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back to bauhaus

Praxisreport 2022

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Reversible Building Design and Reversible BIM- Decoding circular capacity of buildings

At the core of all design concepts and interventions in the built environment lays the question: How urban interventions can eliminate negative impacts on ecological system (as degradation of biodiversity, pollutions, depletion of resources, climate change) and transform them into a positive ones.

The need to preserve the living conditions on the planet for future generations is one of the greatest challenges that humankind addresses today. According to the UN, the increasing consumption reflecting rapid growth of population and economic prosperity, resulted in tripling of raw material extraction in last three decades. Earth's resources and biocapacity to support human living and prosperity will be compromised if more effective and circular patterns of resource use are not implemented.

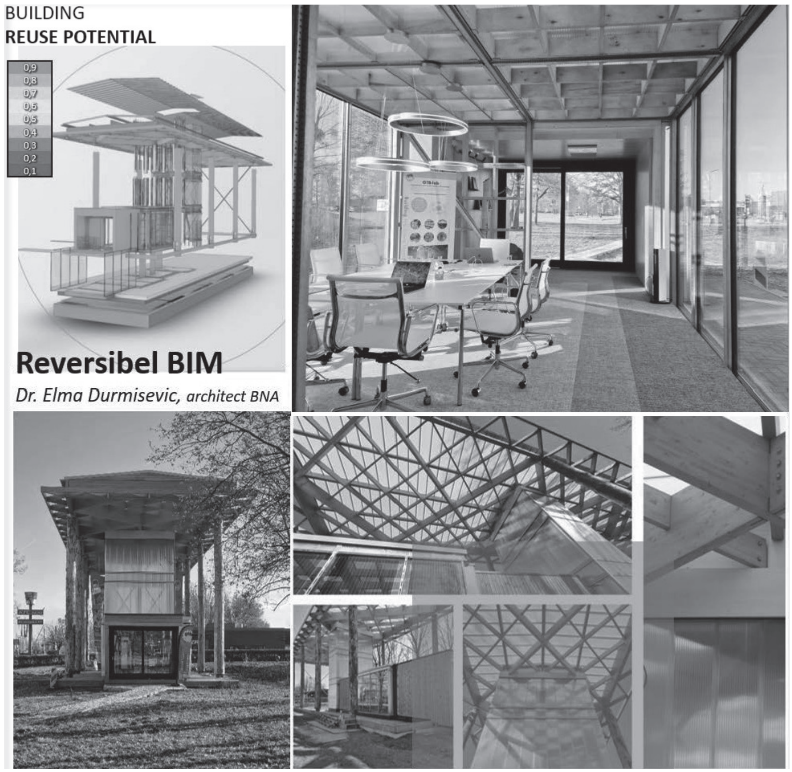
4D Architects is an architectural office based in Amsterdam.
The office was founded by dr. Elma Durmisevic in 1999.
The aim of the office is to contribute to the practice and theory of sustainable design and construction and promote the design of transformable structures which could bridge the gap between the green engineering demands, the changing market demands and the construction industry demands. The activities of the office are supported by Prof. Jan Brouwer, who has great experience in design of industrialized and energy efficient buildings and flexible systems.

Just published Circularity gap report argues that in order to bring human activities back within the safe limits of the planet, global material extraction and consumption would have to be reduced by one-third. (Circularity Gap Report, 2021). At the same time the report from 2021 indicated that almost 60% of the built environment required to accommodate urban population by 2050 remains to be built (Circularity Gap Report, 2021).

This indicates a huge gap between the need for resources and restrictions imposed by the planets biocapacity. This gap can only be bridged by multiple and effective reuse of resources and industrial concepts where waste does not exist and where rest materials from one process are resource for another.
Looking at the built environment the physical impact of increasing building mass has become undeniable. In Europe, the building sector accounts for 38% of the total waste production, 40% of the carbon dioxide (CO_2) emissions and 50% of all natural resources are used within construction (EIB, 2015).
This lecture presents a new concept for design and construction of buildings which will unlock multi-layered capacity of buildings and their materials and enable their different reuse options. Such approach envisions buildings and cities as material banks for the future.

