ingredients with a detailed level of tracking and reporting.



(photo: BC architects & studies, BC materials)

HUNTING LODGE

BC architects & studies, BC materials
(BE), 2012

This hunting lodge, built of rammed earth, blends in with the surrounding forest. For the walls 30 m³ of rammed earth was produced on-site: the earth was excavated, dried and mixed with gravel before it was pressed together. As they exist of locally resourced materials only, and were not chemically altered, they could become 'earth' again one day.



(photo: BC architects & studies, BC materials)

06

PURE

Prefer components that consist of a single material instead of a blend.



Benefits

Mono-material components require less processing before recycling or biodegradation. Their purity increases the time and energy efficiency of closing their material loop.

Related design concept

Urban mining

Actions and advice

Avoid composite components and limit the number of different materials combined in a single product.

Select materials that are unfinished and not treated with a different chemical compound.

If mixed, verify if materials can be separated by hand or industrial processes in an efficient way.

Anticipate possible contamination of the material when it is installed, finished, maintained or deconstructed.



(photo: Olivier Beart)

RECLAIMED CERAMIC TILES

Rotor DC

Institut de Génie Civil, Liège (BE), 2014

In 2014 Rotor DC recovered more than 1,000 m² of floor tiles produced back in the 1930s from the modernist 'Institut de Génie Civil' in Liège. The durable ceramic tiles of the institute's floors had been laid out in geometric art-deco patterns, fully intact and carefully inventoried by Rotor DC. Thereafter, it was possible to recover the tiles one by one. Most mortar was removed with a pneumatic hammer and the tiles could be pressure washed after softening the remaining mortar in a biological acid.



(photo: Olivier Beart)

DURABLE

Use components that resist the wear and tear of use and reuse.



Benefits

Durable components withstand intensive use as well as repeated disassembly and reconstruction. Keeping their value over time, it is more likely that these components will be used again.

Related design concepts

Pace-layering

Support and infill

Kit-of-parts

Open building systems

Buildings as material banks

Actions and advice

Select components that have a long expected service life or that are already reused.

Look for materials that are robust, hard-wearing, timeless and age naturally.

Use components that are easy to repair or remanufacture rather than those that must be replaced entirely.

Prefer reliable solutions; requiring limited cleaning and maintenance or any other intervention.

Avoid unwanted deterioration by robust detailing and anticipate vandalism, corrosion, etc.

Embrace people's appreciation; a valuable design may become heritage.



(photo: Jeroen Van Der Wielen)

PEOPLE'S PAVILION

Bureau SLA and Overtreders W

Dutch Design Week, Eindhoven (NL), 2017

Using only borrowed or recycled materials, the designers had to find a simple way to assemble and disassemble the materials of this People's Pavilion and return them intact. For instance, the framework is made of 19 wooden components strapped together using tension belts and cable ties. Although not new, "this system required extensive testing, but has almost no ecological footprint," tell the designers.



(photo: Jeroen Van Der Wielen)

SIMPLE

Go for low-tech, legible solutions rather than complicated ones.



Benefits

Simple solutions are easy to understand, apply and adapt. They facilitate and speed up the recovery of building components and encourage their maintenance, repair and reuse.

Related design concept

Buildings as material banks

Actions and advice

Limit the total number of (different) components and connections and find opportunities for repetition.

Adopt components with standard dimensions and make use of conventional connections.

Introduce tolerances and margins in the design to simplify further the construction process.

Avoid the need for expertise and opt for solutions that can be adapted without special knowledge, skills or tools.

Look for fast assembly and disassembly techniques, as in plug-and-play systems.



(photo: Lenny Codd)

BOX HOUSE: U-BUILD SYSTEM

Studio Bark / Structure Workshop / Cut and Construct

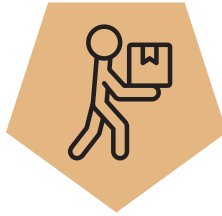
Bicester (GB), 2017

“Designed by architects, approved by engineers, built by you” is the catchphrase of the self-build system U-Build. Delivered flat-pack, assembled to boxes and then stacked and bolted to form walls, floor and roof, the system claims to be easy and cost effective. “The system components are designed such that they can be lifted by 1-2 people and assembled with basic tools, empowering a wide group of people to engage with construction,” the developers state. Their ultimate goal for the U-Build system is to provide a sustainable, circular economy solution for buildings, within the context of a global environmental crisis.

The Dutch system JUST in CASE of Studio JVM (p. 46), the Brussels MODS of MCB Atelier and WoonBox of Samenlevingsopbouw Brussel are comparable solutions. Their elements are standardised and designed for easy transport and (dis)assembly too.

MANAGEABLE

Design building components that can be grabbed, moved and handled easily.



Benefits

Manageable components simplify building adaptations and increase the feasibility of take-back programs and return logistics. This practicability is crucial to make component reuse financially competitive with wasteful replacements.

Related design concepts

Kit-of-parts

Open building systems

Actions and advice

Use components that are light enough to be installed by one or two people, with minimal mechanical aid.

Limit the size of components so they are convenient for transport and can enter a building without difficulty.

Shape components in such a way they can be lifted and stacked ergonomically and efficiently.



