Development of the BCEF and DeCon Tools

Muheeb Al-Obaidy[1,2]*, and Shady Attia[1]

[1] Sustainable Building Design Laboratory, Department of Urban and Environmental Engineering, School of Engineering, Université de Liège, 4000 Liège, Belgium
[2] Sustainable Building Materials, Construction Department, Colruyt Group, 1500 Halle, Belgium

* Correspondence: shady.attia@uliege.be; Tel.: +32 43669155

This expert consultation report documents the development and validation of two interconnected tools aimed at enhancing circularity assessment in the building sector: the Building Circularity Evaluation Framework (BCEF) and the Expert System for Disassembly (DeCon). The report consolidates insights from multiple stakeholder workshops and structured expert interviews conducted between October 2024 and February 2025 with key partners including the Colruyt Group and the Sustainable Building Design Lab at the University of Liège. The consultations aimed to ensure the methodological robustness, operational feasibility, and industry relevance of both tools. Specific attention was given to selecting meaningful indicators for circularity assessment, validating disassembly criteria, and evaluating integration strategies with existing life cycle assessment (LCA) and building information modeling (BIM) workflows. Findings from these sessions contributed directly to refining indicator sets, prioritizing automation, and enhancing user experience in real-world contexts. The outcomes provide a practical foundation for architects, engineers, and sustainability practitioners committed to advancing circular building design and end-of-life adaptability.

Keywords:

circular building design, disassembly, decision support, BCEF, DeCon tool, sustainability assessment, early-stage design, expert consultation, usability testing

Al-Obaidy, M., & Attia, S. (2025). Development of the BCEF and DeCon Tools. Université de Liège. ISBN 978-2-930909-25-7.

Part I – Expert Consultations

Colruyt Group Expert Consultation on DeCon
(25 October 2024, Halle, Belgium)

SBD Lab Internal Consultation on BCEF
(03 December 2024, Liège, Belgium)

Colruyt Group Follow-up Consultation on BCEF and DeCon
(12 February 2025, Halle, Belgium)

Part II – Technical Appendices

Appendix 2 – Scope and Assumptions for BCEF Calculation Options

- Table A.2 – Scope and Components

Appendix 3 – Disassembly Potential Audit Sheet

Appendix 4 – DP Report : Calculation Option 1 (DeCon Tool)

Appendix 5 – DP Report: Calculation Option 2 (DeCon Tool)

Appendix 6 – DP Report: Calculation Option 3 (DeCon Tool)

Appendix 7 – Functional Adaptation

Appendix 8 – Sensitivity Analysis Dataset

Appendix 1A

Summary Report: Colruyt Group Circular Construction Consultation – Expert System (DeCon)

Partner: Colruyt Group – Sustainable Building Materials, Construction Department

Consultation Type: On-site workshop and structured expert interviews

Date: 25 October 2024

Location: Colruyt Group Headquarters, Halle, Belgium

Participants: Saartje van Cauwelaert, Hilde Carens, Muheeb Al-Obaidy, and Shady Attia

Objectives:

- The primary objectives were to comprehensively develop and update the list of disassembly criteria and potential barriers, and to rigorously validate the first version of the Expert System (DeCon) for evaluating building disassembly potential.
- The consultation aimed to explore practical applications of the system in real-world projects and gather expert feedback for iterative refinement.

Methodology:

- The methodology included systematic usability testing of the first version of DeCon, complemented by interactive briefings and technical discussions.
- Participants were introduced to the system's core functionalities, data requirements, and output interpretations. Specific attention was given to the audit process, data input workflows, and connection mapping between core and shell elements.
- Real case studies, including the 't Centrum and Green Office buildings, were analyzed to understand operational challenges and potential improvements.
- The team engaged in detailed scenario analyses to evaluate the robustness and adaptability of the system across different building typologies and design stages.
- Discussing the design of the expert system (DeCon), end results, and the final reports.