This can be achieved by designing products and buildings in such a way that they can be reused with a minimum loss of value and without harmful emissions entering the environment. To achieve this Dutch government set up the 2050 ambition when construction industry will be organized in such a way, with respect to the design, development, operation, management, and disassembly of buildings, as to ensure the sustainable construction, use, reuse, maintenance, and dismantling of these objects. (Government-wide Program 2015).
Even though many European countries have adopted similar environmental goals and strategies not much progress has been done in implementing circular economy principles into construction sector.
Instead of increasing a % of circular economy within a global economy the presenting of circular economy dropped from 9,1% in 2018 to 7,5% in 2022. (Circularity Gap Report, 2021)

Figure 1:
Reversibel BIM © E.Durmisevic



Circularity capacity of exiting building stock

When looking at the building sector the reasons for such fall back of circular economy in last three years can be found in the fact that there are many unknowns related to the reuse capacity/potential and performance of buildings and construction materials. But more importantly buildings were never designed with recovery and reuse of its materials in mind. Buildings were perceived as static structures while their multi-layered capacity on spatial and structural level built up useing different materials with different functions, durability and use lifetime were not part of design and construction optimisation process. (Elma Durmisevic 2006) This has also been concluded by ground-breaking UIA Super Circular Estate Project in the Netherlands.

During this project a 10-story housing block has been deconstructed, 9 deconstruction and reuse techniques have been tested and three new buildings were built using materials from flat buildings.

The project aimed at gaining better understanding of reuse capacity of existing building materials and their environmental and economic impact. It has been concluded that recovery of materials form exiting buildings is very labour intensive because of complex recovery process, but also highly damaged materials are recovered, while their reparation or remanufacturing processes are demanding and costly. This has been reflected in the prise difference between houses built with reused materials compared with a prise of construction of conventional house.

The conventional house was 2,5 time less expensive. Based on lessons learned it has been recommended that circularity gap can be reduced by introducing financial incentives into a nowadays economy which will help to turn an economic weal towards circular economy such as for example increase of CO2 tax, tax on raw material and reduction of labour tax. (Elma Durmisevic 2021). But the key project's recommendation was to set up new rules for new construction which will foster construction of reversible building structures whose materials can be easily recovered and reused with higher value in the future.

Figure 2: Deconstruction and new construction with reused materials within UIA Super Circular Estate project Kerkrade the Netherlands © E.Durmisevic 2021

DIRECT REUSE

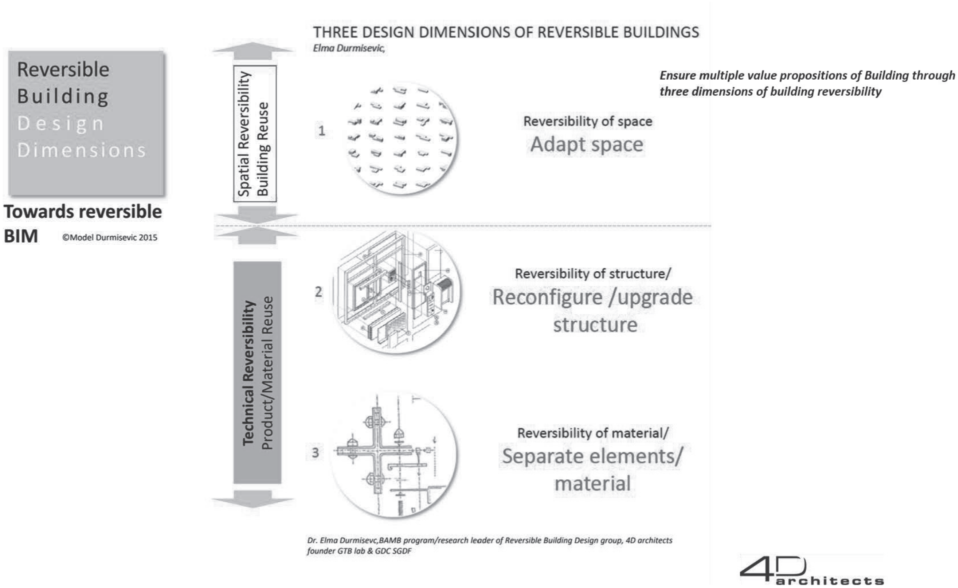
LOAD BEARING STRUCTURE OF HOUSE TYPE A AND B

