The circular supermarket chain

Introducing the Circular Economy in the Building Specification

Arko van Ekeren
4141016
06-07-2018
Building industry is responsible for 50% all waste.
The Lidl and circularity

415 Stores

Small renovation
8 years

Large renovation
20 years
The Lidl and circularity
Which changes have to be made to make the Lidl’s Specification circular, with an emphasis on materials and assembly?
Introduction

Methodology

Literature

- Circularity Principles
- Specification Definition
- Assessment methods

Analysis

- Specification Analysis

Case study

- Analysis original roof

Design

- Technical Redesign
- Green Redesign

Research Question

Circular Specification
1. Assessment method
2. Specification analysis
3. Changes to the Lidl’s Specification to make it circular
Principles of the Circular Economy

What are the principles for circularity in the built environment?
Principles of the Circular Economy

- Eliminate waste
- Maintain value
- Employ renewable sources
Introduction

Principles of the Circular Economy
How is the Dutch Specification currently implemented?
**Dutch Specification**

<table>
<thead>
<tr>
<th>Cycles</th>
<th>Sub Phases</th>
<th>Initiation</th>
<th>Preparation</th>
<th>Realisation</th>
<th>Use</th>
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<tr>
<td>1.</td>
<td>Intiative</td>
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<td>Attainability study</td>
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<td>3.</td>
<td>Project definition</td>
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<td>4.</td>
<td>Concept design</td>
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<td>Preliminary design</td>
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<td>6.</td>
<td>Final design</td>
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<td>Bestek</td>
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<td>8.</td>
<td>Price negotiation</td>
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<td>9.</td>
<td>Work preparation</td>
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<td>10.</td>
<td>Realisation</td>
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<td>11.</td>
<td>Finished product</td>
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<tr>
<td>12.</td>
<td>Maintenance</td>
<td></td>
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</tr>
<tr>
<td>13.</td>
<td>Demolition</td>
<td></td>
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</tr>
</tbody>
</table>
What are the current methods to assess the level of circularity in building designs?
Material Circularity Indicator

Disassembly Potential

1. Functional Decomposition
2. Clustering/Systematisation
3. Open Versus Closed Hierarchy
4. Base Element Specification
5. Assembly Sequences
6. Interface Geometry
7. Type of the Connection
8. Life Cycle Coordination
What are the circular bottlenecks in the current Lidl’s Specification?
<table>
<thead>
<tr>
<th>SITE</th>
<th>STRUCTURE</th>
<th>SKIN</th>
<th>SERVICES</th>
<th>SPACEPLAN</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 - Stut- en sloopwerken</td>
<td>20 - Funderinspalen en damwanden</td>
<td>30 - Kozijnen ramen en deuren</td>
<td>51 - Binnenriolering</td>
<td>41 - Tegelwerken</td>
</tr>
<tr>
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<td>21 - Betonwerken</td>
<td>31 - Systeembekleding</td>
<td>52 - Waterinstallaties</td>
<td>42 - Dekvloeren en vloersystemen</td>
</tr>
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<td>13 - Bemaling</td>
<td>22 - Metselwerken</td>
<td>33 - Dakbedekking</td>
<td>53 - Sanitair</td>
<td>43 - Metaal- en kunststofwerken</td>
</tr>
<tr>
<td>14 - Buitenriolering en drainage</td>
<td>24 - Ruwbouwtimmerwerk</td>
<td>34 - Beglazing</td>
<td>54 - Brandbestrijdingsinstallaties</td>
<td>44 - Plafond- en wandsystemen</td>
</tr>
<tr>
<td></td>
<td>25 - Metalen draagconstructies</td>
<td>35 - Natuur- en kunststeen</td>
<td></td>
<td>45 - Afbouwtimmerwerk</td>
</tr>
<tr>
<td></td>
<td></td>
<td>37 - Isolatie</td>
<td></td>
<td>46 - Schilderwerk</td>
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<td></td>
<td></td>
<td>38 - Gevelschermen</td>
<td></td>
<td>48 - Vloerbedekking</td>
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<td>40 - Stukadoorwerken</td>
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<td>22 - Metselwerken</td>
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<td></td>
<td>25 - Metalen draagconstructies</td>
<td></td>
<td>24 - Ruwbouwtimmerwerk</td>
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</tbody>
</table>

