Consistent BIM-led LCA during the entire building design process

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Introduction

- Life Cycle Assessment (LCA) is a suitable method for holistic evaluation of the environmental performance of buildings
- Most time for LCA of buildings is spent on gathering the necessary information
- Building Information Modelling (BIM) can provide the necessary input and speed up the process
Early design

- Revit, Navisworks, Excel, API
- 200 Revit, GBS, ATHENA Impact Estimator, Excel
- Dprofiler, CostLab, eQUEST, SimaPro, ATHENA EcoCalculator, Excel
- Revit, Dynamo, Excel
- Revit, Excel
- Revit, Excel, SIMIEN, SimaPro 7.3
- Grasshopper, Rhinoceros
- Revit, Excel, SIMIEN, SimaPro 7.3
- BIM tool (N/S), Excel
- Revit, Ecotect, IESVE, Excel, Athena Impact Estimator
- Revit, Athena Impact Estimator, Excel
- 300 Revit, Korea LCI database
- Grasshopper, Design Builder, DIVA, Ladybug, Galapagos, Octopus, Rhinoceros
- Revit, Revit DB link, MS Access, Athena Impact Estimator, Excel, Visual Studio
- Revit, Tally, GBS
- Revit, Revit API, External db
- Revit, Insight
- Revit, Ecotect, Excel
- Revit, Dynamo, Excel
- Revit, Power Pivot, FME, Google Maps API
- Revit, Dynamo, MySQL, Grasshopper, Slingshot, Archsim, Octopus, EnergyPlus
- Revit, Excel
- ArchiCAD, Excel
- 300 Revit, Excel, Glondon BIM5D, eBALANCE, Designbuilder,

Detailed design

LOD 200 Tools
- Revit, GBS, ATHENA Impact Estimator, Excel
- Dprofiler, CostLab, eQUEST, SimaPro, ATHENA EcoCalculator, Excel
- Revit, Dynamo, Excel
- Revit, Excel
- Revit, Excel, SIMIEN, SimaPro 7.3
- Grasshopper, Rhinoceros
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- BIM tool (N/S), Excel
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Risk

Focusing on only known data during design doesn’t allow to optimise

Environmental impact

Design phase

LCA results
- Unknown data
- Known data
Problem

- Current BIM-LCA approaches are defined for a specific design stage / Level of Development (LOD) and do not allow for consistent feedback from early to detailed design stages.

- Only assessing the defined components misses a large share of the impact.
Develop a framework to

- use LCA as a consistent decision-making tool during all phases of the design process.
- consider the available information in the BIM model with as much accuracy as possible in each design stage.
Method

1. Definition of an evolution of LOD
2. Consistent combination of LCA databases
3. Link between LODs and LCA databases

1.A Definition of design phases
1.B Definition of LODs
1.C Definition of element categories
1.D LOD evolution
1A Design stages

1. Project Planning (PP)
2. Project (P)
3. Building Permit Application (BPA)
4. Tendering (T)
5. Construction (C)
1B LODs

Pre-LOD | LOD 100 | LOD 200 | LOD 300 | LOD 400

m² floor area
1C Element categories

Construction categories
1. Structure (C)
2. Envelope (E+F)
3. Interior (G)
4. Technical equipment (D)

Architectural elements
1. Base plate / foundation
2. Exterior wall under ground
3. Exterior wall above ground
4. Window
5. Interior wall
6. Partition wall
7. Column
8. Ceiling
9. Balcony
10. Roof
11. Technical equipment*
1D LOD evolution

LOD 400
LOD 300
LOD 200
LOD 100

Early design stages
Detailed design stages

Structure
Technical equipment
Envelope
Interior

PP P BPA T C t
2 LCA databases

- **Per material***: KBOB list “Ökobilanzdaten im Baubereich 2009/1:2016”
  (https://www.kbob.admin.ch/kbob/de/home/publikationen/nachhaltiges-bauen/oekobilanzdaten_baubereich.html)

- **Per component***: Bauteilkatalog
  (http://www.bauteilkatalog.ch/ch/de/Bauteilkatalog.asp)


