HS PF

Design for Circularity

Decision Support Method for Industry

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Problem statement

In future, industrial product development and design processes need to consider the entire life cycle of products to automatically evaluate product design improvements regarding circular economy such as lifetime extension, reuse, or high-quality recycling. This requires the assessment of environmental and climate friendliness and energy and resource efficiency in addition to the usual property and utility profiles and economic assessments of products under development.
At current, there is still a lack of feasible and practice-oriented solutions for the fully integrated consideration of environmental impacts, resource efficiency, and circularity aspects in the early phases of product design and development processes. (Tura et al. 2019)

Research aim

To further close this application and research gap, our research target is the operationalization of design for circularity approaches through largely automated consideration in industrial product development processes. For this purpose, the research consortium DfC-Industry (Design for Circularity in industrial product development) has been established, which is funded by the German Federal Ministry for Economic Affairs and Climate Action and Project Management Jülich. Our research comprises, systematic literature analyses to explore and categorize the state of the art of circular economy concepts, indicators, norms, and applications. Specific assessment of industry partners' product development processes provide points of reference and identification of relevant decision makers for a design for circularity.

Scientific implications

This information is eventually combined with expert judgment to generate a systematic decision support for a design for circularity with actual industrial relevance and applicability. The actual implementation of circular design, although being one crucial element of corporate sustainable development, is currently not well established. First research outcomes from DfC-Industry provide practical solutions to achieve such goal and to support the relevant actors involved in product development to easily and systematically consider circular economy and environmental information in their design processes. This is supported by digital and AI-based solutions to integrate resource efficiency and environmental assessments into design environments and business model development.

Decision tree as decision support for a Design for Circularity

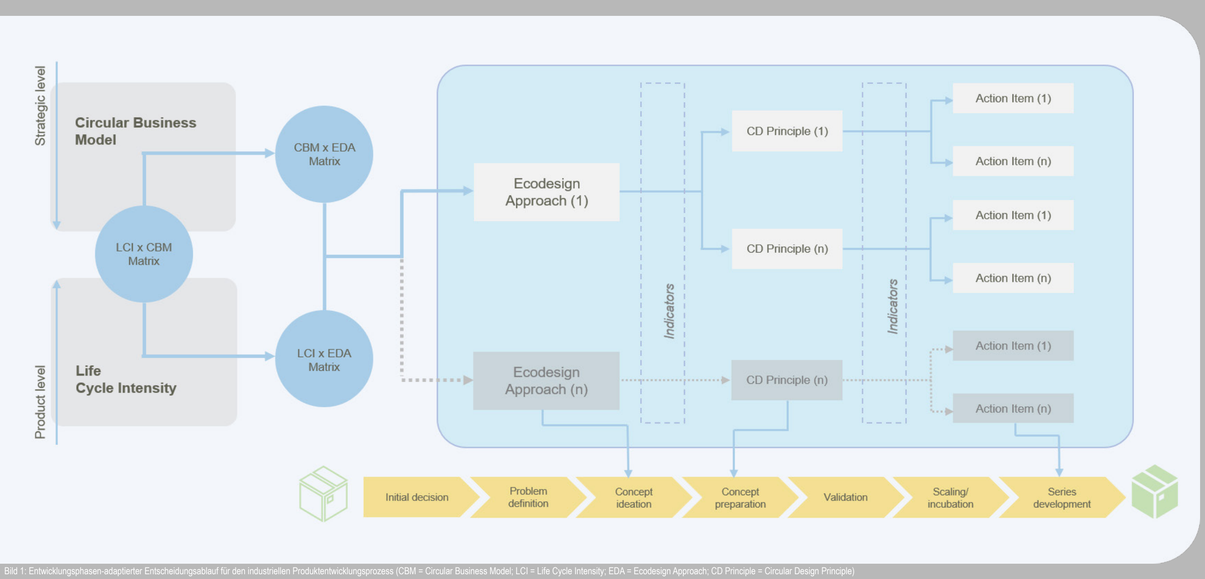

Bild 1: Entwicklungsphasen-adaptierter Entscheidungsablauf für den industriellen Produktentwicklungsprozess (CBM = Circular Business Model; LCI = Life Cycle Intensity; EDA = Ecodesign Approach; CD Principle = Circular Design Principle)