- SITE: Site works
- STRUCTURE: Structural works
- SKIN: Skin works
- SERVICES: Service works
- SPACEPLAN: Space planning

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Sand-lime brick
Sand-lime brick
## Sand-lime brick

![Sand-lime brick image]

### Feedstock

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>Value/functional unit</th>
<th>180.1 kg/m²</th>
<th>€100</th>
<th>€/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Harvest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Virgin Feedstock</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recycled</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reused</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Recycling Efficiency

- **UF 4.5**
  - Recycling Efficiency: 4.5
  - Value Potential: €30,-
  - Cost: €70,-
Sand-lime brick

Feedstock
- Renewable Harvest
- Virgin Feedstock
- Recycled
- Reused

End-of-life
- Landfill
- Incinerated
- Recycled
- Reused
- Composting

Value/functional unit: 180.1 kg/m²
Cost: €100 €/m²

Recycling Efficiency: 4.5

Value Potential
- Cost: €30,- €70,-
Sand-lime brick

Feedstock
- Renewable Harvest
- Virgin Feedstock: 80%
- Recycled: 20%
- Reused

End-of-life
- Landfill: 8%
- Incinerated
- Recycled: 92%
- Reused
- Composting

Value Potential
- Cost: €100,-
- Value used: €30,-
- Value left: €70,-

Life Span
- Technical LS: 75+
- Functional LS: 50, 25, 25

Value left
- MCI
- LFI

UF
- 0.47
- 4.5
**Sand-lime brick**

### Life Span

**Technical LS**
- 0
- 25
- 50
- 75+

**Functional LS**
- 0
- 25
- 50
- 75+

### Value Potential

**Cost**
- €100,-

**Value used**
- €30,-

**Value left**
- €70,-

### Recycling Efficiency

- UF: 4.5
- MCI: 0.37
- LFI: 0.14

### Feedstock

- Renewable Harvest
- Virgin Feedstock
- Recycled
- Reused
- Landfill
- Incinerated
- Composting

### Feedstock (Technical LS)

- Value-functional unit: 180.1 kg/m²
- €100 €/m²

### Feedstock (Functional LS)

- Value-functional unit: 4.5
- €30,-
- €70,-
**Steel beams**

<table>
<thead>
<tr>
<th>Analysis</th>
<th>Case study</th>
<th>Redesign</th>
<th>Reimplementation</th>
</tr>
</thead>
</table>

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Steel beams

Introduction

Analysis

Case study

Redesign

Reimplementation

Steel beams

value/-
functional
unit

60 kg/m²
€n.d. €/m²

Feedstock

Renewable Harvest

Virgin Feedstock

Recycled

Reused

End-of-life

Landfill

Incinerated

Recycled

Reused

Composting

LFI 0.25
Steel beams

Introduction

Analysis

Case study

Redesign

Reimplementation

Value Potential

Cost

Value used

Value left

MCI

Life Span

Technical LS

Functional LS

Feedstock

Value/functional unit

60 kg/m²
€n.d. €/m²

Renewable Harvest

Virgin Feedstock

Recycled

Reused

End-of-life

Landfill

Incinerated

Recycled

Reused

Composting

LFI

UF

MCI

0.25
0.9
0.78

Value Potential

Cost

Value used

Value left

MCI

0 1

Life Span

75+
50
25
0

Technical LS

Functional LS

Steel beams
<table>
<thead>
<tr>
<th>Specification Code</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Height (m)</th>
<th>Wall Thickness (mm)</th>
<th>Number of Stories</th>
<th>Building Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>10.5</td>
<td>7.5</td>
<td>8.0</td>
<td>250</td>
<td>5</td>
<td>Office</td>
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<tr>
<td>02</td>
<td>12.0</td>
<td>10.0</td>
<td>10.0</td>
<td>200</td>
<td>6</td>
<td>Residential</td>
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<tr>
<td>03</td>
<td>15.0</td>
<td>15.0</td>
<td>10.0</td>
<td>150</td>
<td>7</td>
<td>Commercial</td>
</tr>
</tbody>
</table>

**Analysis**

**Step 1: Calculate Volume of Materials**

- Concrete: 1500 m³
- Steel: 500 tons
- Glass: 1000 m²

**Step 2: Calculate Unrecoverable Waste**

- Concrete: 150 m³ (10%)
- Steel: 40 tons (8%)
- Glass: 100 m² (10%)