New generation of circular reversible buildings

In order to move towards circular use of resources buildings need to be perceived as dynamic structures with multiple material layers and multiple reuse options relaying on reversibility of the building structure. Revisable Building is concept developed by E.Durmsevic which has been tested during H2020 BAMB project. Such dynamic reversible building has two pillars (i) Spatial Reversibility enabling modifications of buildings to meet different user needs without demolition and waste generation and (ii) Technical Reversibility which enables reconfiguration of structure, reuse of elements and separation of materials. (Durmisevic, 2019). with integrated systems, products and materials, Reversible building introduced three design dimension which are unlocking circularity potential of building and its materials being spatial, structural and material reversibility dimension.

Maturity of the tree building reversibility dimensions will determine circularity capacity of building and bult environment. By measuring individual design dimension of existing buildings and design solutions for new buildings it is possible to classify all buildings in a range form circular, partly circular and not circular buildings or building solutions. (Durmisevic, 2019). Suh approach has been further formalised through development of Reversible Building Design Tools.

Figure 3: Reversible Circular Buildings dimensions
© E.Durmisevic 2006



Development of comprehensive circularity tool which will measure all three dimensions of circularity resulting into a circularity profi- le of building requires a broader set of tools. The lecture presented a toolkit which managed to cluster all relevant tools that can support decision making duing design, transformation and deconstruction of an building into Reversible Building Design (RBD) toolkit.

RBD toolkit has been verified during Hori- zon2020 BAMB project aims to provide one stop shop for the development of circular buildings. RBD toolkit includes bought (i) design guide- lines and protocol for development of circular buildings (many are integrated into EU guide- lines for circular building design) (ii) assess- ment tools which can help to assess reversibi- lity performance of circular buildings (buildings transformation Capacity and Reuse Potential of its materials) (iii) decision support tool regar- ding reuse and deconstruction strategies. RBD tools are Transformation capacity tool, Virtual Simulator, Reuse Potential Tool and Reversible BIM tool. The tools have been tested and veri- fied during EU BAMB and Interreg NEW Digital Deconstruction projects (Figure 4).

Figure 4:
Reversible Building Design Tool kit on RBD platform
© E.Durmisevic

Transformation Capacity tool

Spatial reversibility of building is measured by transformation capacity (TC) tool which is BIM based and excl. based and addresses four indicators of building's ability to accommodate different building functions and user needs being: (1) dimension, (2) position of fixed cores, (3) disassembly and (4)capacity of loadbearing structure and installation cores. TC tool analyses interplay between fixed and variable spaces in a building and maps their ability to accommodate different use scenarios. When doing so Transformation Capacity tool looks into flexibility of technical aspects which determine energy and climate concepts of a building and its loadbearing capacity as well as spatial flexibility in terms of volume and hight in relation to the fixed parts of the building and their capacity to accommodate different use functions. Transformation score ranges from 01 to 0,9. For example TC score 0,1 means that building does not have transformation capacity and will be demolished at the and of use life. TC score 0,4 would mean that building can be transformed with major reparations and major demolition activates. TC score 0,9 means that building has high transformation Capacity and can change function and accommodate more than two use scenarios without demolition activities involved. (Durmisevic, 2019).

