

## Sustainable Design of L-Bracket Using Fusion 360 CAD Software: A Comparative Analysis

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**ABSTRACT:** The world nowadays moving toward fifth industry revolution, which much focus on sustainability in all product life cycle. This study aims to contribute in this direction by utilizing CAD software sustainability analysis at the design stage of L-Bracket (used as support for shelf to a wall). This paper evaluate the sustainability of L-Bracket by using the Manufacturing Sustainability Insight (MSI) tool integrated into the Fusion 360. The analysis concentrates on calculating the amount of equivalent carbon dioxide emissions (CO<sub>2</sub>e in gram) depending on three primary aspects: L-Bracket design (with and without side support), material type (Steel and Aluminum) and the type of manufacturing process (under Subtractive and Additive types). The results shows that the selection of material and manufacturing processes can lead to significant reductions in CO<sub>2</sub>e emissions (around 85% to 92% respectively) when using steel and sheet metal fabrication, while design change has no effects. These findings demonstrate the importance of considering sustainability early in the design stage, which could help designers to make more environmental decision.

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**Received:** 18 March 2025

**Accepted:** 15 April 2025

**DOI:** <https://doi.org/10.71107/aqhj6274>

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### I. INTRODUCTION

This study use the design of L bracket<sup>1</sup> which is an intermediate component that attach one object to another, align part within an enclosure or fortify a part by supplying extra structural support. It has many shapes, such as:

- L-bracket, most used type has single bend with angle 90 up to 120.
- Z-bracket, often used to anchor parts because it has two bends in opposite direction.
- U-channel, ideal for mounting parallel surfaces, has two bends at facing angles.
- Hat channel, welded inside parts made of weaker metal to keep them from collapsing.

- Gusset bracket, welded inside metal parts for added fortification such as using in bridges.

The L shape is the most spread one, so select it for this study (design without side support and add side support to be part of comparison). Most materials used in manufacturing are Stainless Steel, Aluminum and Rolled Steel.

The Industry 5.0 moving forward to implementing sustainability in all product life cycle and Computer-Aided Design (CAD) tools could help to achieve this objective. Refer to Matt Oosthuizen<sup>2</sup> the manufacturing sector contributes to approximately 20% of global carbon emissions and 54% of energy consumption, and about 80% of a product's environmental impact can be determined in the design phase. One tool that supports this transition is CAD software, such as Fusion 360, which incorporates features that help assess the environmental impact of designs.

Determining the sustainability of a design requires post-production calculations, which involve material use, energy consumption during production and emissions during the product's lifecycle.

However, recent developments in CAD software have enabled real-time assessments of environmental impact during the design phase. While much research has been done on the theoretical aspects of sustainable design, there is a lack of studies focusing on practical, real-life

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product comparisons. This paper aims to fill this gap by demonstrating how CAD software, particularly Fusion 360, can help engineers to make sustainable design decisions early in the product development process.

The main objective of this paper is design of L-Bracket for sustainability. This through investigating the amount of CO<sub>2</sub>e emission on various factors including shape optimization, material selection and manufacturing process selection.

## II. LITERATURE REVIEW

Sustainable design integrates environmental considerations into the design phase of products, services and buildings<sup>3</sup>. It is based on the principles of the 3Rs—Reduce, Reuse, and Recycle—with the aim of minimizing waste, conserving resources, and improving the health and well-being of communities. The integration of sustainability into the design process allows manufacturers to reduce the carbon footprint (GHG emissions) of their products and extend product lifecycles.

Standards such as ISO 14040 and ISO 14044 provide frameworks for life cycle assessment (LCA) in environmental management, helping industries adopt sustainable practices.

Computer-Aided Design (CAD) software has revolutionized the design and manufacturing sectors by enabling engineers to model, analyze, and simulate products before they are physically manufactured. This capability enhanced by tools like the Manufacturing Sustainability Insight (MSI) add-on in Autodesk Fusion 360, which helps optimize designs by calculating the carbon dioxide equivalent emissions (CO<sub>2</sub>e) associated with material selection, manufacturing processes, and transportation. While limited studies have explored the role of CAD in sustainable design, there is growing recognition of the value these tools bring in reducing energy consumption, material use, and Green House Gas emissions (GHG).

Fusion 360 MSI add-on, powered by Gravity Climate APT, allows designers to assess the environmental impact of their designs in real-time. By calculating CO<sub>2</sub>e emissions from raw material selection, manufacturing processes and transportation. MSI enables designers to make informed decisions that minimize environmental harm.

Numerous case studies have examined sustainability within engineering design. Emelia<sup>4</sup>, investigates environmental sustainability in product design, covering a historical perspective on sustainable design spanning forty years (from 1980 to 2020). As a result, using life

cycle analysis (LCA) methodology had a great role in evaluating environmental impacts throughout the product lifecycle.