**Case Study**

**Reimplementation**

- New Design Concept
- Increased Energy Efficiency
- Improved Structural Stability

**Redesign**

- Exterior Facade
- Interior Layout
- Space Utilization

**Introduction**

- Overview of the Project
- Objectives
- Scope

**Specifications**

- Material Grades
- Construction Practices
- Safety Measures

**Technical Details**

- Floor Plans
- Elevations
- Sections

**Technical Drawings**

- Structural Diagrams
- Mechanical Systems
- Electrical Layouts

**Material List**

- Concrete
- Steel
- Glass
- Wood

**Cost Estimation**

- Labor Costs
- Material Costs
- Overhead Costs

**Project Schedule**

- Milestones
- Gantt Chart
- Risk Management

**Environmental Impact**

- Carbon Footprint
- Water Consumption
- Energy Consumption

**Project Team**

- Architects
- Engineers
- Contractors

**Project Timeline**

- Project Initiation
- Design Development
- Construction
- Post-Construction

**Project Budget**

- Total Cost
- Budget Allocation
- Change Orders

**Project Management**

- Project Management Plan
- Quality Control
- Change Management

**Risk Management**

- Risk Identification
- Risk Assessment
- Risk Response

**Sustainability**

- LEED Certification
- Green Building Practices
- Renewable Energy Sources

**Conclusion**

- Key Learnings
- Recommendations
- Future Opportunities
Functional life span

Structure
- Beton 21.04
- Kalkzand-steen 22.02
- Baksteen 22.02
- Spouwmuur isolatie 22.03
- Staal constructie 25.03
- Staaldak 25.04
- Kozijnen 30
- Gevel bekleding 31
- LD-PE 33.03
- Isolatie 37
- FPO 33.05
- Leidingen 52
- Tegelwerk wand 41.02
- Tegelwerk vloer 41.04
- Raster plafond 44
- Kalkzand-steen binnenwand 22.02
- HSB 24.04

Skin

Service

Space Plan

Analysis
### Specification Analysis

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<tr>
<th>SKIN</th>
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<tbody>
<tr>
<td>30 - Kozijnen ramen en deuren</td>
<td>Sufficient</td>
</tr>
<tr>
<td>31 - Systeembekleding</td>
<td>Partially sufficient</td>
</tr>
<tr>
<td>33 - Dakbedekking</td>
<td>Insufficient</td>
</tr>
<tr>
<td>34 - Beglazing</td>
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</table>
How can a building system, as described in the Specification, be redesigned into a circular one?
Disassembly Potential

TC = 0.44

30% - 70% demolition
Assembly (A)
Assembly (A)

Case study

Corrugated steel
Case study

LD-PE Vapour
Case study

FPOBarrier
Material Circularity

Steel load-bearing structure
Sendzimir profile plate
PIR Insulation
FPO (sarna filament TS 77-20)
Material Circularity

Feedstock

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight (kg/m²)</th>
<th>Circular (%)</th>
<th>Linear (%)</th>
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<tbody>
<tr>
<td>Steel load-bearing structure</td>
<td>60</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Sendzimir profile plate</td>
<td>6.9</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>PIR Insulation</td>
<td>4.8</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>FPO (sanafill TS 77-20)</td>
<td>3.3</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

Renewable | Virgin | Recycled | Reused
Material Circularity

**Feedstock**
- Steel load-bearing structure: 60 kg/m²
- Sendzimir profile plate: 6.9 kg/m²
- PIR Insulation: 4.8 kg/m²
- FPO (sarnafil TS 77-20): 3.3 kg/m²

**End-of-life**
- Steel load-bearing structure: 100%
- Sendzimir profile plate: 100%
- PIR Insulation: 100%
- FPO (sarnafil TS 77-20): 100%
Material Circularity

<table>
<thead>
<tr>
<th>Feedstock</th>
<th>End-of-life</th>
<th>LFI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel load-bearing structure</td>
<td>0% 100%</td>
<td>0.20</td>
</tr>
<tr>
<td>60 kg/m²</td>
<td></td>
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</tr>
<tr>
<td>Sendzimir profile plate</td>
<td>0% 100%</td>
<td>0.20</td>
</tr>
<tr>
<td>6.9 kg/m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIR Insulation</td>
<td>0% 100%</td>
<td>1.00</td>
</tr>
<tr>
<td>4.8 kg/m²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FPO (sarnafil TS 77-20)</td>
<td>0% 100%</td>
<td>0.58</td>
</tr>
<tr>
<td>3.3 kg/m²</td>
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</tr>
</tbody>
</table>

