Integrated Decision Support for Circular, Industrialised & Bio-based Construction Works

by N. Cihan Kayacetin, Stijn Verdoort, Lode Lefevre and Alexis Versele
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Introduction

The Circular and Bio-based Construction Industry (CBCI) Interreg Project aims to standardize processes for achieving circular development in the construction sector. The outcomes of research are displayed in real-life settings via creation of living labs (LL).

This study investigates an integrated approach for supporting decision-making during design phase. Goals of the study are:

- Integration of circularity tools into current assessment tools
- Providing support for the design of LL Ghent
Decision Support

It was observed current life cycle assessment practices provide solid outcomes for environmental impact, but there is a need for integration with circularity tools for estimation of end-of-life (EoL) scenarios.

This study investigates the relationship between tools as seen below:

- **Circularity**
  - Reuse and recycling – BBRI Tool
  - Material flows – CB’23 Platform

- **Environmental impact**
  - Life cycle assessment (LCA)
Decision Support - Methodology

BBRI evaluation on reuse and recycling

- Result:
  - New material flows in CB’23
  - New percentages for end-of-life scenarios

Model LCA processes with new end-of-life scenario percentages

- Result:
  - Better impact for most of the circular materials

Compare the new results with standard TOTEM LCA results

- Result:
  - Estimate variation from standard LCA process
The Flemish Construction Confederation and BBRI introduce a tool to help developers, architects, contractors in the construction sector to support decision-making with a circular perspective. Four sections are available:

- change-oriented design
- environmental impact
- urban mining
- transition towards a circular world
For this study, ‘Design for reuse and recycling’ calculator is utilized, which is a part of the ‘Change-orientated design’ pillar. In the reuse and recycling calculator, the following properties are scored:

- avoided material impact
- functional independence
- technical detachability
- physical characteristics
- recyclability.
Platform CB’23 stimulates the transition to a circular and sustainable construction economy with a material quantification method. The method incorporates three aspects:

- preservation of material supplies
- environmental impacts and
- technical and economic value preservation
Inclusion of Module D in LCA for assessing benefits beyond lifetime is crucial for a circular building design.

- There are recommendations for assumed destinations for EoL in the existing LCA frameworks (TOTEM)
- There is a lack of methods on how to model EoL for a higher precision, and specifically for circular buildings.
LL Ghent follows the principles below in order to reach the above mentioned goals:

- Sustainability
- Circularity
- Bio-based materials use
- Industrial materials and methods
- Involvement of social economy
Case Study - LL Ghent

The Living Lab is a single terraced building prototype to be industrialized in a flexible and affordable way for renewal projects in vulnerable urban neighbourhoods. Novelty of the construction is:

- After the first assembly as a prototype on the Technology Campus of the KU Leuven, it will be disassembled and reassembled in one of the renewal areas in Ghent after the Interreg-project.
Nine preliminary designs (PD) were drafted to compare different materials and construction methods.

- PD1: Masonry - Traditional
- PD2: Masonry - Optimized
- PD3: Steel – Post-beam
- PD4: Steel framing
- PD5: Wood framing
- PD6: Wood – Post-beam-Insulated panel (IP)
- PD7: Wood – Structural Insulated (straw) Panel (SIP)
- PD8: Wood – Cross Laminated Timber (CLT)
- PD9: Wood – Insulated bock system

