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Integração de BIM e ACV para Análises de Descarbonização: Método Simplificado aplicado a um Empreendimento de HIS

BIM and LCA Integration for Decarbonization Analysis: Simplified Method Applied to a Social Housing Development

Integración de BIM y ACV para Análisis de Descarbonización: Método Simplificado Aplicado a un Proyecto de Vivienda de Interés Social (VIS)

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Resumo: A aplicação prática de metodologias de Avaliação de Ciclo de Vida (ACV) integradas ao Building Information Modeling (BIM) exige um domínio técnico aprofundado sobre softwares e tecnologias, o que limita seu alcance a profissionais com menor experiência. Neste contexto, a pesquisa teve como objetivo criar e aplicar um método simplificado para análises de descarbonização, contribuindo para a acessibilidade da realização de ACV no ambiente BIM. Para isso, o estudo concentra-se em um único software, adaptando as funcionalidades nativas do Autodesk Revit® para quantificar o CO₂ Incorporado (CI) sem a necessidade de interoperabilidade com outras plataformas ou programas. A aplicação do método foi realizada por meio de um estudo de caso em um empre-

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endimento Habitacional de Interesse Social (HIS) localizado em um município de pequeno porte no interior do Rio Grande do Sul. Os cálculos de CO₂ foram realizados a partir da manipulação de parâmetros na ferramenta "tabela de quantidades" (BoQ). Como resultado, a metodologia proposta permitiu prever uma descarbonização de até 62,27% ao comparar diferentes sistemas construtivos de vedação. Dessa forma, a pesquisa contribui para a consolidação de uma ferramenta auxiliar, acessível e replicável em projetos de edificações, tornando a sustentabilidade um elemento operativo e mensurável ao longo do processo.

Palavras-chave: BIM; ACV; Descarbonização; Método; HIS.

Abstract: The practical application of Life Cycle Assessment (LCA) methodologies integrated with Building Information Modeling (BIM) requires advanced technical proficiency in software and digital technologies, which limits their accessibility for less experienced professionals. In this context, the aim of this research was to develop and apply a simplified method for decarbonization analyses, contributing to greater accessibility of LCA implementation within the BIM environment. To achieve this, the study focuses on a single software platform, adapting the native functionalities of Autodesk Revit® to quantify Embodied CO₂ (EC) without the need for interoperability with other programs or platforms. The method was applied through a case study of a Social Housing development located in a small municipality in the interior of Rio Grande do Sul, Brazil. CO₂ calculations were performed by manipulating parameters within the "Schedule/Quantities" (BoQ) tool. As a result, the proposed methodology enabled the prediction of up to 62.27% decarbonization when comparing different wall system configurations. In this way, the research contributes to consolidating an auxiliary, accessible, and replicable tool for building projects, making sustainability an operational and measurable component throughout the design process.

Keywords: BIM; LCA; Decarbonization; Method; Social Housing

Resumen: La aplicación práctica de metodologías de Evaluación del Ciclo de Vida (ACV) integradas al Building Information Modeling (BIM) exige un dominio técnico avanzado de softwares y tecnologías, lo que limita su alcance para profesionales con menor experiencia. En este contexto, la investigación tuvo como objetivo crear y aplicar un método simplificado para análisis de descarbonización, contribuyendo a la accesibilidad de la ACV en el entorno BIM. Para ello, el estudio se concentra en un único software, adaptando las funcionalidades nativas de Autodesk Revit® para cuantificar el CO₂ Incorporado (CI) sin necesidad

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de interoperabilidad con otras plataformas. La aplicación del método se realizó mediante un estudio de caso en un emprendimiento de Vivienda de Interés Social (VIS) ubicado en un pequeño municipio del interior de Rio Grande do Sul. Los cálculos de CO₂ se llevaron a cabo mediante la manipulación de parámetros en la herramienta de "cuadro de cantidades" (BoQ). Como resultado, la metodología propuesta permitió prever una descarbonización de hasta un 62,27% al comparar diferentes sistemas constructivos de cerramiento. De este modo, la investigación contribuye a la consolidación de una herramienta auxiliar, accesible y replicable en proyectos de edificación, haciendo de la sostenibilidad un elemento operativo y mensurable a lo largo del proceso.

