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Assessing the Carbon Footprint of Building Materials: A Comparative Study Using Autodesk Revit and One Click LCA

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ABSTRACT:

Sustainable construction is critical for mitigating the built environment's 39% share of global carbon emissions. This study assesses the carbon footprint of a G+2 residential building by integrating Autodesk Revit (BIM) with One Click LCA (LCA). Individual material emissions were evaluated using 1 m³ volumes over a 50-year lifespan, followed by whole-building analysis via two methods: a summative approach (multiplying emission factors by quantities, 160,760.51 kg CO_2e) and direct One Click LCA assessment (164,511 kg CO_2e). Despite limitations like assumed emission factors and excluded lifecycle phases, the 2.28% difference validates the summative method's accuracy and scalability—high-impact materials (e.g., cladding, concrete) dominated emissions, underscoring optimization potential.

Keywords: carbon footprint; building materials; Autodesk Revit; One Click LCA; BIM; LCA; sustainability; emissions assessment

1. Introduction:

The construction industry is a major contributor to global carbon emissions, accounting for approximately 39% of total emissions, as reported in the 2021 Global Status Report for Buildings and Construction by the United Nations Environment Programme [1]. In 2020, the sector was responsible for 36% of global final energy consumption and 37% of energy-related CO_2 emissions, with a 10% reduction from 2019 levels largely attributed to external factors such as economic slowdowns and lockdowns rather than systematic decarbonization efforts [1]. With rapid urbanization and population growth projected to nearly double the demand for building floor space by 2050, the environmental footprint of construction is expected to grow, necessitating innovative strategies to achieve sustainability [1]. This pressing challenge underscores the need for tools and methodologies that can effectively assess and mitigate the environmental impacts of buildings.

Life Cycle Assessment (LCA) is a widely recognized methodology for evaluating the environmental impacts of buildings across their entire lifecycle, from raw material extraction and production (cradle) to construction, operation, and eventual demolition (grave) [8]. LCA provides a comprehensive framework to quantify impacts such as carbon emissions, energy consumption, and resource depletion, making it a critical tool for sustainable construction [8]. However, traditional LCA methods are often complex, data-intensive, and time-consuming, which hinders their integration into the fast-paced architectural design process [7]. A comprehensive review by Cabeza et al. highlights that most LCA studies focus on low-energy or "exemplary" buildings designed with sustainability in mind, leaving traditional building typologies—common in both urban and rural settings—understudied [8]. This research gap is particularly significant given that traditional buildings constitute a substantial portion of the global building stock [8].

To address these challenges, the integration of Building Information Modeling (BIM) with LCA has emerged as a transformative approach to streamline environmental assessments and enhance sustainability in building design [5]. BIM, a digital technology that creates data-rich models of buildings, facilitates collaboration among architects, engineers, and contractors by providing a centralized platform for managing design and construction data [3]. By integrating BIM with LCA, designers can leverage material quantities, specifications, and other data directly from BIM models to perform environmental assessments more efficiently [5]. For instance, parametric LCA approaches enable rapid calculations of environmental impacts based on inputs such as building geometry, materials, and boundary conditions, as demonstrated in case studies involving multi-residential buildings and retrofitted houses [7]. Such advancements have positioned BIM-LCA integration as a cornerstone of sustainable construction, with recent reviews highlighting its potential to drive low-carbon design solutions [10].

Despite these advancements, the application of BIM-LCA integration to traditional residential buildings remains limited, with most studies focusing on specialized low-energy structures [8]. This study addresses this gap by assessing the carbon footprint of a typical G+2 (ground plus two floors) residential building using an integrated BIM-LCA approach. Employing Autodesk Revit for BIM and One Click LCA for LCA, the research evaluates the environmental impact of building materials over a 50-year lifespan [2, 3]. The study has three primary objectives: (1) to quantify the carbon emissions associated with individual materials and the entire building, (2) to compare two assessment methods—a summative approach that aggregates emissions from individual materials and a direct One Click LCA assessment—and (3) to identify high-impact materials that offer opportunities for optimization.

