Title:
Evaluating CAD-Integrated Environmental Assessment Tools for Ecodesign Applications: Comparison with Reference LCAs

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Introduction

Several CAD software providers offer modules that integrate environmental functionalities, enabling the estimation of a product environmental impacts directly from its 3D model. These tools represent a promising opportunity for industries, as they facilitate the early integration of environmental considerations into the design process, particularly for small and medium-sized enterprises (SMEs) that may lack means for expert assessment tools. However, the underlying methodologies, databases, and the scope of the environmental assessment covered vary significantly across software solutions, which may lead to substantial discrepancies in the results obtained. The purpose of this study is to examine the degree of trust that a designer might place in the results obtained using these solutions, in order to use them as a starting point for an ecodesign process. More specifically, the objectives are: (i) to assess the consistency and comparability of the results obtained using different CAD tools, by comparing them against a reference LCA; (ii) to identify and analyze discrepancies and their underlying causes; and (iii) to evaluate the implications of these discrepancies for design decision-making. This work is conducted in collaboration with an industrial partner, the CETIM (Technical Center for Mechanical Industry in France), which help ensuring industrial relevancy: case studies, software solutions and objectives were jointly defined.

Related works

Several studies have evaluated the assessment capabilities of CAD-integrated tools by comparing their results with reference LCAs. Early works focus on SolidWorks' environmental assessment tool, SolidWorks Sustainability, by modelling and assessing simple mechanical parts or consumer product [3-5]. These studies calculate error percentages for these assessments and showed significant differences with LCA dedicated software such as Gabi or SimaPro. More recent works extend the comparisons to multiple CAD-integrated tools, including Eco Materials Adviser in Inventor, 3DExperience's Ecodesign Engineer role, NX sustainability Impact Analysis or Fusion 360's Makersite add-on [1],[2],[6]. [6] propose to compare three different CAD software solutions with a reference LCA, but the analysis is limited to a single case study, limiting the possibility of a more systematic analysis.

Some gaps remain in the literature: newer software solutions, such as Fusion EcoDesigner, have not been tested. Additionally, most studies primarily focus on the numerical accuracy of the results, while the broader ability of these tools to support ecodesign practices remains less explored. This work therefore aims to provide a perspective oriented towards potential use of the results in an ecodesign context, specifically the ability of these tools to support the identification of environmental hotspots and to provide a solid basis for ecodesign decision-making. This study is conducted by evaluating different CAD tools against a set protocol and three case studies.

Benchmark methodology and initial results

Defining the case studies

The benchmark protocol is designed to evaluate the robustness and relevance of CAD-integrated environmental assessment modules under realistic industrial conditions. The case studies are defined in collaboration with the CETIM and intended to ensure representativeness. The following requirements are applied to select and define the case studies:

(1) The products have to be representative of the mechanical industry while covering different industrial sectors, allowing the evaluation of the tools under diverse technical contexts. (2) Each assembly is limited to approximately ten to fifteen components, ensuring a balanced level of complexity compatible with the duration of the study while remaining sufficiently representative of real industrial products. (3) Material diversity is also a key criterion, in order to assess the ability of CAD tools to handle different material families, including technical materials. (4) Exploitable CAD models and a complete bill of materials are required.

Based on these criteria, three case studies are selected: a miniature DC motor for light robotics applications, a two-way solenoid valve used for lubricant control in machine tools, and a gear pump integrated into an industrial hydraulic system. Figure 1 shows the modeled case studies. Each product exhibits distinct functional characteristics and material compositions providing a robust basis for comparative analysis.

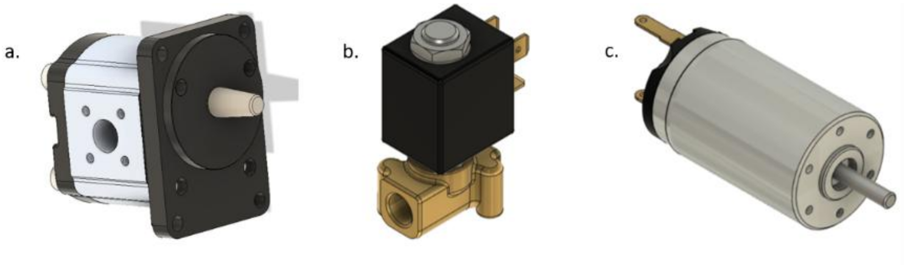

Fig. 1: Designed case studies: (a) The gear pump, (b) The two-way solenoid valve, (c) The miniature DC motor.