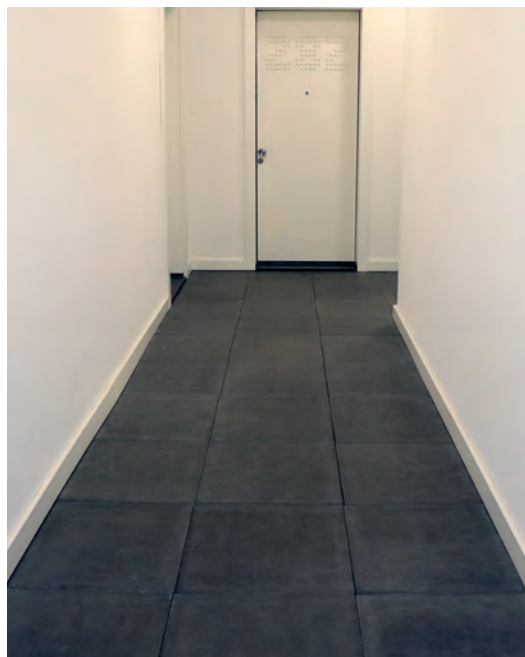
(photo: Luuk Kramer)

PATCH22

FRANTZEN et al architecten

Buiksloterham, Amsterdam (NL), 2016

The PATCH22 building in Amsterdam, a 30 m tall high-rise in wood, is as polyvalent as possible. To allow for functional changes, pipes are not only bundled in the raised floor of the central corridor from which they can reach any spot of the adjacent apartments. Those floors are also covered with loose concrete tiles, making pipes easily accessible and giving users the freedom to organise their apartment, office or workshop as they wish.



(photo: Ineke Tavernier)

ACCESSIBLE

Integrate components so they can be reached and recovered without much effort or damage.



Benefits

Accessible components can be reached and recovered faster without being damaged or damaging components that sit around them. Furthermore, accessibility encourages efficient repair, replacements and adaptations.

Related design concepts

Pace-layering

Support and infill

Actions and advice

Strive for as many components as possible that can be inspected directly, i.e. without removing another component.

Provide room to inspect, adapt, recover and move around the component safely and ergonomically.

Make sure the connection between components is visible and directly accessible or made accessible in only a few steps.

Provide space around the connection to inspect, fasten and unfasten it, if required with the necessary tools.

Include as-built drawings and instructions about reaching high-maintenance building components.



(photo: Detiffe)

GREENBIZZ

architectesassoc+

Brussels (BE), 2016

Environmental incubator, workshop and office centre Greenbizz breathes sustainability. Its eight to ten meters high workshop facades are preassembled and bolted in a reversible way to the concrete structure. To make the façade-high panels fit, they are installed on a wooden ruler on the concrete plinth. Further tolerances were anticipated by slits in the angled iron plates connecting the panels to the concrete structure at roof level.



(photo: architectesassoc+)

REVERSIBLE

Make it possible to undo connections without damage to the components they join.



Benefits

Reversible connections enable selective disassembly and recovery of building parts. Eventually, purer material flows also make recycling and biodegradation more efficient.

Related design concepts

Pace-layering
Support and infill

Actions and advice

Make use of connections that can be undone rather than permanently fix building components together.

Verify if the connected components, and, if possible, also the connection, remain intact during repeated disassembly.

Avoid connections that leave unwanted traces or damage to the building after disassembly.

Often, reversible connections are not continuous, so special attention is required for air and vapour tightness.

A reversible connection itself may, but does not have to, be reusable. It can be recyclable or biodegradable too.



(photo: Sybold Voeten)

ABT DAMEN DELFTECH OFFICES

BiermanHenket architecten

Delft (NL), 2001

Anticipating its end-of-life from the start, this office building for engineering firms ABT and DAMEN (now DEMO) is designed for disassembly. The space partitioning walls and ventilation ducts, both visible in the interior, are integrated independently from the concrete load bearing structure. A well-thought tracing and non-hierarchical lay-out of all components allow each part to be altered without demounting or damaging another one.



(photo: Sybold Voeten)

12

INDEPENDENT

Assemble components so they are structurally, functionally and geometrically separated.



Benefits

Independence of components allows to disassemble one component without removing another, simplifying its recovery for reuse. Independence also facilitates efficient repair, replacements and adaptations.

Related design concepts

Pace-layering
Support and infill

Actions and advice

Verify if the geometry of an assembly allows to take out one component without disassembling another one.

Aspire a structural and functional lay-out that allows removing those components that require more frequent interventions.

To speed up recovery, enable the disassembly of building components from different spots simultaneously.

Provide disassembly and reassembly instructions for building systems that are intended to be reused.

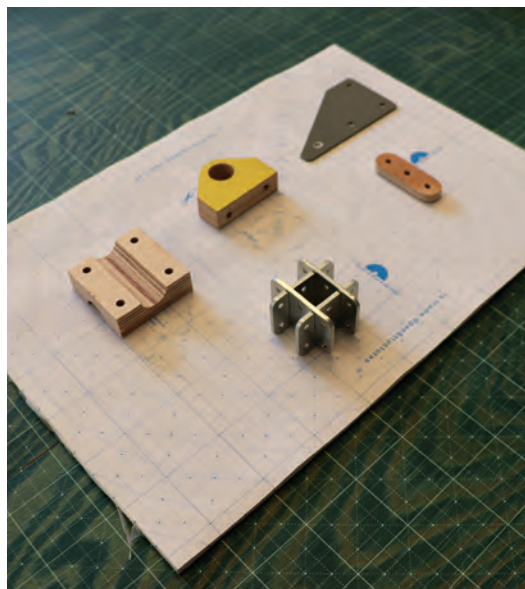


(photo: Ineke Tavernier)