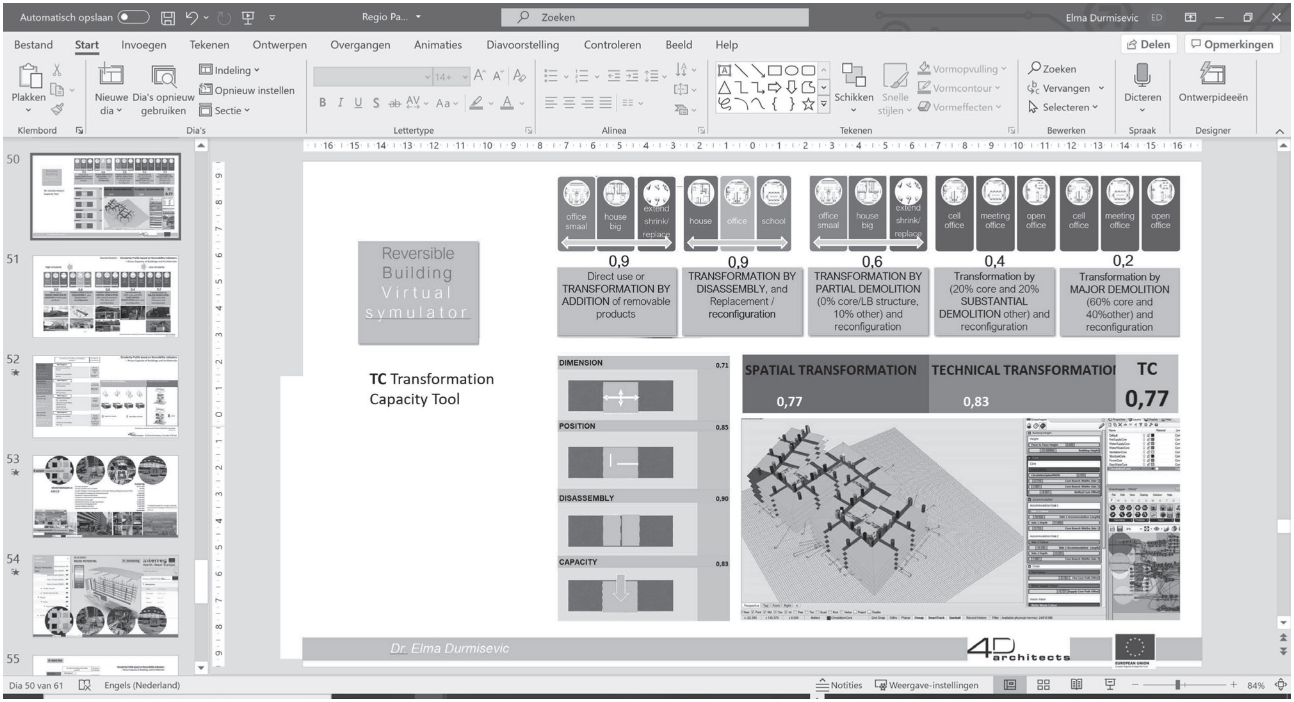
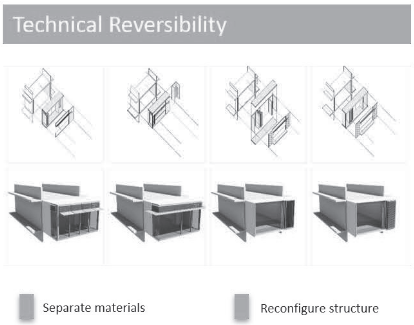