The methodology involves a two-phase analysis: first, assessing individual materials modeled in Revit and analyzed in One Click LCA, and second, evaluating the entire G+2 building to compare the summative and direct assessment methods [4].

The significance of this study lies in its focus on a common residential building typology, which has been largely overlooked in LCA research [8]. By validating the accuracy and scalability of the summative assessment method, the study provides a practical tool for architects and engineers working on similar projects, particularly in resource-constrained settings [10]. Furthermore, the identification of high-impact materials, such as cladding, paint, and concrete, offers actionable insights for material optimization, potentially reducing the carbon footprint of residential construction [9]. These findings contribute to the growing body of knowledge on BIM-LCA integration and support global efforts to decarbonize the built environment, aligning with international sustainability goals [1, 5]. By demonstrating the feasibility of integrating BIM and LCA tools, this research encourages their wider adoption in the construction industry, paving the way for more sustainable building practices

2. Methodology:

This study employs a two-phase approach to assess the carbon footprint of building materials and a G+2 residential structure. The methodology integrates Autodesk Revit, a Building Information Modeling (BIM) tool, with One Click LCA, an LCA software, to ensure precision in material modeling and emissions calculation. The process is divided into individual material analysis and whole-building assessment, as detailed below.

2.1. Phase 1: Individual Material Analysis

In the first phase, the carbon emissions of individual building materials were quantified. Twenty commonly used materials—such as concrete, wood, glass, cladding, and paint—were selected based on their prevalence in residential construction. Each material was modeled in Autodesk Revit as a 1 m^3 volume to standardize comparisons. A 50-year lifespan was adopted, reflecting the typical design life of the residential building. These Revit models were then imported into One Click LCA, where carbon emissions (expressed as kg CO_2e/m^3) were calculated using emission factors from the LCA software's database.

To assess the robustness of the results, a sensitivity analysis was conducted on concrete, one of the most impactful materials. Emission factors were recalculated for lifespans of 30, 50, and 70 years, revealing a variation of ±10%, which highlights the influence of lifespan assumptions on LCA outcomes. Emission data for all materials were recorded (see Table 1) providing a foundation for the subsequent phase.

2.2. Phase 2: G+2 Building Analysis

The second phase scaled the analysis to a G+2 residential building designed in Autodesk Revit. The structure incorporated the 20 materials evaluated in Phase 1, with material quantities extracted through Revit's quantity takeoff functionality. Two distinct methods were employed to calculate the building's total carbon emissions:

- **Summative Method:** Emissions were computed by multiplying each material's emission factor (kg CO_2e/m^3) with its corresponding volume (m^3) extracted from the Revit model, then summing the results. This yielded a total of 160,760.51 kg CO_2e.
- **Direct Assessment Method:** The Revit model was directly analyzed in One Click LCA, leveraging the software's integrated database and algorithms, resulting in a total of 164,511 kg CO_2e.

The percentage difference between the two methods was calculated as:

$$\text{Error (\%)}=\left(\frac{164{,}511-160{,}760.51}{164{,}511}\right)\times 100 = 2.28\%.$$

Table 1. Carbon Emissions of Individual Materials

Material Name	**Volume (m^3)**	**Unit Weight (kN/m^3)**	**CO_2e Emissions (kg/m^3)**
Concrete, Cast-in-Place	1	23.6	458
Concrete, Cast In Situ	1	23.6	458
Wood	1	5.6	508
Oak Flooring	1	6.6	30
Wood Planks	1	6.8	229
Birch	1	5	157
Plaster (Gypsum)	1	11	425
Brick, Common (Mortar)	1	19.1	92