CAD software tools selection

Three CAD software tools are selected for the benchmark:

- **EcoDesign Engineer role – 3DEXPERIENCE by Dassault Systèmes** is selected for its apparently advanced level of LCA integration, as suggested by features such as the use of the EcoInvent database and multiple impact assessment methods.
- **SolidWorks Sustainability – SolidWorks by Dassault Systèmes** is chosen because of its widespread adoption in industry. SolidWorks includes a built-in environmental impact assessment module directly integrated into the CAD environment and is identified by the CETIM as a very common software solution among French SMEs.
- **EcoDesigner – Fusion 360 by Autodesk** is also considered, as it appears to offer an interconnected workflow with SimaPro (LCA software), enabling CAD designers to estimate environmental impacts in a straightforward and user-friendly manner.

The benchmark protocol is then applied to these three CAD solutions, as summarized in Figure 2. Assemblies are reconstructed or imported to ensure consistency in geometry and mass. Materials are assigned using the native libraries available in each software, without external database modification, in order to preserve realistic usage conditions.

Environmental assessment modules are configured using default or recommended settings. The analyses are intentionally conducted without advanced parameter tuning, reflecting typical use by designers in industrial SMEs rather than by LCA experts. Tool-specific constraints are documented, including differences in material granularity, limited transparency of datasets, and predefined life cycle scenarios.

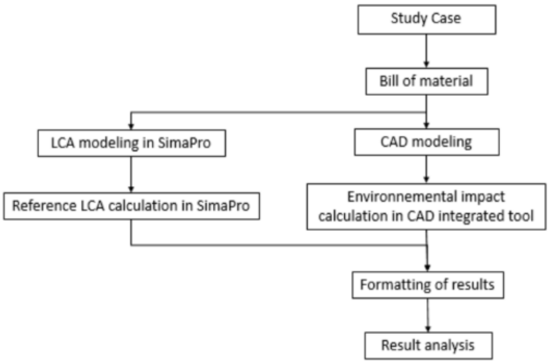

Fig. 2: Activity diagram of the protocol used to compare environmental impact results from CAD-integrated tools with a reference LCA calculated in SimaPro.

Reference Life Cycle Assessment modelling and environmental impacts
Reference LCAs are conducted using SimaPro 9.4 and ecoinvent database v3.9.1, in order to establish a baseline for comparison with CAD-based assessments. A cradle to gate system boundary is considered, as to focus on the automatically extracted data in CAD software. The cradle-to-gate scope includes raw material extraction, material processing, and manufacturing, up to the product leaving the factory gate. This scope focuses on material and manufacturing choices, which are directly influenced by design decisions, and is supported by the majority of the tested CAD tools.

For each case study, LCA models are constructed using the same bills of materials extracted from the CAD assemblies. The manufacturing scenarios are defined based on assumptions derived from the materials used, their shape, and the likely processes involved.
For the mass used in the reference LCAs, values are extracted from the CAD models. As material densities differed slightly between CAD software, resulting in small variations in calculated component masses, separate reference LCAs are established to ensure consistent comparisons with each CAD-based assessment.

Impact assessment methods are selected to align with those used in CAD-based tools: EF 3.1 for comparison with 3DEXPERIENCE that uses EF 3.0 (unavailable in our SimaPro version), CML for SolidWorks Sustainability (V3.09 on SimaPro, unknown version in SolidWorks), and ReCiPe 2016 Midpoint (H) V1.08 for Fusion 360 EcoDesigner, inferred from the reported indicators and their units due to the lack of methodological transparency.