OPENSTRUCTURES

Thomas Lommée and Christiane Högner
Brussels (BE), since 2005

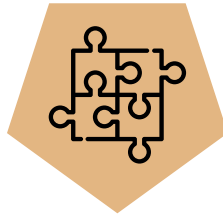
Since 2005, OpenStructures (OS) brings the principles of design for reuse into practice and allows everyone to do the same. The OS grid, a generative dimensioning system of 4 cm by 4 cm guarantees the compatibility of all OS components. Driven by creativity, Lommée and Högner show how free the grid is, for example when building their own record player. But as often they are surprised finding grids around us, like in our kitchen where cupboards and appliances of different manufactures fit as if by magic.



(photo: Ineke Tavernier)

COMPATIBLE

Use building components that can be interchanged and (re)combined.



Benefits

Compatibility increases the possibility to recombine and reuse components time and again. Possibly, compatibility also makes it easier to find spare parts and thus facilitates repair.

Related design concepts

Kit-of-parts

Open building systems

Actions and advice

Design the building or building system according to one or more “modules” with a recurring size.

Use components that have a standardised shape and size, produced by multiple manufacturers.

Verify if components can be exchanged with others, or if a completely new configuration could be created.

Aspire compatibility within the same building system, and among different systems.

Also apply geometric patterns and principles, such as scale, symmetry and rotation.



(photo: Bas Princen)

VILLA

OFFICE Kersten Geers David Van Severen
Buggenhout (BE), 2012

This single-family house is simple yet fascinating. Its generality not only originates from the spatial lay-out of nine identical rooms and their connectedness at both levels, but also from the doubled walls at ground level. As a result, each space can be transformed from an insulated indoor room to an outdoor loggia and vice versa, allowing the residents to use the house in accordance with their needs and the changing seasons.



(photo: Bas Princen)

MULTI-PURPOSE

Design buildings and spaces that support changing needs and requirements without alterations.



Benefits

A multi-purpose design avoids obsolescence and makes time and material intensive refurbishments unnecessary, extending the service life of buildings and building parts.

Related design concepts

Pace-layering

Support and infill

Kit-of-parts

Open building systems

Actions and advice

Create an open lay-out with well-connected and generous spaces for maximum versatility and accessibility.

Integrate moveable or mobile components such as sliding, turning or folding walls, for quick and easy changes.

Anticipate multiple use scenarios with extra capacity and redundancy: spatially, technically and structurally.

Make the whole building accessible for all and allow daylight and ventilation in every room.

Provide sufficient and well-spread access points to technical rooms, services and shafts.



(photo: © Hufton + Crow)

1111 LINCOLN ROAD

Herzog & de Meuron

Miami Beach (US), 2010

This mixed-use development in Miami Beach comprises a refurbished office building, new private residences and a fully open concrete structure for parking and retail. “The car park is a public facility, like a train station or an airport,” state the designers. Therefore, they conceived the garage with floors of varying heights. They can be used for parties, film shoots, fashion shows, concerts or other social or commercial activities.



(photo: © Hufton + Crow)

15

VARIED

Introduce diversity
rather than a one-fit-all solution.



Benefits

A varied built environment allows users to relocate themselves rather than refurbish or replace their buildings to fulfil changing needs. This way, those buildings' service life is extended, and their components are reused.

Related design concepts

Pace-layering

Support and infill

Actions and advice

Develop a varied typology, for example of apartment units, to attract and fulfil the needs of a broad audience.

Introduce various use scenarios in a single project; think of residential, commercial and community functions that could follow on each other.

Provide spaces with diverse capacities and capabilities, for an optimal fit over time between supply and demand.



(photo: François Lichtlé)

FORMER BELLE-VUE BREWERY

L'Escaut architectures

Brussels (BE), 2015

Situated along the Brussels canal, the site of the former Belle-Vue brewery could be redeveloped while conserving the old malt-house thanks to the possibility to densify the site while retaining its qualitative outdoor spaces. The site now hosts two hotels and a tourism training centre, a museum and “casco” office spaces. They are easily accessible by public transport and car, and profit from the canal view.

LOCATION AND SITE

Recognise and develop the qualities
of a place responsibly.



Benefits

A well-located and qualitative site remains attractive and valuable over time. Buildings on these sites have higher chances to be maintained and redeveloped in the future.

Actions and advice

Situate buildings where they are easily and safely accessible by foot, bike and shared transport.