*background data based on Ecoinvent 2.2*
### 3 Link between LOD and database

<table>
<thead>
<tr>
<th>LOD</th>
<th>Database</th>
<th>Use of Database</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>Swiss Buildings Database</td>
<td>Average value at building level</td>
</tr>
<tr>
<td>100</td>
<td>Bauteilkatalog</td>
<td>Average value at building element level</td>
</tr>
<tr>
<td>200</td>
<td>Bauteilkatalog</td>
<td>Average value at building component level</td>
</tr>
<tr>
<td>300</td>
<td>Bauteilkatalog</td>
<td>Specific value at building component level</td>
</tr>
<tr>
<td>400</td>
<td>KBOB</td>
<td>Specific value at material level</td>
</tr>
<tr>
<td>LOD 400</td>
<td>LOD 300</td>
<td>LOD 200</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>Hard wood</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Wood fibre insulation board</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Concrete</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Reinforcement steel</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Pine wood</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Larch wood</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Plaster</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Hard wood</td>
<td>GWP</td>
<td>GWP</td>
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<tr>
<td>Gypsum</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Paint</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Gypsum finishing</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Paint</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Wooden finishing</td>
<td>GWP</td>
<td>GWP</td>
</tr>
<tr>
<td>Paint</td>
<td>GWP</td>
<td>GWP</td>
</tr>
</tbody>
</table>
### Case study

<table>
<thead>
<tr>
<th>Architectural element</th>
<th>Area [m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Base plate / foundation</td>
<td>228.0</td>
</tr>
<tr>
<td>2. Exterior wall under ground</td>
<td>183.0</td>
</tr>
<tr>
<td>3. Exterior wall above ground</td>
<td>723.5</td>
</tr>
<tr>
<td>4. Window</td>
<td>200.7</td>
</tr>
<tr>
<td>5. Interior wall</td>
<td>1368.1</td>
</tr>
<tr>
<td>6. Partition wall</td>
<td>391.4</td>
</tr>
<tr>
<td>7. Column</td>
<td>0</td>
</tr>
<tr>
<td>8. Ceiling</td>
<td>1140.0</td>
</tr>
<tr>
<td>9. Balcony</td>
<td>90.0</td>
</tr>
<tr>
<td>10. Roof</td>
<td>228.0</td>
</tr>
<tr>
<td>11. Technical equipment</td>
<td>912.0*</td>
</tr>
</tbody>
</table>
Results for embodied Global Warming Potential

![Diagram showing embodied Global Warming Potential for different stages of construction, including Pre-Design, Project Planning (PP), Project (P), Building Permit Application (BPA), Tendering (T), and Construction (C). The diagram compares Swiss buildings Db with Bauteilkatalog and KBOB.]
## Sensitivity towards LOD evolution

<table>
<thead>
<tr>
<th>Building components</th>
<th>Design phases</th>
<th>PP</th>
<th>P</th>
<th>BPA</th>
<th>T</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structure</td>
<td>100</td>
<td>300</td>
<td>400</td>
<td>400</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Envelope</td>
<td>100</td>
<td>200/300</td>
<td>300</td>
<td>400</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Technical equipment</td>
<td>100</td>
<td>200</td>
<td>200/300</td>
<td>300/400</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Interior</td>
<td>100</td>
<td>200</td>
<td>200</td>
<td>200/300</td>
<td>400</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing environmental impact across different design phases](image)

- **Graph Description**: The graph illustrates the environmental impact (kg CO₂ eq/m²) for different design phases (Pre-design, PP, P, BPA, T, C) across building components. The colors represent maximum, minimum, and average environmental impact.

- **Key Takeaways**:
  - Structure shows a peak environmental impact in the BPA phase.
  - Envelope has a lower impact with a notable increase in the PP phase.
  - Technical equipment and Interior components have moderate impacts with slight variations across phases.

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Conclusions and future developments

- Mixing various LOD and LCA databases works (identical background data)
- Low sensitivity towards LOD choices
- Forecast of the final environmental impact
- LCA for decision support (always as accurate as possible)
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- Mixing various LOD and LCA databases works (identical background data)
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- Integration of operational environmental impact
- Framework developed for Swiss context -> transfer to other countries
- Implementation as tool for BIM software
Thank you very much for your attention!