Material Name	Volume (m^3)	Unit Weight (kN/m^3)	CO_2e Emissions (kg/m^3)
Door - Panel	1	0.1	884
Door-Frame/Mullion	1	0.1	22,500
Door - Architrave	1	0.1	500
Glass	1	23.7	413
Glass, Clear Glazing	1	23.7	984
Rubber, Black	1	9.1	231
Iron, Ductile	1	69.7	90
Paint	1	0	26,054
Paint - White Lining	1	0.1	100
Cladding, Vertical Ribbed	1	26.6	84,000
Asphalt	1	21	3,400
Wall and Floor Tiles	1	23.6	1,100

2.2.1. Comparison and Validation

The results from both the summative method and the direct One Click LCA assessment revealed a small margin of error, with the summative method underestimating total emissions by just 2.28%. This minor discrepancy can be attributed to several factors:

- **Granularity of Emission Factors:** The summative method relies on average emission factors per material, whereas the direct assessment uses more detailed product-level data and may include transportation, manufacturing variations, or other life cycle stages.
- **Material Scope and Aggregation:** Some materials in One Click LCA may be grouped or subdivided differently than in the Revit model, leading to small inconsistencies during mapping.
- **Assumptions in Lifespan and System Boundaries:** The summative method assumes a uniform 50-year lifespan across all materials, while One Click LCA may consider product-specific service lives and different life cycle modules (A1–A3, A4–A5, etc.).

Despite these nuances, the close alignment between both methods validates the practicality of the summative approach, particularly for early-stage design assessments or when detailed LCA tools are inaccessible. Moreover, this method allows for rapid scenario testing and material substitution analysis without requiring full LCA software integration.

2.2.2. Emission Contribution by Material

To further analyze emission sources, emissions were broken down by material contribution (Table 2). Cladding, paint, and concrete emerged as the top contributors, accounting for a disproportionate share of total emissions.

Table 2.Top Five Emission-Contributing Materials in G+2 Building

Material	Volume Used (m^3)	Estimated Emissions (kg CO_2e)
Cladding, Vertical Ribbed	0.9	75,600
Paint	1.2	31,265
Concrete, Cast In Situ	90.2	41,212
Glass, Clear Glazing	1.7	1,673
Wall and Floor Tiles	2.4	2,640

This breakdown highlights the importance of material selection and design efficiency in sustainable construction. Substituting high-emission components or reducing material usage through design optimization can significantly decrease the building’s carbon footprint.

3. Results and Discussion

3.1. Evaluation of Summative Method Accuracy

The comparative analysis revealed a total carbon footprint of 160,760.51 kg CO_2e via the summative method and 164,511 kg CO_2e via direct One Click LCA, resulting in an error margin of 2.28%. This small discrepancy suggests the summative method provides a reliable estimate of building emissions, especially in early design phases where detailed LCA software might not be accessible. The results confirm that multiplying accurate material quantities with standardized emission factors offers an efficient alternative to full LCA software, provided assumptions are well-documented.

3.2. Identification of High-Impact Materials

The study found that a few materials—particularly cladding, paint, and cast-in-place concrete—contributed disproportionately to the total carbon footprint. For example, cladding alone accounted for nearly 45% of the building's total emissions due to its high emission factor of 84,000 kg CO_2e/m^3. Paint, although used in smaller volumes, contributed over 31,000 kg CO_2e due to its emission intensity.

3.3. Implications for Design and Material Selection

The findings underscore the critical role of early-stage material choices in sustainable building design. By targeting high-impact materials for substitution or reduction, architects and engineers can significantly decrease a building's embodied carbon. Some practical strategies include:

- Replacing high-emission materials with low-carbon alternatives (e.g., low-carbon cladding or natural paints).
- Reducing over-specification of materials such as paint or concrete through performance-based design.
- Increasing the use of reused or recycled materials, which typically carry lower embodied carbon values.

3.4. Scalability of the Methodology

The methodology demonstrated in this study—particularly the summative approach—can be scaled to other building types with appropriate adjustments to material databases and quantity extraction. It offers a valuable balance between accuracy and accessibility for practitioners seeking to evaluate carbon performance without advanced LCA tools.