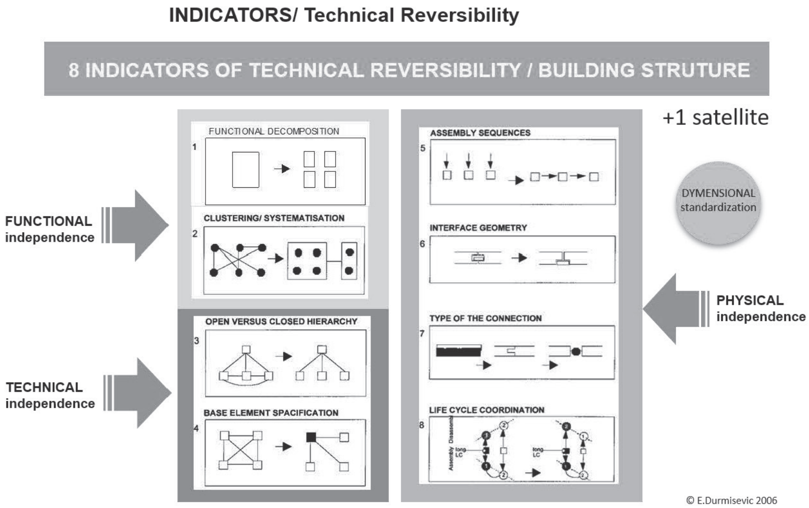
Figure 5:
Transformation Capacity (TC) Tool © E.Durmisevic

Reuse Potential Tool

Technical reversibility of building is measured by Reuse Potential tool which measures how ease an element can be recovered and reused without damages. The tool analyses functional, technical and physical dependences that elements have within a building structure. (Durmisevic, 2006). Reuse Potential tool calculation takes into account hierarchical dependence within assembly of building parts, pattern and number of relations between building elements, assembly sequences, base element of the assembly, level of prefabrication, geometry of product edge, type of connections, Life Cycle Coordination and remaining technical life Reuse Potential (RP) score (ranges between 0,1 worst and 0,9 best) sorts all building elements into three categories: (i) irreversible buildings (are building elements/materials with low Reuse Potential, materials are in degrading loop towards recycling and down cycling), (ii) partly reversible buildings (partial Reuse Potential, materials can be remanufactured or reused after major repair and (iii) reversible buildings (buildings whose materials can be directly reused or after minor repair or reconfiguration). Reversibility of buildings measured by Reuse Potential indicates reuse options that products and materials have after being recovered. As it measures the effort and time, the model also considers number of disassembly steps and operations needed to recover an element. Ultimately model's results form a solid base for environmental and economic assessment of disassembly and recovery operations (Figure 4). This calculation system is based on Model Durmisevic published in 2006 updated in 2009 and tested and verified during EU H2020 BAMB-Buildings as Material Banks Project (Durmisevic, 2006; Durmisevic 2019).

Figure 6: Indicators of technical reversibility of building being a part of Reuse Potential and transformation capacity calculation © E.Durmisevic, 2006





Reversible BIM

Reversible BIM module is a BIM software module based on model (Durmisevic, 2006; Durmisevic 2015), that based on captured cloud of points (from 3D scanning) and with use of Revit plugin for digital reversibility assessment, enables the reconstruction of the digital models of existing buildings covering spatial dimensions, relationships, quantities and reversibility properties of building and its components. Besides its application on exiting building I is used to asses reversibility of new design solutions as well.

Conventional BIM does not support above specified indicators of reversibility. Relations between objects are not easy to identify/distinguish and information is lacking regarding the type of connections. In order to upgrade conventional BIM towards Reversible BIM key data representing indicators of reversibility and reuse (as number of relations between elements, type of connections, assembly dependencies, number of assembly sequences) have been integrated into Revit by adding plugins. This has created a smooth transition from linear BIM towards circular /Reversible BIM (BAMB Book Strategies for Circular Building, Durmisevic, 2019).

Reversible BIM is the process of designing, constructing and operating a building (i) with the reversibility principles specified in model (Durmisevic, 2006) and (ii) with reuse of computer-generated object orientated information in mind. It is identified as a value maintaining and re-creating process through the multiple lifecycles of a building and its parts (Durmisevic, 2019).