Key Outcomes:

- It was observed that the Expert System (DeCon) demonstrated higher value when operated alongside an experienced design for disassembly (DfD) specialist.
- The current prototype was found to be limited in scope, effectively addressing only the connections between the building's core and shell components. Experts emphasized the need to expand future versions to encompass more granular details such as interior partitions, façade systems, and service elements.
- A significant limitation was identified concerning geometry input and data handling. The evaluation process required extensive manual effort: two weeks were needed to inventory connections for the 't Centrum building using a Revit model, and three weeks for the Green Office building using an AutoCAD file. To mitigate this challenge, participants proposed the integration of audit sheets directly into the DeCon system, enabling automatic data uploads and reducing the dependency on manual entry.

- The consultation underlined the importance of establishing clear and standardized disassembly barriers that are adaptable to diverse project contexts. The feedback led to an updated and more detailed list of criteria and barriers, ensuring higher precision and consistency in future assessments.

Use in This Study: Insights from this consultation were crucial in advancing the development of the Expert System (DeCon). The refined disassembly criteria and proposed system enhancements will significantly improve the framework’s practicality and relevance. These outcomes support the broader objective of promoting circular design approaches and enabling more effective end-of-life strategies in building projects, thereby contributing to the sustainability ambitions of Colruyt Group and the wider construction industry.

Appendix 1B

Summary Report: Sustainable Building Design SBD Lab Consultation – BCEF

Partner: SBD Lab, University of Liege

Consultation Type: On-site workshop and structured expert interviews

Date: 03 December 2024

Location: University of Liege, Liege, Belgium

Participants: Muheeb Al-Obaidy and Shady Attia

Objectives:

- Critically evaluate and select the most relevant Key Performance Indicators (KPIs) within the Building Circularity Evaluation Framework (BCEF) to support early design decision-making.
- Review and align BCEF indicators with European regulatory frameworks, including Level(s), and with the strategies of FCRBE, COST Action CA21103 and the industry partners such as Colruyt Group experts.
- Synthesize outcomes from the recent workshop with Colruyt Group to refine the indicator set and integration approach.

Methodology:

- The consultation involved a detailed review of the BCEF framework structure, emphasizing the relevance and operational feasibility of its indicators in practical design contexts.
- The team engaged in scenario-based analysis, applying the BCEF indicators to hypothetical early design cases to evaluate clarity, ease of use, and integration potential with life cycle impact assessment (LCIA) tools.
- Outcomes from prior workshops with the FCRBE, COST Action CA21103, and Colruyt Group experts were analyzed to ground the discussion in real-world application experiences.

Key Outcomes:

- Indicator Prioritization and Validation: The Global Warming Potential (GWP) and Resource Circularity (RC) indicators were endorsed as primary indicators. Their compatibility with existing LCA-based evaluation systems and their strong alignment with European sustainability goals underscore their critical role in early-stage design evaluations.
- Role of Disassembly Potential (DP): Disassembly Potential was emphasized as a distinctive and essential metric within BCEF. Drawing on Colruyt Group's feedback, the indicator was refined to include an updated list of disassembly criteria and context-specific barriers, ensuring a robust assessment of future adaptability and reversibility of building elements.
- Land Use: While considered less critical from an operational standpoint, Land Use indicator was retained to ensure comprehensive alignment with regulatory standards and future-proofing for evolving sustainability assessments. Their inclusion supports a holistic understanding of environmental impacts beyond material and carbon metrics (Level(s)).

- Integration with Digital Tools: The integration of BCEF indicators into digital audit sheets and design software was discussed as a strategic necessity. This echoes experts identified challenge regarding manual data input in the expert system (DeCon). Automating indicator evaluation by linking BIM models and audit data was recommended to enhance efficiency and reduce evaluation timeframes.

Use in This Study: Findings from this workshop will inform updates to the BCEF framework, guiding both academic research and practical implementation in collaboration with FCRBE, COST Action CA21103, and the industrial partners such as Colruyt Group.

Appendix 1C

Summary Report: Colruyt Group Circular Construction Consultation - BCEF

Partner: Colruyt Group – Sustainable Building Materials, Construction Department

Consultation Type: On-site workshop and structured expert interviews

Date: 12 February 2025

Location: Colruyt Group Headquarters, Halle, Belgium

Participants: Saartje van Cauwelaert, Hilde Carens, and Muheeb Al-Obaidy

Objectives:

- Validate the 2nd beta version of Expert System (DeCon) to evaluate the building disassembly potential.
- Validate the operational feasibility of BCEF indicators to evaluate the building circularity in the early design stage.
- Assess the compatibility of BCEF with Colruyt's strategy and existing LCA tools used.