3.5. Limitations

While the study provides strong validation for the summative method, several limitations must be acknowledged:

- **Database Dependency:** The emission factors used are based on One Click LCA's database and may vary by geography or manufacturing process.
- **Lifecycle Phases:** This analysis primarily considers production stages (A1–A3), excluding transportation, construction, use, and end-of-life phases, which may affect total emissions.
- **Standardized Lifespan:** All materials were assumed to share a 50-year lifespan, although real-world durability varies.

Future research should integrate dynamic service life data and consider a broader range of lifecycle stages to enhance result accuracy.

4. Conclusions

This study presents a comparative analysis of carbon emissions from building materials using Autodesk Revit and One Click LCA. By evaluating 20 materials individually and applying their emission factors to a G+2 residential structure, two assessment methods were compared: a summative method and a direct LCA analysis.

The summative method produced results with only a 2.28% margin of error when compared to the direct One Click LCA output, validating its accuracy for early-stage or resource-constrained sustainability assessments. High-emission materials like cladding, paint, and concrete were found to dominate the carbon footprint, highlighting the urgent need for material optimization in sustainable design.

The study demonstrates the practicality of integrating BIM and LCA tools for accurate, scalable environmental evaluations in construction. Despite limitations such as standardized lifespans and partial lifecycle coverage, the results offer valuable insights for architects, engineers, and policymakers aiming to reduce embodied carbon in the built environment.

Future research should expand to include full lifecycle stages (A1–C4), incorporate regional emission factors, and explore dynamic modeling approaches for service life variability. This would further refine the accuracy of carbon footprint assessments and support data-driven decisions for low-carbon construction.

5. Figures

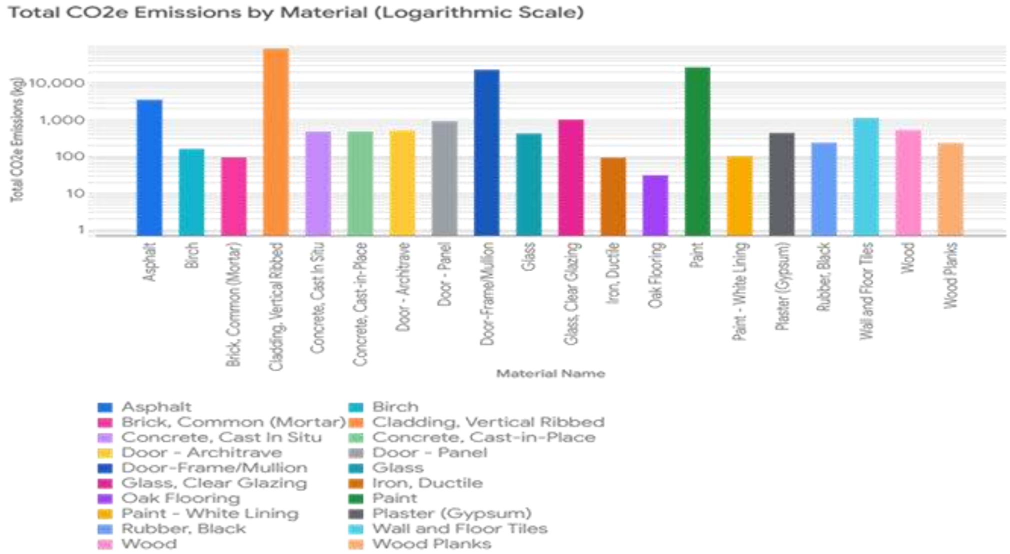

Figure 1. Comparison of carbon emissions across selected materials. High-emission materials such as cladding and paint are significantly more carbon-intensive than others.