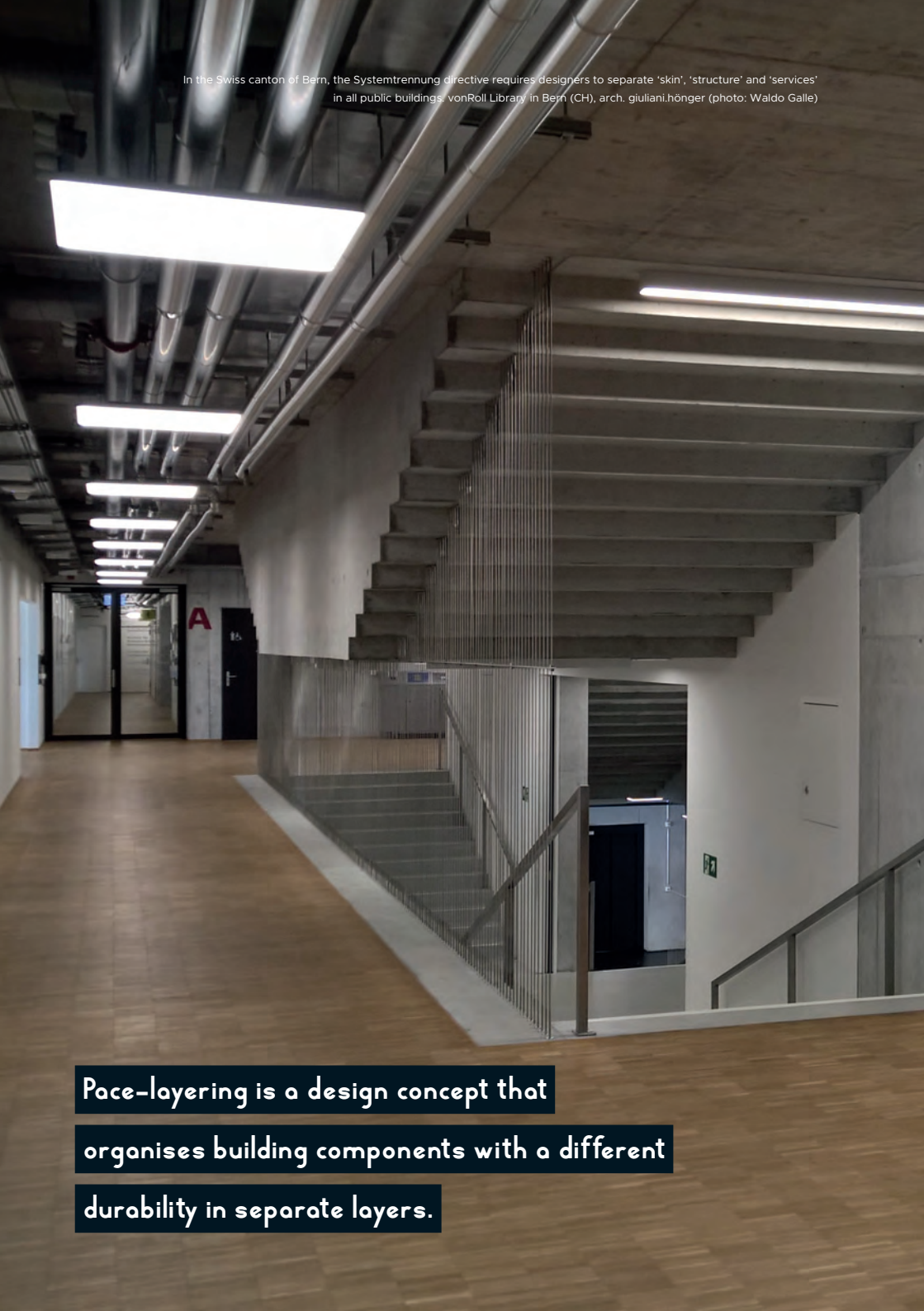
Connect to existing infrastructure and public utilities, such as district heating and local composting.

Include public amenities, such as a fountain, play garden, repair café or cooperative shop.

Safeguard outdoor spaces and wide views, or create links to qualitative spaces in the immediate vicinity.

Design a site that can be densified with new (temporary) facilities and other amenities.

In the Swiss canton of Bern, the Systemtrennung directive requires designers to separate 'skin', 'structure' and 'services' in all public buildings. vonRoll Library in Bern (CH), arch. giuliani.hönger (photo: Waldo Galle)



Pace-layering is a design concept that organises building components with a different durability in separate layers.

3. Concepts

In practice, a variety of concepts exist, combining circular design qualities in an intelligent way, adapted to the specific context of each project. Here we collect some typical ones.