Comparison methodology and interpretation framework
Two complementary comparison approaches were adopted to analyze the results. First, a comparison of environmental impact values obtained from CAD-based assessments and reference LCAs is used as an indicator to analyze differences in terms of orders of magnitude. This comparison provides a first-level assessment of consistency between approaches. However, as the underlying calculations rely on different databases, system boundaries, and modelling assumptions, this comparison does not aim to establish strict quantitative equivalence. Instead, it provides an order-of-magnitude assessment to contextualize the results. Nevertheless, this quantitative comparison remains informative, as it allows major deviations to be identified and supports the analysis of the influence of assessment scope and tool complexity.

Second, the results are compared based on relative components' contributions to the environmental impacts to examine whether the same conclusions would be drawn from the results. This analysis reflects a more design-oriented perspective: beyond absolute values, environmental

assessments are primarily used to identify hotspots and guide improvement efforts. The CAD-based results are therefore compared to the reference LCAs to assess whether similar design conclusions would be drawn. To support this analysis, three indicators are defined: hotspot coverage, which evaluates whether the main contributing components are consistently identified; missed impacts, which quantifies the share of impacts associated with overlooked hotspots; and contribution deviation within hotspots, which assesses differences in the distribution of impacts among key components.
By combining quantitative comparison and contribution-based analysis, the protocol enables discrepancies to be interpreted in light of modelling constraints and scenario simplifications, while focusing on their implications for design decision-making.

Synthesis of results and design-oriented implications

The comparison of environmental impact values between CAD assessments and reference LCAs shows contrasted results. Ecodesign Engineer (3DX) exhibits low deviations across case studies, although differences remain for specific impact categories due to methodological variations. SolidWorks Sustainability and EcoDesigner (F360) show larger deviations, partly explained by differences in environmental databases and modelling possibilities. For instance, the absence of magnet materials in both databases strongly affects the results of the DC motor.

The analysis of component contributions confirms these trends. Ecodesign Engineer (3DX) shows consistently high hotspot coverage, with very limited missed impacts and low contribution deviation within hotspots, leading to similar interpretations as the reference LCAs. In contrast, SolidWorks Sustainability and EcoDesigner (F360) results are more variable: hotspot identification is more partial and case-dependent, resulting in higher missed impacts and larger deviations in contribution distribution.

To illustrate these differences, Figure 3 presents the comparison between CAD assessments and LCA results for the gear pump, using the climate change indicator. The top five impacting components are identified to better highlight the differences with the reference LCAs. In this example, Ecodesign Engineer (3DX) is consistent with the reference LCA, with similar hotspot identification and ranking. For EcoDesigner (F360), the absence of bushings can be observed, along with more important deviations of the results. Both EcoDesigner (F360) and SolidWorks Sustainability also show differences in the contribution of some components (shafts are not identified among the most impacting components for instance), that could lead to variations in the interpretation of impact distribution.