Konstantinos<sup>5</sup> integrate Computer-Aided x (CAx) system in promoting sustainable production practices. The use of Life Cycle Environmental Cost Analysis (LCECA) was discussed in order to assess the environmental impacts of products. Moreover, the concept of Environmentally Conscious Manufacturing and Product Recovery (ECMPR) was introduced. Therefore, they emphasized sustainable practices in production and end-of-life management. Kriswanto<sup>6</sup> examined the evolution of sustainable design and development, categorizing historical approaches into eight distinct areas, including life cycle assessment (LCA) and eco-design design strategies, multi criteria decision making, performance management, customer's side and miscellaneous. The first two categories are integral to the modern framework of sustainable engineering.

Adyalkar<sup>7</sup> explored how CAD and CAM can be applied to facilitate the development of eco design. They highlighted the significant role where these tools can play in enhancing design sustainability.

Matt Oosthuizen<sup>2</sup> presented how Fusion 360 Manufacturing Sustainability Insights (MSI) tool, supports engineers in making environmentally conscious decisions.

Katarina<sup>8</sup> applied an environmental assessment tool from four different CAD software platforms to analyze the environmental impact of a wooden chair design. They demonstrated the benefits of such tools in identifying and mitigating the environmental impacts associated with product design.

## III. THEORY (METHODOLOGY)

This section summarize the overall methodology for sustainable design of L-Bracket, as shown in [Figure 1](#), using Autodesk Fusion 360.

### A. Design L-Bracket

Draw the design 2D sketch, and then make 3D modeling and safe it.

### B. Adjust Parameters Under Consideration

Open MSI add on and select the three parameters of sustainable design, which are material type, manufacturing type and manufacturing country, and adjust selection to the needed option.

### C. Compute CO<sub>2</sub>e Emissions

MSI compute the amount of CO<sub>2</sub>e emission in gram according to the above three parameters, and show it as number value and stacked column.

- *Material Emissions:* Embodied carbon emissions from raw material extraction and processing.
- *Manufacturing Emissions:* Emissions resulting from energy consumption during the manufacturing process.
- *Transportation Emissions:* Emissions associated with the transportation of raw materials to the manufacturing site.

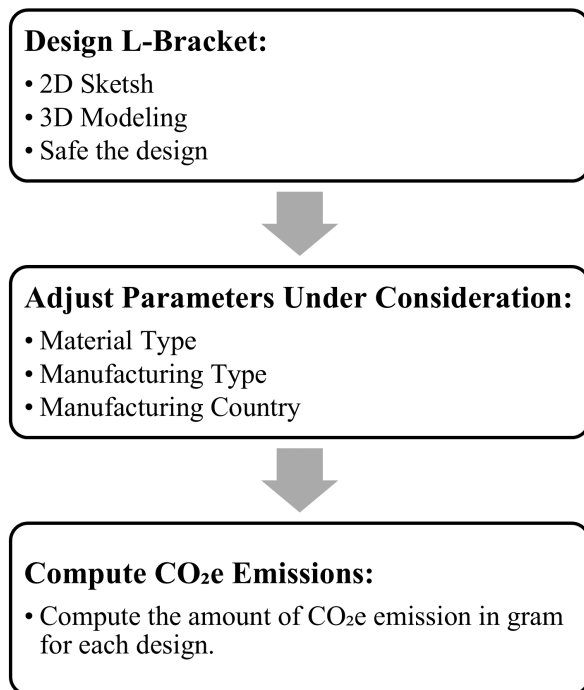


FIG. 1: The methodology flowchart.

Apply the comparison between two L-Bracket designs one without side support and the other with side support over the three parameters that mentioned above, see [Figure 2](#).

The analysis based on several assumptions, includes:

- Use of billet material for mass production,
- Use standard materials from the Fusion 360 library,

- Use manufacturing processes (Subtractive and Additive Manufacturing),
- Select Saudi Arabia as manufacturing location (nearest country to Sudan that available in Fusion 360 country list),
- Compute CO<sub>2</sub>e emissions made from raw material extraction up to product manufacturing (does not take on account the postproduction emissions).

Finally compare the amount of carbon dioxide equivalent emissions (CO<sub>2</sub>e) for each designs and parameters to find out the most sustainable option.

## IV. RESULTS AND DISCUSSION

In this paper effect of L-Bracket design and MSI parameters were investigated in three subsection, based on the amount of CO<sub>2</sub>e emissions as represent in [Table I](#).

The result for the first design (D1) when using steel as a material and changing the manufacturing type found that subtractive Sheet Metal process has the lowest CO<sub>2</sub>e emissions (39g), then additive type (DED, Binder jetting and L-PBF) up to 274g, after that subtractive type (CNC Milling and CNC Turning) about 501g, respectively. Same things happen with second design (D2) along same manufacturing types, also when changing the material to Aluminum CO<sub>2</sub>e emissions follow same pattern with slight change in numbers. Move through these three subsections for more elaborations:

### A. L-Bracket Design

The result show that the two L-Bracket designs has same amount of CO<sub>2</sub>e when reinforce the material and manufacturing process see [Figure 3](#).