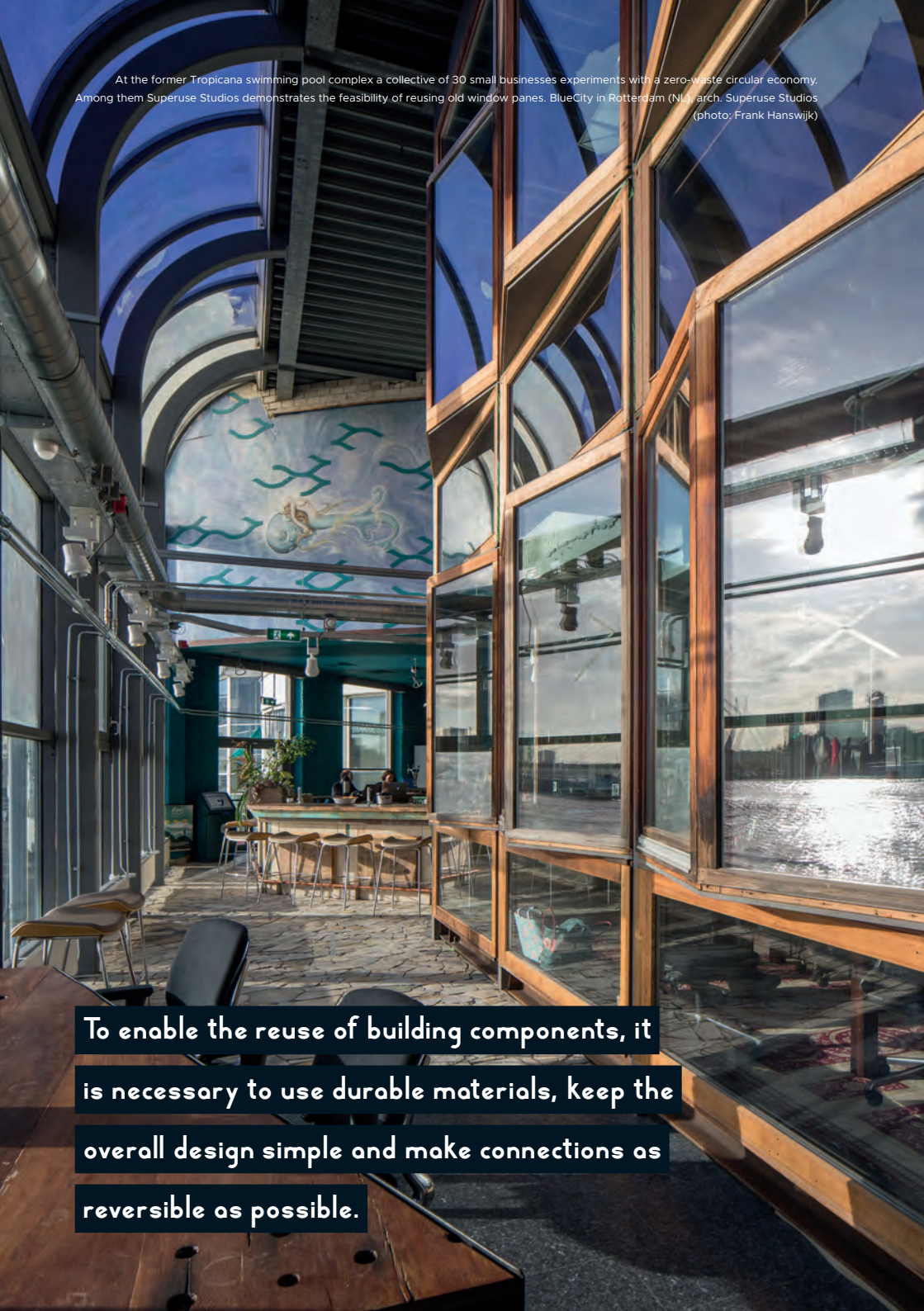
Between Pace-Layering and Support and Infill

Pace-layering is a design concept that organises building components with a different durability in separate layers. Organising these layers in such a way that a layer with components of a shorter service life is independent from, and more accessible than, a layer with components with a longer life span, allows preserving the components' integrity during subsequent alterations. The regularly cited layering concept 'Site, Structure, Skin, Services, Space Plan and Stuff' was formulated by Steward Brand but the concept has also been studied by Francis Duffy and Bernard Leupen.

Pace-layering is not new. It was Nikolaas John Habraken who argued for a distinction between just two basic layers: the multi-purpose base building, called 'support' and the fit-out, called 'infill'. His distinction is foremost one of design responsibility and only secondarily a technical one. Further, in heritage projects new interventions are frequently independent from, and connected in a reversible way to, the existing structure to preserve the latter's value (p. 4). As another example, in the Swiss canton of Bern, the Systemtrennung directive requires designers to separate 'skin', 'structure' and 'services' in all public buildings (p. 42).

Related design qualities are Durable, Accessible, Reversible, Independent and Multi-purpose.

At the former Tropicana swimming pool complex a collective of 30 small businesses experiments with a zero-waste circular economy. Among them Superuse Studios demonstrates the feasibility of reusing old window panes. BlueCity in Rotterdam (NL), arch. Superuse Studios (photo: Frank Hanswijk)



To enable the reuse of building components, it is necessary to use durable materials, keep the overall design simple and make connections as reversible as possible.

Between Kit-of-Parts and Open Building Systems

Kit-of-parts is a design concept that proceeds from systems of durable, multi-purpose, compatible and manageable building components, like Meccano toys. Those components are shaped according to a set of dimensional standards and assembled in a reversible way, optimising their production and construction process, facilitating their stock management and increasing their reuse potential. As illustrated by the construction kits of for example Jean Prouvé or the Cellophane House of KieranTimberlake, whole-kit buildings are useful for specific purposes, while kitchen systems and office partition walls are kit-of-parts that are used and reused every day.

The kit-of-parts concept can be extended from individual to multiple building systems. If the components of different producers are designed in such a way that they can be combined and reused in multiple building projects thanks to mutual agreements on the components' shape and dimensions, we speak of an 'open building system'. As discussed by Frank De Troyer and Asko Sarja, open building systems do not have the intention to standardise solutions through simple modularity, but to increase reuse possibilities by maximising compatibility.

Related design qualities are Durable, Manageable, Reversible, Compatible and Multi-Purpose.

Between Buildings as Material Banks and Urban Mining

Designing buildings as material banks approaches the built environment as a stockpile of valuable components, waiting to be reclaimed whenever the building that hosts these components becomes obsolete. To enable the reuse of building components, it is necessary to use durable materials, keep the overall design simple and make connections as reversible as possible. The Dutch architectural office Superuse Studios is forerunner in reuse and demonstrates its feasibility in projects like BlueCity (p. 45) and REwind Rotterdam.