**Case Study - LL Ghent**

Heavy-weight

Light-weight

Bio-based
# Case Study - LL Ghent

<table>
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<th>PDs &amp; Comp</th>
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<th>2 - Side Façade</th>
<th>3 - Internal Wall</th>
<th>4 - Inclined Roof</th>
<th>5 - Floor</th>
<th>6 - Floor on Soil</th>
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<tr>
<td><strong>1 - Masonry</strong></td>
<td>Masonry wall brick finish</td>
<td>Masonry wall with slate finish</td>
<td>Brick and plaster and paint</td>
<td>I beam + mineral wool + roof tiles</td>
<td>Vaulted concrete with stone tiles</td>
<td>Concrete slab with stone tiles</td>
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<tr>
<td><strong>2 - Masonry Optimized</strong></td>
<td>Masonry wall with facade click finish</td>
<td>Masonry wall with slate finish</td>
<td>Gypsum board + bio-based paint</td>
<td>I beam + cellulose + roof tiles</td>
<td>Concrete with ceramic boxes + stone tiles</td>
<td>Glass granulate + wood finish</td>
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<tr>
<td><strong>3 - Steel Post Beam</strong></td>
<td>Steel structure Sandw. panel Aluminium cladding</td>
<td>Steel structure Sandwich panel</td>
<td>Gypsum board + bio-based paint</td>
<td>Steel structure Sandwich panel</td>
<td>Steel plate concrete Stone tiles</td>
<td>Concrete slab with stone tiles</td>
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<td><strong>4 - Steel Framing</strong></td>
<td>Steel framing Aluminium cladding</td>
<td>Steel framing Stale finish</td>
<td>Gypsum board + bio-based paint</td>
<td>Steel framing PUR insulation Steel sheeting</td>
<td>Steel profile Stone tiles</td>
<td>Concrete slab with stone tiles</td>
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<tr>
<td><strong>5 - Wood Framing</strong></td>
<td>Wood framing brick finish</td>
<td>Wood framing slate finish</td>
<td>Gypsum board + bio-based paint</td>
<td>I beam + mineral wool + roof tiles</td>
<td>Trusses Wood finish</td>
<td>Concrete slab with stone tiles</td>
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<tr>
<td><strong>6 - Wood Post Beam</strong></td>
<td>Caisson + osb Ceramic finish</td>
<td>Caisson+osb Slate finish</td>
<td>Gypsum board + bio-based paint</td>
<td>Caisson+osb Mineral wool roof tiles</td>
<td>Trusses Caisson+osb Wood finish</td>
<td>Caisson+osb Wood finish</td>
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<tr>
<td><strong>7 - Wood SIP Straw</strong></td>
<td>Timber framing Straw bale</td>
<td>Timber framing Straw bale Slate finish</td>
<td>Gypsum board + bio-based paint</td>
<td>I beam + cellulose + roof tiles</td>
<td>Trusses Engineering wood floor</td>
<td>Sea shells Pearls Wood finish</td>
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<tr>
<td><strong>8 - Wood CLT</strong></td>
<td>CLT Wood fibre</td>
<td>CLT Wood fibre Shield</td>
<td>Gypsum board + bio-based paint</td>
<td>CLT Wood fibre</td>
<td>Trusses CLT</td>
<td>Concrete slab Resol insulation</td>
</tr>
<tr>
<td><strong>9 - Wood Modular Block</strong></td>
<td>Modular blocks Wood fibre Wood finish</td>
<td>Modular blocks Wood fibre Slate finish</td>
<td>Gypsum board + bio-based paint</td>
<td>I beam + cellulose + roof tiles</td>
<td>Modular block Cork insulation</td>
<td>Concrete slab Resol insulation</td>
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</tbody>
</table>
Results - Circularity

Demontability - Reuse & Recycling

Preservation of materials (kg/m²)

-400  0  200  400  600  800  1000  1200

Reused  Recycled  Landfilled  Incinerated  BBRI-VCB

PD1 - Masonry (baseline)  PD2 - Masonry optimized  PD3 - Steel post beam  PD4 - Steel framing  PD5 - Wood framing  PD6 - Wood post beam  PD7 - Wood SIP - straw  PD8 - Wood CLT  PD9 - Modular blocks
Results – Impact Assessment

![Chart showing results of impact assessment for different construction methods.](chart.png)
## Results - Integration - CB’23 revised

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Landfilled</th>
<th>Incinerated</th>
<th>Reused</th>
<th>Recycled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masonry traditional</td>
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<tr>
<td>Masonry optimised</td>
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<tr>
<td>Steel post-beam</td>
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<tr>
<td>Steel framing</td>
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<tr>
<td>Wood framing</td>
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<tr>
<td>Caisson post-beam</td>
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<tr>
<td>Wood SIP straw</td>
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<tr>
<td>CLT</td>
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<tr>
<td>Wood insulated block system</td>
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</tbody>
</table>

### Front facade (kg/m²)

- **Masonry traditional**
- **Masonry optimised**
- **Steel post-beam**
- **Steel framing**
- **Wood framing**
- **Caisson post-beam**
- **Wood SIP straw**
- **CLT**
- **Wood insulated block system**
Results – Integration – CB’23 revised

Inclined roof (kg/m²)

- Masonry traditional
- Masonry optimised
- Steel post-beam
- Steel framing
- Wood framing
- Caisson post-beam
- Wood SIP straw
- CLT
- Wood insulated block system

Categorisation:
- Landfilled
- Incinerated
- Reused
- Recycled

Inclined roof (kg/m²)

- Masonry traditional
- Masonry optimised
- Steel post-beam
- Steel framing
- Wood framing
- Caisson post-beam
- Wood SIP straw
- CLT
- Wood insulated block system

Categorisation:
- Landfilled
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- Reused
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Results – Integration – CB’23 revised

- Masonry traditional
- Masonry optimised
- Steel post-beam
- Steel framing
- Wood framing
- Caisson post-beam
- Wood SIP straw
- CLT
- Wood insulated block system

Floor (kg/m²)

- Landfilled
- Incinerated
- Reused
- Recycled
Results – Integration – LCA revised

Monetisation of CEN indicators (€/m² GFA)

- PD1 - Masonry traditional
- PD2 - Masonry optimised
- PD3 - Steel post-beam
- PD4 - Steel framing
- PD5 - Wood framing
- PD6 - Caisson post-beam
- PD7 - Wood SIP straw
- PD8 - CLT
- PD9 - Wood insulated block system

Life cycle impact (A-D)  Impact reduction (DfD)  Impact reduction (D)
Conclusions

It was observed that the EoL scenarios have significant impact on long-term decision making:

- Existing EoL percentages depending on business-as-usual do not represent the reuse and recycling potential.
- Available circularity tools can provide insight on these potentials.
- Integrated LCA results show that new assumptions on circularity potential have significant impact on impact assessment.
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Visit our website: www.CBCI.eu
N. Cihan Kayaçetin, Arch, PhD
Post-doctoral researcher, KU Leuven
Building Physics and Sustainable Design
cihan.kayacetin@kuleuven.be