Methodology:

- A comprehensive usability test of the DeCon system was conducted, including live demonstrations and hands-on sessions.
- The participants engaged in an in-depth briefing on the BCEF framework, including detailed discussions on six core KPIs.
- Comparative analyses were performed to evaluate consistency with Colruyt's in-house methods. Specific focus was placed on assessing indicator sensitivity, data availability, and integration with BIM and LCIA tools.

Key Outcomes:

- GWP and RC indicators were fully endorsed, with confirmation of their strong compatibility with existing LCA indicators and corporate sustainability goals.
- Land Use, while deemed less immediately operationally critical, was retained to ensure compliance with European regulatory requirements (e.g., Level(s)) and to address long-term strategic alignment.
- The DP indicator was significantly emphasized, with an updated and approved list of disassembly criteria and potential barriers, thereby enhancing the capacity to evaluate end-of-life adaptability and reversibility of building elements.
- Participants also recognized the value of integrating early-stage quantification tools to simulate design alternatives and inform procurement strategies.
- The iterative feedback suggested the need for future automation of data flows between audit sheets and DeCon to improve evaluation efficiency and accuracy. Moreover, the workshop highlighted the importance of continuous stakeholder engagement and expert involvement to interpret results and support design decision-making.

Use in This Study: The insights gained have been instrumental in refining the BCEF framework. Adjustments to indicator weighting and prioritization ensure practical applicability for commercial projects and greater alignment with circular procurement practices. These refinements provide a robust foundation for supporting future circular design initiatives and strategic decision-making by both design professionals and building owners committed to sustainable transformation.

Appendix 2

This appendix provides an overview of the scope and assumptions applied in the three calculation options used to assess circularity through the BCEF framework. The calculation options reflect varying levels of circular design integration, ranging from a comprehensive building inventory (Option 1) to a disassembly-oriented scope (Option 2), and an optimized circular configuration (Option 3). Each option includes or excludes specific material groups and systems based on their actual reuse potential, dismantling feasibility, and alignment with circular economy principles. This structured comparison enables the reproducibility of the results and supports sensitivity analysis by transparently documenting the basis for each scenario.

Table A.2 – Scope and Components of the Three Calculation Options Applied in BCEF

Element Category	Calculation Option 1 (Full building)	Calculation Option 2 (Above-ground)	Calculation Option 3 (Designed for reuse)
Basement structure	Included	Excluded	Excluded
Above-ground structure	Included	Included	Included (only reused or modular components)
Envelope components	Included	Included	Included (if reusable)
Internal partitions	Included	Included	Included (only demountable or reused ones)
Flooring and finishes	Included	Included	Included (reused or designed for reuse)
HVAC and MEP systems	Included	Included	Included (if designed for modular replacement)
Furniture and equipment	Included	Included	Included (only leased or reused furniture)
PV panels	Included	Included	Included
Product-service systems	Included (if any)	Included (if any)	Included (emphasis on service contracts)