The buildings as material banks concept can be extended further to the idea of urban mining, considering cities as quarries of 'raw' materials that can be recycled into new construction products. Considering the local availability of those materials, their purity, safety, overall ease of recovery and the existence of suitable logistics, might serve as useful guidelines towards the feasible implementation of this urban mining concept.

Related design qualities are Safe and Healthy, Pure, Durable, Simple and Reversible.

The wooden construction elements of the JUST in CASE system of studio JVM are standardised and can be used and reused both for support and infill. (photo: Jeroen van Mechelen)



4. More Actions and Opportunities

Embed the design qualities in every stage of the life cycle of a building. Using them during the design, construction and operation phase keeps them high on the agenda and avoids unpleasant surprises or discussions.

Apart from the individual design qualities, the following advice facilitates the transition towards an economy of closed material loops. It includes lessons learnt by researchers and practitioners actively working on building design in

a circular economy. Some of them are situated beyond the traditional scope of the designer, but are nevertheless considered interested leverages and enablers.

Anticipating future changes led to different building layers: a brick skin and an independent wooden interior structure. House Asper in Gavere (BE), arch. KADERSTUDIO (photo: KADERSTUDIO)

Understanding the needs of the user remains crucial to combine the design qualities to suitable concepts. If that user is not known, imagine divergent scenarios to test the robustness and resilience of your design.

Start from the Beginning

Embed the design qualities in every stage of the building's life cycle. Using them during the design, construction and operation phase keeps them high on the agenda and avoids unpleasant surprises or discussions.

Allow User-Controlled Adaptations

Acknowledge that a building's construction is not the end, but only the start of its dynamic service life. Therefore, look for and propose generic systems, adaptable by the user, rather than fixed solutions.

Imagine 'Scenarios'

Understanding the user's needs remains crucial to combine the design qualities to suitable concepts. If that user is not known, imagine divergent scenarios to test the robustness and resilience of your design (p. 49).

Deliver and Share Data

Materials passport, as-built models, component labels, disassembly plans, intervention reports, condition assessments, etc. Documenting reduces risks and facilitates an asset's future valorisation.

Consider Digitalisation and 'Sensing'

Digital building modelling and management facilitate the collection and follow-up of relevant data. Complementary, sensors allow optimal

use and management of spaces and technical services.

Enhance Supervision and Communication

Actively informing about, and involving construction partners in the design qualities, together with on-site inspection and management, increases the quality and long-term value of the executed work.

Preassemble

The preassembly of building components off-site provides higher quality and efficiency and therefore lower initial cost. In addition, it is expected that pre-grouping components also speeds up their disassembly.

Keep up Maintenance and Operation

The expected service life of a building component depends on its maintenance as well as on its initial design quality. Therefore, anticipate and plan regular maintenance and avoid vacancies or obsolescence.

Evaluate New Business Models

Leasing and performance contracts, take-back schemes and shared use are opportunities to increase component's utility over time and facilitate closed material flows, while sharing costs.

References and further reading

Achterberg, E., Hinfelaar, J. & Bocken, N. *The Value Hill Business Model Tool: identifying gaps and opportunities in a circular network*. www.scienceandtheenergychallenge.nl/sites/default/files/multimedia/organization/sec/2016-06-16_NWO_Sc4CE/NWO_Sc4CE_-_Workshop_Business_Models_-_Paper_on_Circular_Business_Models.pdf (18/09/2017)

Adaptable Futures. *Toolkit*. adaptablefutures.com/our-work/toolkit (17/08/2018).

Addis, W. & Schouten, J. *Design for Deconstruction: Principles of Design to Facilitate Reuse and Recycling* (Construction Industry Research & Information Association, 2004).

Brancart, S. *Rapidly Assembled Systems with Flexible Components, a Dialogue between Active-Bending and Transformability* (Vrije Universiteit Brussel, 2018).

Brand, S. *How Buildings Learn: What Happens after They're Built* (Penguin Books, 1995).

Leefmilieu Brussel. *Praktische handleiding voor de duurzame bouw en renovatie van kleine gebouwen*. http://app.leefmilieubrusel.be/handleiding_duurzaam_gebouw.

Carmona, M. Contemporary Public Space, Part Two: Classification. *Journal of Urban Design* 15(2), 157-173 (2010).

Ceraa, evr-Architecten, 1010au & Alive Architecture. *Living Lab: (Re)Making Healthy Spaces* (OVAM, 2016).

Chini, A. & Balachandran, S. Anticipating and Responding to Deconstruction through Building Design. *Proceedings of the CIB Task Group 39 Deconstruction Meeting: Design for Deconstruction and Materials Reuse*, 175-185 (International Council for Research and Innovation in Building Construction, 2002).

Circle Economy. *A Practical Approach to Circular Buildings*. www.circle-economy.com/a-practical-approach-to-circular-buildings (17/08/2018).

Circular Flanders. *De nieuwe strategische tool van de Green Deal Circulair Aankopen* (OVAM).

Crowther, P. *RAIA/BDP Environment Design Guide, Design for Disassembly - Themes and Principles* (Royal Australian Institute of Architect's, 2005).

Debacker, W. *Structural Design and Environmental Load Assessment of Multi-Use Construction Kits for Temporary Applications on 4Dimensional Design* (Vrije Universiteit Brussel, 2009).