- The combination of dimensions was done by matrices, each of which was evaluated during the project by several experts in circular economy and the PEP from the perspective of science and industrial development practice.
- The multi-stage selection process within the decision tree is determined by the consideration of the three dimensions **Circular Business Models (CBM), Ecodesign Approaches (EDA) and Life Cycle Intensity (LCI).** A decision matrix compares variants and provides decision support through an evaluation grid.
- By evaluating the interactions, dependencies and influencing factors can be determined. Evaluated matrices then serve as the basis for creating a decision tree for circularity assessment. (Grünig and Kühn 2013)
- A decision tree transparently represents the complex, multi-stage decision-making process with all possible decision options. Through the branches of the tree, chained decisions can be visualised in a logical sequence.
- Benefit arises from the systematic description of all decision options. (Schawel and Billing 2012)
- Based on products or business models, suitable EDAs are thus filtered, resulting in suitable circular design solutions.

LCA automation

- The LCA automation aims at a rough estimation of circularity and environmental implications of the product structure, part masses, part material data, part manufacturing and assembly, which are included in the so-called master representation.
- The geometry and its properties (e.g. symmetry, bounding box, tolerances) are automatically identified from the 3D representation in order to calculate suitable production processes and the gross weight using a decision tree. Results are mapped to sustainability data.
- An analysis of contributors to product carbon footprint can be used to advise the designer to rethink certain materials and processes to improve sustainability. The structural information can be used to improve ecodesign decisions like ability to disassemble and repair.

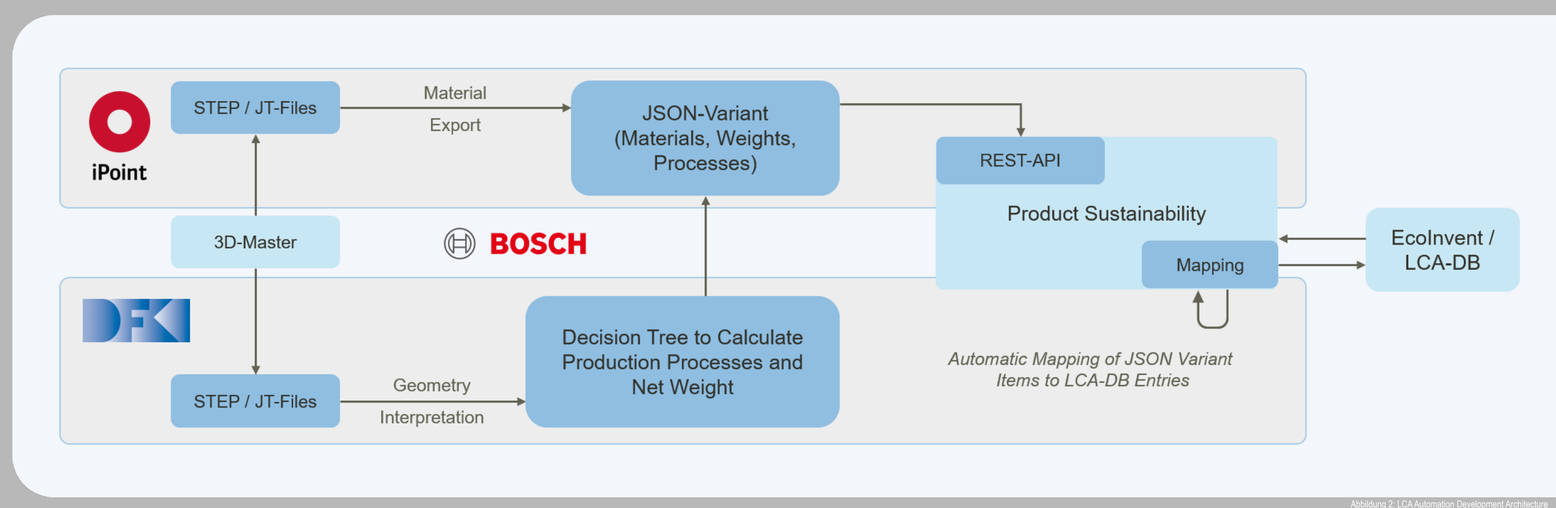

Abbildung 2: LCA Automation Development Architecture

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References and poster pdf available for download on the project website.

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