Appendix 3: Disassembly potential audit sheet

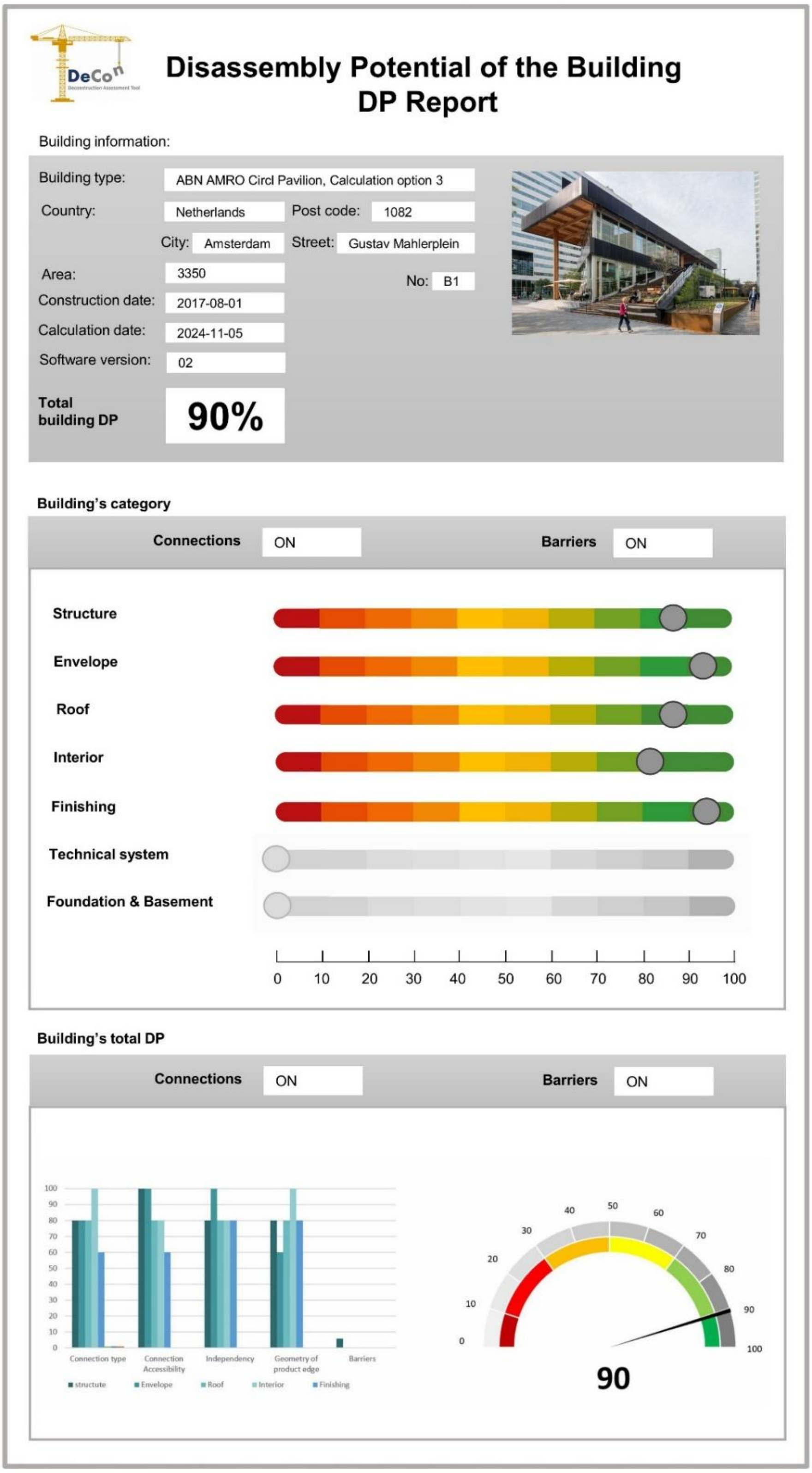
Audit sheet to evaluate the disassembly potential (ABN AMRO Circl pavilion)