### B. Material Type

The material show big difference, that Steel has lower CO<sub>2</sub>e emissions comparing to Aluminum (make reduction about 85% when using Steel instead of Aluminum) see [Figure 4](#).

### C. Manufacturing Type (Process)

The process type reflect that subtractive manufacturing has lower CO<sub>2</sub>e emissions comparing with additive manufacturing when using Sheet Metal Fabrication (about 92% reduction in CO<sub>2</sub>e), and higher when using CNC Milling or Turning (about 83% addition in CO<sub>2</sub>e) see [Figure 5](#).

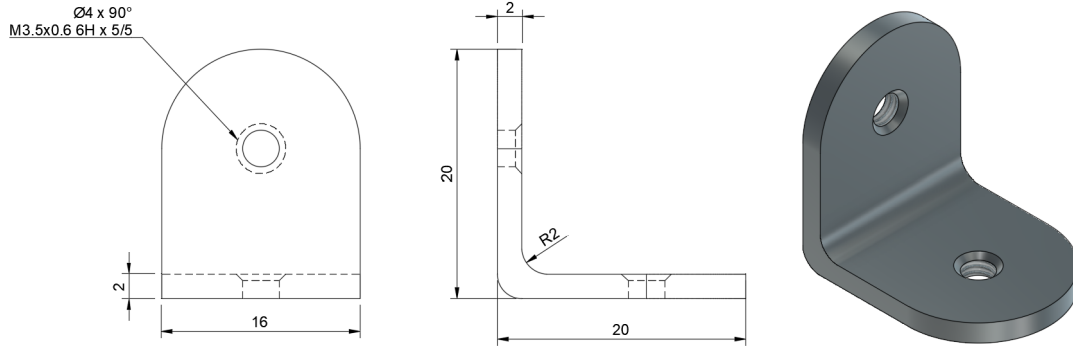


FIG. 2: The drawing of L-Bracket without side support (dimension in mm).

TABLE I: The CO<sub>2</sub>e emissions for different combination of design, material and manufacturing process.

Design	Material	Manufacturing Type	CO <sub>2</sub> e emissions (g)
D1*	Steel	Subtractive (Sheet Metal)	39
D1	Steel	Subtractive (CNC Milling and CNC Turning)	496 – 501
D1	Steel	Additive (Binder jetting, DED and L-PBF)	179 – 274
D1	Aluminum	Subtractive (Sheet Metal)	267
D1	Aluminum	Subtractive (CNC Milling and CNC Turning)	4200
D1	Aluminum	Additive (Binder jetting, DED and L-PBF)	414 – 484
D2**	Steel	Subtractive (Sheet Metal)	39
D2	Steel	Subtractive (CNC Milling and CNC Turning)	496 – 502
D2	Steel	Additive (Binder jetting, DED and L-PBF)	180 – 276
D2	Aluminum	Subtractive (Sheet Metal)	265
D2	Aluminum	Subtractive (CNC Milling and CNC Turning)	4176 – 4182
D2	Aluminum	Additive (Binder jetting, DED and L-PBF)	180 – 276

\*D1: L-Bracket without side support

\*\*D2: L-Bracket with side support

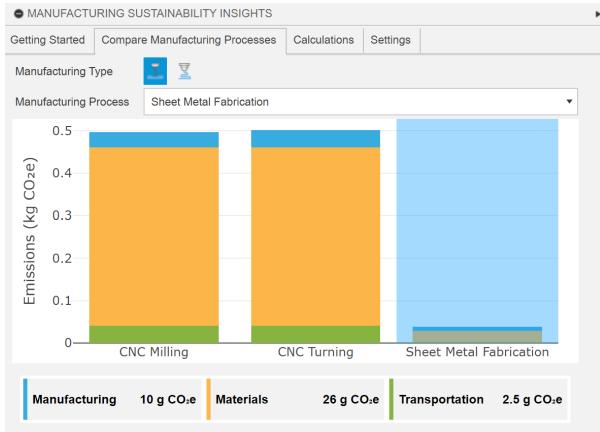
The comparative analysis of the L-bracket designs revealed that the choice of material and manufacturing process had the most significant impact on the design sustainability. In this study, finding that use Steel as a material and Sheet Metal Fabrication as a type of Subtractive Manufacturing is the most sustainable combination.

This result is consistent with existing literature, which emphasizes the importance of incorporating sustainability into the early stages of product design, and using CAD tools (as Fusion 360 MSI) make it possible, which enabled designers to make informed decisions that reduce CO<sub>2</sub> emissions as a result of optimize selection of material and manufacturing process.