Structure and roof MCI

Total LFI = 0.25

Roof only MCI

Total LFI = 0.54
Material Circularity

Feedstock

- Steel load-bearing structure: 60 kg/m² (60% recycled, 40% virgin)
- Sendzimir profile plate: 6.9 kg/m² (60% recycled, 40% virgin)
- PIR Insulation: 4.8 kg/m² (100% recycled)
- FPO (sarna fill TS 77-20): 3.3 kg/m² (100% recycled)

End-of-life

- Weight
  - Landfill: 0%
  - Incinerated: 0%
  - Recycled: 100%
  - Reused: 0%
  - Composted: 0%

LFI

- Steel load-bearing structure: 0.20
- Sendzimir profile plate: 0.20
- PIR Insulation: 1.00
- FPO (sarna fill TS 77-20): 0.58

Utility Factor

- MCI: 0.20
- LFI: 0.82
- MCI: 0.20
- LFI: 0.31
- MCI: 1.00
- LFI: 0.00
- MCI: 0.58
- LFI: 0.22

Structure and roof MCI

Total LFI = 0.25

Roof only MCI

Total LFI = 0.54
Material Circularity

**Structure and roof MCI**

- **Total LFI** = 0.25
- **Total MCI** = 0.69

**Roof only MCI**

- **Total LFI** = 0.54
- **Total MCI** = 0.19
What did we learn?

FD SYS
BE
LCC
RPA
G
C
Green
Technical
Green Redesign
Load-bearing Structure
Sandwich panel System
Introduction

Analysis

Case study

Redesign

Reimplementation

Accoya Gluelam

ECOBoard

Metisse

Derbipure
**Disassembly Potential**

- **Functional Decomposition**
- **Systematisation**
- **Base Element**
- **LifeCycle Coordination**
- **Assembly**
- **Geometry**
- **Connections**
- **Relational Pattern**

TC = 0.81

0% - 30% demolition
Green Redesign

System

Component

Element

Material

ml = 0.8

Clustering to functionality

c = 1
Green redesign

Material Circularity

**Feedstock**

- **ECOBoard**: 8.9 kg/m²
- **Vapour Barrier (LD-PE)**: 0.2 kg/m²
- **Metisse**: 5.04 kg/m²
- **Derbipure**: 3.2 kg/m²

**End-of-life**

- **Landfill**
- **Incinerated**
- **Recycled**
- **Reused**

**LFI**

- **0.02**
- **0.5**
- **0.08**
- **0.5**

**Utility Factor**

- **0.02**
- **0.5**
- **0.08**
- **0.5**

**MCI**

- **0.97**
- **0.55**
- **0.93**
- **0.55**

**Green redesign MCI**

- **Total LFI = 0.37**
- **Total MCI = 0.52**
Technical Redesign

Technical
Technical Redesign

Make it generic
Technical Redesign

Original

- PIR

Recyclable

- Rockwool

(FPO) Sarnafil 77 - 20

Derbipure
Material Circularity

Technical Redesign

Total LFI = 0.37
Total MCI = 0.52
Which changes have to be made to make the Lidl’s Specification circular, with an emphasis on materials and assembly?
Development strategy - linear
Development strategy - reuse
Development strategy - fully circular
Changes

- Non-circular materials to circular materials, which can be exonomicly-recycled or are renewable.
- Enable reuse, remove static construction methods make all connections reversible.
- Make dimensions and connections generic
- Implement criteria from the Circualrity Indicator to the Specification.
- Change the development strategy, reuse elements and components which are still preforming at their technical
Recommendation further research

A full circular Assessment method
- Inclusion of emissions and the biological cycle

Recycling Efficiency
- Economical recycling processes, which are there, how often employed?

Economic viability
- How much value is actually saved, when will there be a return on investment?

Lidl from construction waste
- How long will it take before we can build a Lidl supermarket out of demolition and renovation waste?

Supermarket in the Biological cycle
- The current design is fully in the technological cycle, I propose a step for the roof and load-bearing structure. How far can we actually get?