		DfD Criteria				
1	**Structure**	**Composition type**	**Connction type**	**Connection accessibility**	**Independency**	**Geometry of product edge**
	1.1.	Column & Beam	Connections with	Freely accessible without	No independency	Open, no obstacle to the
	1.2.	Column & Slab	Connections with	Freely accessible without	No independency	Open, no obstacle to the
	1.3.	Column & Bearing wall	Connections with	Freely accessible without	No independency	Open, no obstacle to the
	1.4.	Column & Foundation	Connections with	Freely accessible without	No independency	Open, no obstacle to the
	1.5.	Beam & Slab	Connections with	Freely accessible without	No independency	Open, no obstacle to the
	1.6.	Beam & Conc. slab	Connections with	Freely accessible without	No independency	Open, no obstacle to the
	1.7.	Beam & Secondary beams	Connections with	Freely accessible without	No independency	Open, no obstacle to the
	1.8.	Slab & Bearing wall	Connections with	Freely accessible without	No independency	Open, no obstacle to the
	1.9.	Bearing wall elements	Connections with	Freely accessible without	No independency	Open, no obstacle to the
2	**Foundation & Basement**					
	2.1.	Conc. raft & Conc. wall	Hard chemical	Not accessible -	Full integration of	Closed, complete
	2.2.	Conc. wall & conc. slab	Hard chemical	Not accessible -	Full integration of	Closed, complete
	2.3.	Conc. Column & Conc. Beam	Nail connection	Not accessible -	Full integration of	Closed, complete
3	**Envelope**					
	3.1.	Façade elem. & Column	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	3.2.	Façade elem. & Beam	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	3.3.	Façade elem. & Slab	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	3.4.	Façade elem. & Floor	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
4	**Roof**					
	4.1.	Roof & Column	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	4.2.	Roof & Beam	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	4.3.	Roof & Insulation	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
5	**Interior**					
	5.1.	Partition wall & Slab	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	5.2.	Partition wall & Column	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	5.3.	Glass wall & Column	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	5.4.	Glass wall & Slab	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	5.5.	Stair & Slab	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	5.6.	Railing & Slab	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
6	**Finishing**					
	6.1.	Floor layers	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
	6.2.	Cladding	Screw connection	Freely accessible without	No independency	Open, no obstacle to the
7	**Technical system**					
	7.1.	PV system	Bolt and nut	Freely accessible without	No independency	Open, no obstacle to the
	7.2.	Lighting system elem.	Bolt and nut	Freely accessible without	No independency	Open, no obstacle to the
	7.3.	Cables / Cables tray	Bolt and nut	Freely accessible without	No independency	Open, no obstacle to the
	7.4.	HVAC system elem.	Bolt and nut	Freely accessible without	No independency	Open, no obstacle to the
	7.5.	Firefighting system elem.	Screw connection	Freely accessible without	No independency	Open, no obstacle to the

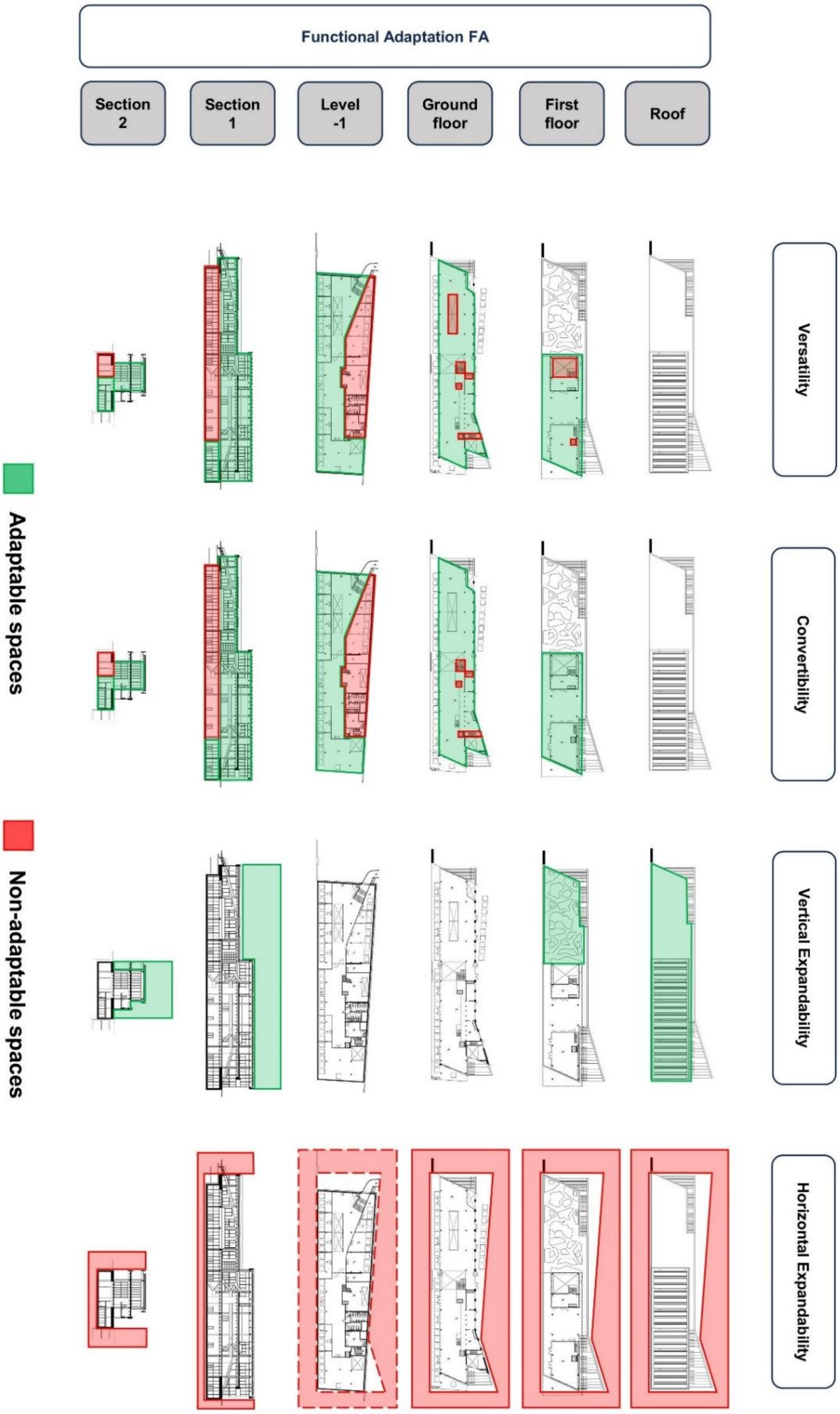
Appendix 4: Disassembly potential report of calculation Option 1 from the Expert System (DeCon tool).