Debacker, W., Galle, W., Vandenbroucke, M., Wijnants, L., Lam, W. C., Paduart, A., Herthogs, P., De Temmerman, N., Trigaux, D., De Troyer, F. & De Weerd, Y. *Veranderingsgericht bouwen: ontwikkeling van een beleids- en transitiekader* (OVAM, 2015).

Deprins, L. *Analysing the Transformability Degree in Design for Change* (Vrije Universiteit Brussel, 2015).

- DGNB System. Save resources. *Using Buildings As a Treasure Trove of Raw Materials – or How to Save Resources During a Development Project*. blog.dgnb.de/en/save-resources (17/11/2018).
- DGNB System. DGNB criteria “Ease of recovery and recycling” (TEC1.6). *German Sustainable Building Council*. www.dgnb-system.de/en/system/version2018/criteria/ease-of-recovery-and-recycling/index.php (17/11/2018).
- DGBC, Metabolic, SGS Search, Circle Economy & Redevco Foundation. *A Framework for Circular Buildings: Indicators for Possible Inclusion in BREEAM* (Dutch Green Building Council, 2018).
- Dorsthorst, B. & Kowalczyk, T. Design for Recycling. *Proceedings of the CIB Task Group 39 Deconstruction Meeting: Design for Deconstruction and Materials Reuse*, 71-81 (International Council for Research and Innovation in Building Construction, 2002).
- Duffy, F. Measuring building performance. *Facilities* 8(5), 17-20 (1990).
- Durmisevic, E. *Transformable Building Structures: Design for Disassembly as a Way to Introduce Sustainable Engineering to Building Design and Construction* (Technische Universiteit Delft, 2006).
- Durmisevic, E. & Brouwer, J. Design Aspects of Decomposable Building Structures. *Proceedings of the CIB Task Group 39 Deconstruction Meeting: Design for Deconstruction and Materials Reuse* (International Council for Research and Innovation in Building Construction, 2002).
- Durmisevic, E. et al. *Buildings as Material Banks, D15: Reversible Building Design Guidelines and Protocol* (2018).
- Ellen MacArthur Foundation. *Circularity Indicators for Measuring Circularity in a Circular Economy*. www.ellenmacarthurfoundation.org/programmes/insight/circularity-indicators (17/08/2018).
- Facilitair Bedrijf. *GRO. De nieuwe handleiding van het facilitair bedrijf. Op weg naar toekomstgerichte bouwprojecten* (Vlaamse Overheid, 2017).
- Galle, W. *Scenario Based Life Cycle Costing, an Enhanced Method for Evaluating the Financial Feasibility of Transformable Building* (Vrije Universiteit Brussel, 2016).
- Galle, W., Cambier, C., Denis, F., Vandervaeren, C. & De Temmerman, N. The Dynamic Design Matrix: a Major Review of the Flemish Design Principles for Closed Material Loops. *10th International Conference on the Environmental and Technical Implications of Construction with Alternative Materials* (WASCON, 2018).
- Gorgolewski, M. Designing with Reused Building Components: Some Challenges. *Building Research & Information* 36(2), 175-188 (2008).
- Grandry, H. *Reversible Design: Development of a Prefabricated External Wall System for Transformable Buildings > Research Explorer* (Vrije Universiteit Brussel, 2017).
- Henrotay, C. *A Contribution to an Integrated and More Sustainable Design Approach for the Material Support of Shelter after Disaster* (Vrije Universiteit Brussel, 2008).
- Herthogs, P. *Enhancing the Adaptable Capacity of Urban Fragments* (Vrije Universiteit Brussel, 2016).
- Herthogs, P., De Temmerman N. & De Weerd, Y. Assessing the Generality and Adaptability of Building Layouts Using Justified Plan Graphs and Weighted Graphs: a Proof of Concept. *Proceedings of the 3rd International Conference Central Europe towards Sustainable Building* (Czech Technical University, 2013).
- Hobbs, et al. *Buildings as Material Banks, D15: Reversible Building Design Guidelines and Protocol* (2018).
- Leupen, B. *Towards Time-based Architecture. Time-based architecture*, 12-20 (O10 Publishers, 2005).
- Leupen, B. *Frame and generic space* (O10 Publishers, 2006).
- Ogbu, L. *Design for Reuse primer (1.1)* (Public Architecture, 2010).
- Ost, T. *Demontabele bouwsystemen: een kijk op de markt* (Pixii Expert Day on Circular Construction, 2018).

OVAM. *Beleidsprogramma*

“Materiaalbewust Bouwen in Kringlopen”,
*Het Preventieprogramma Duurzaam
Materialenbeheer in de Bouwsector 2014-
2020* (OVAM, 2014).

Paduart, A. *Re-Design for Change: a 4
Dimensional Renovation Approach towards a
Dynamic and Sustainable Building Stock* (Vrije
Universiteit Brussel, 2012).

Paduart, A., De Temmerman, N., Trigaux, D.,
De Troyer, F., Debacker, W., Danschutter, S. &
Servaes, R. *Casestudy ontwerp van gebouwen
in functie van aanpasbaarheid: Mahatma
Gandhiwijk Mechelen* (OVAM, 2013).

Paduart, A., Elsen, S. & De Temmerman, N.
*DynamicWall: towards Reusable Partition
Systems* (Innoviris, 2015).