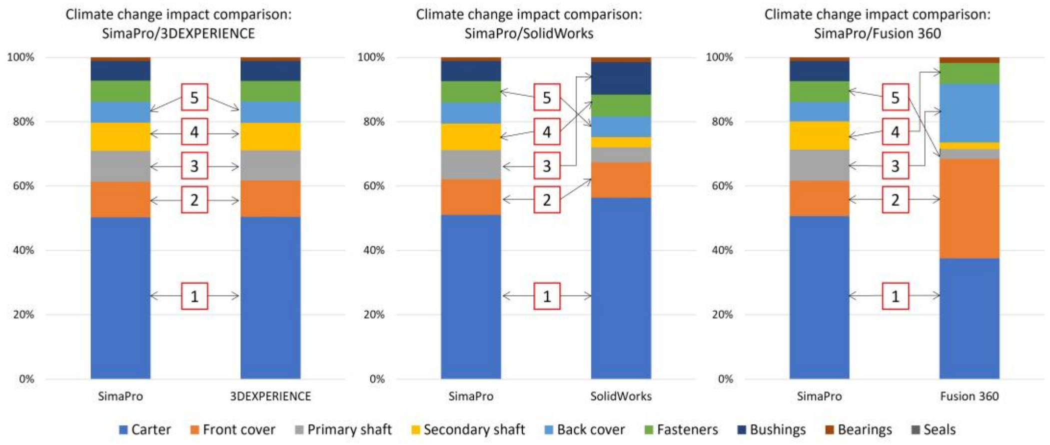

Fig. 3: Comparison of components contribution to climate change between the reference LCAs and CAD assessments for the gear pump, with the order of the five most contributing components highlighted; left) Ecodesign Engineer (3DEXPERIENCE), center) SolidWorks Sustainability, right) Ecodesigner (Fusion 360).

Discussion

The work presented can be discussed through three perspectives. First, the proposed methodology aims to address key challenges in comparing CAD-based environmental assessments with reference LCAs. Rather than relying solely on the comparisons of environmental impact values, which are highly sensitive to methodological variations (databases, impact assessment methods, system boundaries, modelling assumptions), this approach uses these comparisons to contextualize results in terms of orders of magnitude. In parallel, focusing on the relative contribution of components enables a more design-oriented perspective. As environmental assessments are often used to identify hotspots and guide improvement efforts, the proposed indicators (hotspot coverage, missed impacts, contribution deviation within hotspots) evaluate the consistency of the conclusions that can be drawn from the results, rather than numerical accuracy alone.

Second, the results highlight two main trends. Ecodesign Engineer (3DX) shows higher overall consistency with the reference LCAs, which can be explained by more advanced modelling capabilities and methodological proximity with LCA practices. In contrast, SolidWorks Sustainability and EcoDesigner (F360) rely on more simplified modelling approaches, mainly based on material selection and limited life cycle representation. This leads to larger deviations and a higher risk of missing important contributors, especially when key materials or processes are not represented. These findings illustrate the trade-off between accessibility of simplified assessments and completeness of more advanced approaches.

Finally, this trade-off raises broader questions regarding the intended users of such tools. Even simplified assessments require a certain level of methodological understanding to correctly interpret results and account for modelling limitations. This highlights the importance of improving transparency regarding underlying data and assumptions. In addition, from an ecodesign perspective, integrating more interactive support (e.g. material alternatives, weight reduction strategies, or topology optimization) could further enhance the ability of these tools to support design decision-making.

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References:

[1] Dudkowiak, A.; Grajewski, D.; Dostatni, E.: Analysis of Selected IT Tools Supporting Eco-Design in the 3D CAD Environment, IEEE Access, 9, 2021, 134945–56. https://doi.org/10.1109/ACCESS.2021.3116469.

[2] Edeland, M.; Mood, L.: Utilising LCA Software Tools for Sustainable Product Design: A Case Study of Arjo's R&D Department, M.S. Thesis, KTH, Stockholm, 2025.

[3] Gaha, R.; Yannou, B.; Benamara, A.: A new eco-design approach on CAD systems, Int J Precis Eng Manuf, 15, 2014, 1443–51. https://doi.org/10.1007/s12541-014-0489-4.

[4] Hernandez Dalmau MI: Eco-design Integration into New Product Development Processes: Comparison between LCA Software and CAD-integrated Tools, M.S. Thesis, Purdue University, West Lafayette, IN, 2015.

[5] Morbidoni, A.; Favi, C.; Germani, M.: CAD-Integrated LCA Tool: Comparison with dedicated LCA Software and Guidelines for the Improvement, in Glocalized Solutions for Sustainable Manufacturing, Hesselbach, J.; Herrmann, C. (eds.), Springer, Berlin, Heidelberg, 2011, 569–574. https://doi.org/10.1007/978-3-642-19692-8_99.

[6] Remic, K.; Oblak, L.; Kitek Kuzman, M.; Bizjak Govedič, T.; Dolšak, B.: Environmental Assessment of Forest-Based Industry Products with CAD-Integrated LCA Tools: A Comparative Case Study of Selected Software, Forests, 15(11), 2024, 1909. https://doi.org/10.3390/f15111909.