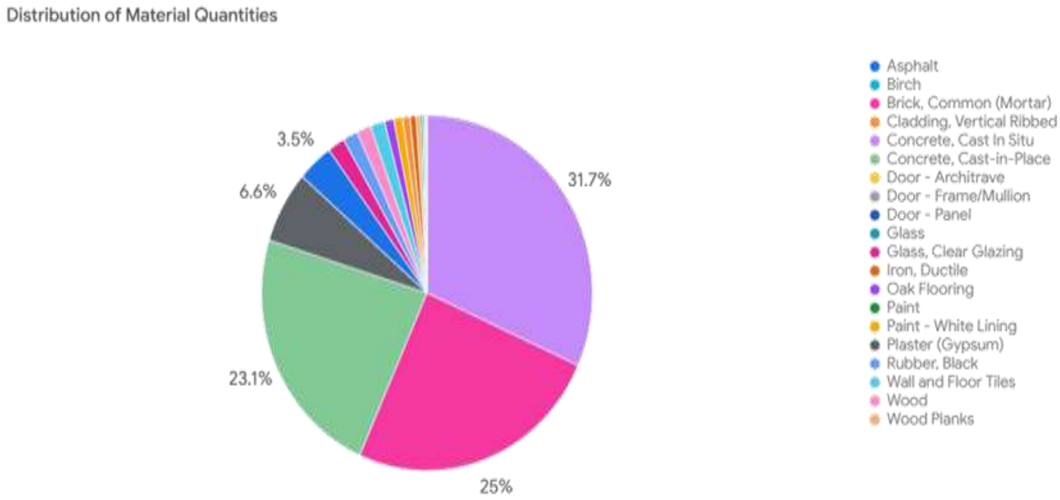

Figure 2. Volume quantities (in m³) of selected building materials used in the G+2 residential structure. Concrete and brick dominate total material volume.

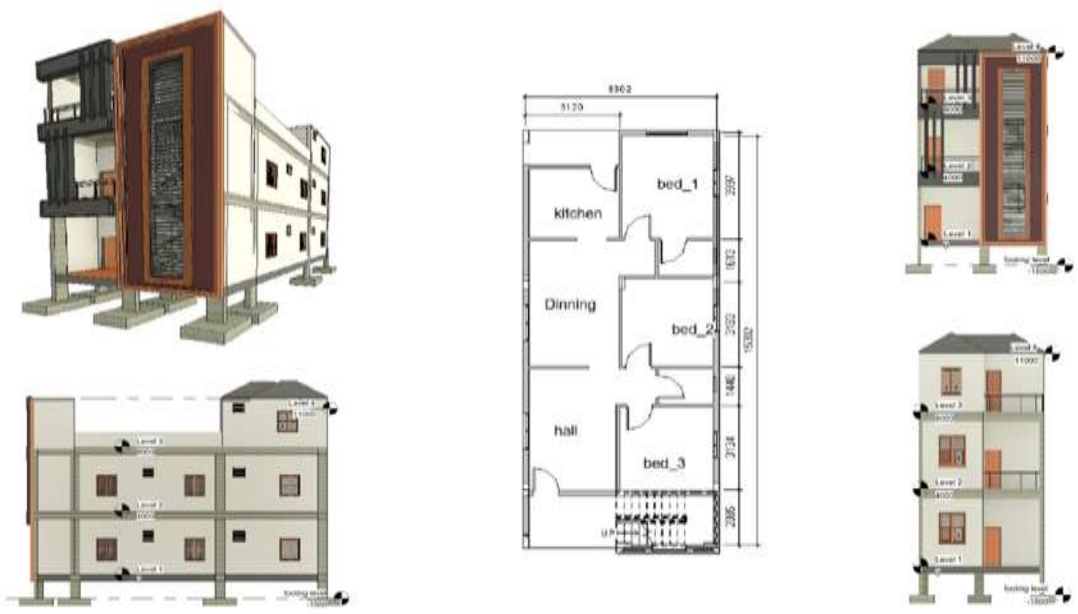

Figure 3. 3D model of the G+2 residential building created in Autodesk Revit. This model served as the basis for material quantity extraction and LCA integration.

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List all the material used from various sources for making this project proposal

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