Romnée, A. & Vrijders, J. *Naar een circulaire
economie in de bouw: Inleiding tot de principes
van de circulaire economie in de bouwsector*
(Wetenschappelijk en Technisch Centrum voor
het Bouwbedrijf, 2018).

Schmidt, R., Eguchi, T., Austin, S. & Gibb, A.
What is the Meaning of Adaptability in the
Building Industry? *Proceedings of the 16th
CIB International Conference on Open and*

Sustainable Building, 17-19 (International
Council for Research and Innovation in Building
Construction, 2010).

Schomaker, A., Potočník, J. & Fricano, F.
*Promoting Remanufacturing, Refurbishment,
Repair, and Direct Reuse as a Contribution to
the G7 Alliance on Resource Efficiency* (2017).

Selleslag, I. *The Dynamic Design Matrix
as a Tool for the Analysis and Design of
Temporary Uses* (Vrije Universiteit Brussel,
2016).

Vandenbroucke, M. *Design, Dimensioning and
Evaluation of Demountable Building Elements*
(Vrije Universiteit Brussel, 2016).

Vandenbroucke, M. *Veranderingsgericht
bouwen, enkele demonteerbare
bouwoplossingen* (Pixii Expert Day on Circular
Construction, 2018).

Verberne, J. *Building Circularity Indicators,
an Approach for Measuring Circularity of a
Building* (Technische Universiteit Eindhoven,
2016).

Wahid, H. *Exploring Adaptability and
Generality in Antwerp's Residential Types*
(Vrije Universiteit Brussel, 2017).

Qualities



Reused
Hergebruikt
Réemployé



Recycled
Gerecycleerd
Recyclé



Renewed
Hernieuwd
Renouvelé



Compostable
Bioafbreekbaar
Compostable



Safe and Healthy
Veilig en gezond
Sûr et sain



Pure
Zuiver
Pur



Durable
Robuust
Solide



Simple
Eenvoudig
Simple



Manageable
Hanteerbaar
Maniable



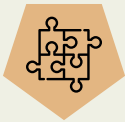
Accessible
Toegankelijk
Accessible



Reversible
Omkeerbaar
Réversible



Independent
Onafhankelijk
Indépendant



Compatible
Compatibel
Compatible



Multi-Purpose
Polyvalent
Polyvalent



Varied
Gevarieerd
Varié



Location and Site
Locatie en site
Emplacement et site

On www.vub.be/arch/circulardesign you can

download this publication in Dutch and French.

Building a Circular Economy

Design Qualities to Guide and Inspire Building Designers and Clients

Coordinator

Waldo Galle

Authors

Charlotte Cambier
Stijn Elsen
Waldo Galle
Wesley Lanckriet
Jeroen Poppe
Ineke Tavernier
Camille Vandervaeren

Project Supervisor

Niels De Temmerman

Graphic Design

Koen Verswijver

Printing

Bema-Graphics - Duffel

Publisher

Vrije Universiteit Brussel
VUB Architectural Engineering
Pleinlaan 2
1050 Brussels

Project Partners

UCLouvain
Rotor
Belgian Building Research Institute
Vrije Universiteit Brussel

ISBN

978-94-91912-13-9

Date of Publication

October 2019

Acknowledgements

This research is made possible thanks to the financial support of the European Regional Development Fund (ERDF) and the Brussels-Capital Region for the research project *Le Bâti Bruxellois : Source de nouveaux Matériaux* (BBSM). We thank all architects, engineers, experts and policy makers for their participation in this research.

Special gratitude goes to our research partners Anne Paduart, Émilie Gobbo, Sophie Trachte, André De Herde, Jeroen Vrijders, Ambroise Romnée, Florence Poncelet, Johan Van Dessel, Michaël Ghyoot, Lionel Devlieger, Lionel Billiet, Sophie Seys and André Warnier.

This document could be further developed and updated as new insights become available. The authors do not warrant that the content of this booklet is accurate, complete or up-to-date. Instead, readers are invited to share their suggestions and insights on www.vub.be/arch/circulardesign.

All rights reserved. No parts of this booklet may be reproduced or transmitted in any form or by any means without the prior written permission of the authors.

The editor has endeavoured to identify the copyright holders for all images. Any copyright holders that the editor was unable to identify are kindly requested to make themselves known in order to comply with relevant legislation.

This booklet has been produced in good faith, but it does not constitute advice. The authors and host institutions exclude all liability whether arising in contract, tort (including negligence) or otherwise, and will not be liable for any direct, indirect or consequential loss or damage, arising in connection with your use of, or reliance on, this booklet.



LE BATI
BRUXELLOIS
SOURCE DE
NOUVEAUX
MATERIAUX



Design Qualities to Guide and Inspire Building Designers and Clients

This publication facilitates the transition towards a circular construction sector through qualitative design choices; a sustainable practice wherein materials cycle in closed loops, using the resources we have access to as efficiently and effectively as possible. To do so, this booklet proposes a set of design approaches, qualities and concepts. Its open structure makes it a must-have for building designers, engineers and their clients.

**Through well-thought design choices, closing
material loops can be encouraged.
So, let's design out waste!**



EUROPEAN UNION
European Regional Development Fund



BRUSSELS-CAPITAL REGION

ISBN 978-94-91912-13-9



9 789491 912139 >