Reversible BIM has two integral features:

1. **Digital Parametric representation of Building** with information about geometry, position, function, relations and connections between building elements. Digital representation of Building uses Reversible BIM template which is structured in a way that enables assessment of reversibility (i.e., disassembly and reuse potential) of building products, being the second feature of Reversible BIM. Reversible BIM translates 3D point-cloud files form 3D scanning into a standardised geometry and properties which enables digital reversibility analyses of the building and its materials.

Such reversibility assessment enables generation of reuse and disassembly strategies for high value recovery of components and materials.

2. **Digital Reversibility Assessment (DRA)** provides assessment of reversibility/Reuse potential using model of (Durmisevic, 2019; Durmisevic, 2020)., developed to assess how easy building products and materials can be recovered without damaging surrounding parts. It also links the assessment to multiple reuse options and category of reversibility of the building/product. The model measures effort and time needed to recover an element form the building as well as the level of damage that occurs during disassembly process (to the element itself and surrounding elements).

This Reversibility assessment is being carried out on three levels of building's technical composition (i.e., building, system and component level) (Durmisevic 2019, 2020).

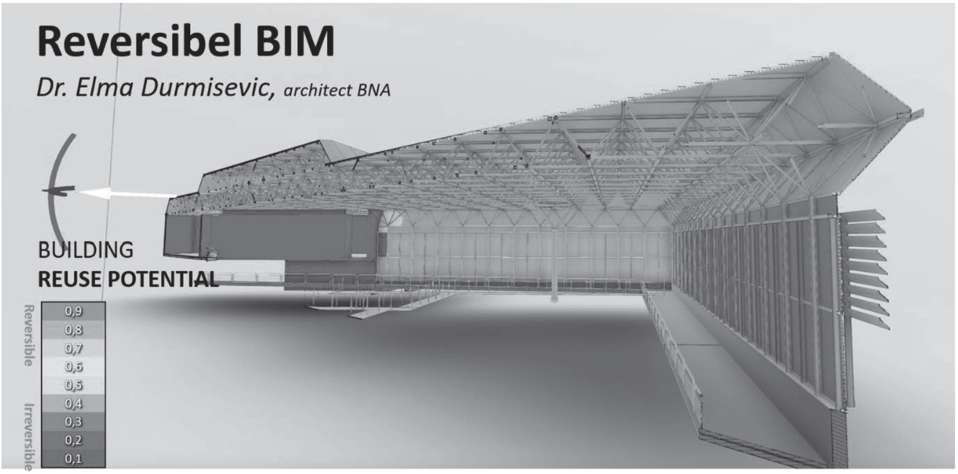
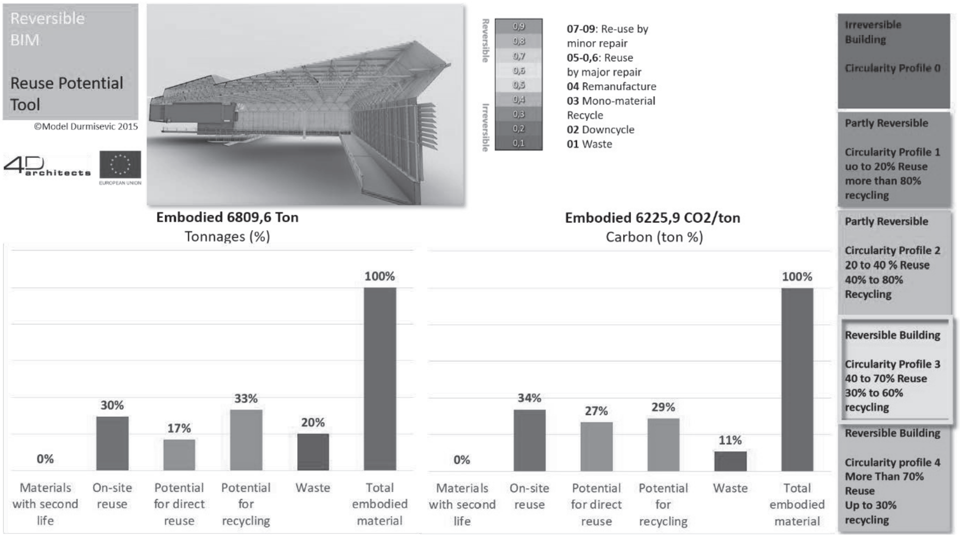