Appendix 5: DP report of calculation Option 2 from the Expert System (DeCon tool).

Appendix 6: DP report of calculation Option 3 from the Expert System (DeCon tool).



Appendix 7: Functional adaptation



Appendix 8: Sensitivity analysis dataset of indicator weight variation

Indicator weights variation [±10%]	BCEF index [%]		
	Calculation option 1	Calculation option 2	Calculation option 3
+10% CF, -10% LF	55.85	66.35	68.10
+10% CF, -10% RC	61.75	71.95	75.50
+10% CF, -10% DP	55.55	65.35	68.50
+10% CF, -10% FA	55.75	66.65	70.01
+10% CF, -10% PSS	60.85	72.75	76.10
+10% LF, -10% CF	51.25	63.55	67.90
+10% LF, -10% RC	59.45	70.55	75.40
+10% LF, -10% DP	53.25	63.95	68.40
+10% LF, -10% FA	53.45	65.25	69.90
+10% LF, -10% PSS	58.55	71.35	76.01
+10% RC, -10% CF	45.35	57.95	60.50
+10% RC, -10% LF	47.65	59.35	60.60
+10% RC, -10% DP	47.35	58.34	61.01
+10% RC, -10% FA	47.55	59.64	62.50
+10% RC, -10% PSS	52.65	65.75	68.60
+10% DP, -10% CF	51.55	64.55	67.50
+10% DP, -10% LF	53.85	65.95	67.60
+10% DP, -10% RC	59.75	71.55	75.01
+10% DP, -10% FA	53.75	66.25	69.50
+10% DP, -10% PSS	58.85	72.35	75.60
+10% FA, -10% CF	51.35	63.25	66.01
+10% FA, -10% LF	53.65	64.65	66.10
+10% FA, -10% RC	59.55	70.25	73.50
+10% FA, -10% DP	53.35	63.65	66.50
+10% FA, -10% PSS	58.65	71.05	74.10
+10% PSS, -10% CF	46.25	57.15	59.90
+10% PSS, -10% LF	48.55	58.55	60.01
+10% PSS, -10% RC	54.45	64.15	67.40
+10% PSS, -10% DP	48.25	57.55	60.40
+10% PSS, -10% FA	48.45	58.85	61.90

FC: Carbon Footprint, LF: Land use Footprint, RC: Reused Content, DP: Disassembly Potential, FA: Functional Adaptability, PSS: Product-Service Systems