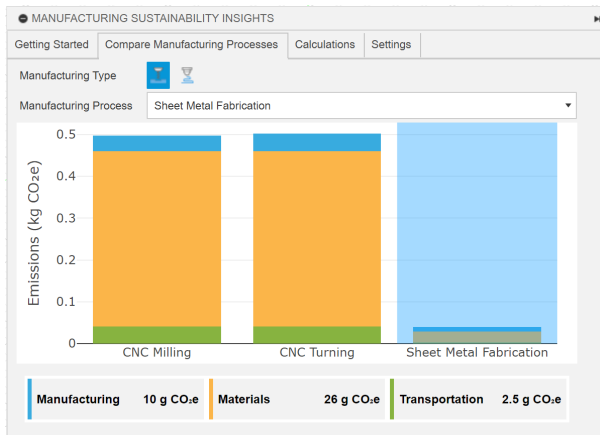
## V. CONCLUSION

The study provided an overall comparison of CO<sub>2</sub>e emissions for L-Bracket design using Fusion 360 MSI tool, by applying three factors including design, material and manufacturing process, finding that:

- The change in L-Bracket design has no effect amount of CO<sub>2</sub>e emissions.
- Material type and manufacturing process show huge impact on amount of CO<sub>2</sub>e emissions.
- Steel has least environmental impact by 85% than Aluminum.
- Sheet metal fabrication has the least amount of CO<sub>2</sub>e emissions over the other manufacturing process. Around 92% reduction in CO<sub>2</sub>e emissions



(a) Without side support.



(b) With side support.

FIG. 3: The CO<sub>2</sub>e emission of the two L bracket designs using Steel and Sheet Metal Fabrication (a) without side support (b) with side support.

comparing to other subtractive type (CNC Milling and CNC Turning), and about 85% reduction in CO<sub>2</sub>e emissions comparing with additive type (DED, Binder jetting and L-PBF).

Finally, this analysis lead to the importance of CAD software tools in enhancing designer decision in early product development stage, and open the door to get more benefits of CAD software. For future work, we suggest comparison between Fusion 360 MSI result and SolidWorks Sustainability tool to see which is more accurate.

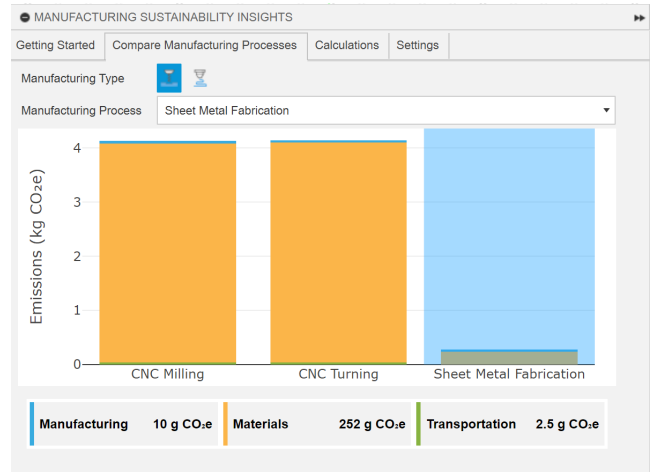


FIG. 4: The CO<sub>2</sub>e emissions of L-bracket without side support using Aluminum material and Sheet Metal Fabrication.

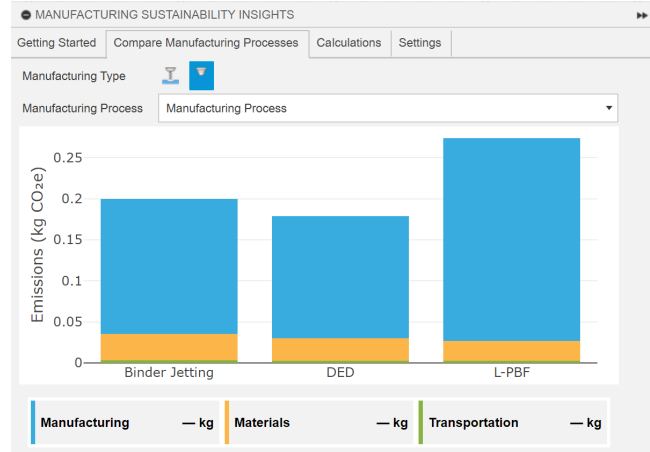


FIG. 5: The CO<sub>2</sub>e emissions of L-bracket without side support using Steel material and Additive Manufacturing Process.

**DECLARATION OF COMPETING INTEREST**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**ACKNOWLEDGMENTS**

This research was conducted at the Sudan University of Science and Technology. The authors extend their

gratitude for the support and for considering our article for publication in this esteemed journal.

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