Figure 7: Colour coded Reversible BIM output indicating Reuse potential of Building Materials within Roman Museum Project in The Netherlands © E.Durmisevic

Figure 8: Digital modules integrated in Digital Deconstruction Platform © E.Durmisevic



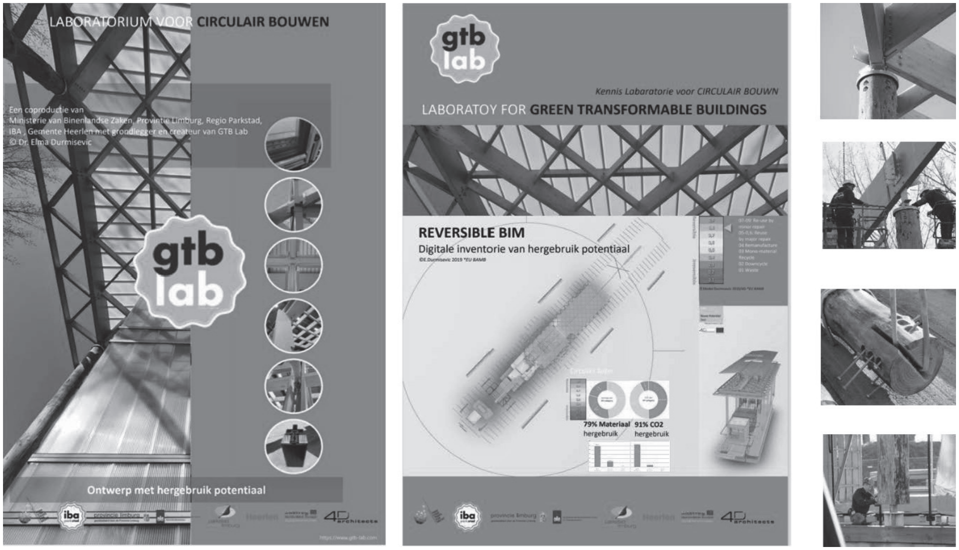
Laboratory for Circular Buildings-
Green Transformable Building Lab

In order to support transition towards circular economy in construction a laboratory for circular buildings in a form of Green Transformable Building Lab (GTB Lab) has been set up. GTB Lab is a light house and living lab in the Netherlands demonstrating use of reversible building design toolkit and application of design principles and construction methods that can unlock disassembly and reuse of building materials in a real-life project. The Lab has two pillars one of physical demonstration of circular building solutions and other focusing on testing of circular building tools (in particular Reversible Building Design tools addressed in previous paragraphs) and standardisation of circular building quality.

Figure 9:
Laboratory for Green Transformable Buildings founded by Elma Durmisevic 2018 © E. Durmisevic 2018

GTB lab brings together front running construction companies and public institutions in the Netherlands around a structure designed as dynamic building which is being transformed once a year showcasing design for transformation, disassembly and reuse.

Solutions tested in GTB Lab are further implemented in different projects by divers' groups of stakeholders. At the same time knowledge captured is being placed on ICT knowledge bank of GTB Lab and made available to all stakeholder groups in construction.
(https://knowledgeplatform.gtb-lab.com)
Next stapes in development towards circular buildings is to use knowledge from the physical experiments as well as Reversible Building Design Toolkit to support regional governments in transition towards circular buildings and standardisation of circular building quality that would set up a norm for future circular projects.



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