Palabras clave: término1; término2; término3; término4; término5.

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1 INTRODUCTION

Specialized literature underscores the critical relevance of the construction sector in the context of anthropogenic carbon emissions. According to Cabeza et al. (2022), buildings account for approximately 31% of global carbon dioxide (CO₂) emissions, of which around 18% derive from embodied carbon (EC), that is, emissions associated with the extraction, processing, transportation, and assembly of materials during the construction phase. In the Brazilian context, data from the Ministry of Science, Technology and Innovations (Brasil, 2022) indicate that, in 2020, the country emitted 3.236 gigatonnes of CO₂, with the category "Manufacturing and Construction Industry" contributing approximately 60.675 gigagrams to this total. These figures reinforce the need to equip the sector with robust methodologies and metrics capable of supporting effective decarbonization strategies.

In this regard, the integration of Building Information Modeling (BIM) and Life Cycle Assessment (LCA) emerges as a promising approach for operationalizing environmental analyses with greater accuracy, transparency, and predictive capacity. The synergy between parametric digital modeling and the systemic logic of LCA enables the quantification of environmental impacts across different project stages, facilitating the traceability of material and energy flows from conception through execution. As highlighted by Lima et al. (2024), this integration significantly enhances the quality of the information generated, expands the analytical scope, and optimizes decision-making processes throughout the building life cycle.

However, the practical implementation of this integration remains limited, mainly due to technical and cognitive barriers. Olawumi et al. (2018) identify as the main challenges the shortage of skilled professionals, fragmentation of technical knowledge, and the high complexity of workflows involving multiple digital platforms. As described by Bueno et al. (2018), the operationalization of LCA within a BIM environment requires the simultaneous use of tools such as Dynamo, Revit, and Excel, as well as specialized expertise in computational modeling and environmental data automation. Other studies, such as that by Crippa (2019), reinforce this technological dependence by proposing methodologies based on standardized classifications (OmniClass) and integration with Life Cycle Inventory (LCI) databases, demonstrating a high level of sophistication but also limited accessibility for less specialized users.

This scenario highlights the need for methodological strategies that reconcile analytical robustness with operational feasibility. Varela (2021) advocates the simplification of environmental impact quantification workflows within the BIM environment, emphasizing the reduction of interoperability dependence and the enhancement of accessibility for the various stakeholders involved in design decision-making. The author also stresses the importance of developing methodological solutions that incorporate environmental criteria directly, without requiring advanced proficiency in multiple software platforms or complex computational routines.

This research positions itself within this critical context and proposes an alternative to the traditional logic of BIM–LCA integration. It is based on the premise that broadening the use of environmental assessment tools in the construction sector requires technically consistent solutions adapted to the real operational conditions of design firms, public institutions, and actors within the supply chain. Accordingly, the objective of

this study is to develop and apply a parameterized method for quantifying embodied CO₂, conceived entirely within the Autodesk Revit® environment, without relying on interoperability with external platforms.

2 LITERATURE REVIEW

The integration between BIM and LCA has predominantly been operationalized through two distinct methods. The first method relies on the use of LCA software that directly or indirectly extracts information from the BIM model for the calculation of emissions and other environmental impacts. However, this strategy presents substantial limitations, notably associated with interoperability failures, extensibility constraints, data incompatibility, and the loss of components during conversion and export processes. As an alternative, the second method consists of the incorporation of emission factors (EFs), sourced from LCA databases, directly into the BIM model, adding new semantic and functional layers—constituting the conceptual basis of Green-BIM. This approach enables not only the integrated assessment of carbon emissions and energy consumption, but also the evaluation of resource-efficiency strategies directly within the BIM environment (Hussain et al., 2023).

Obrecht et al. (2020), upon reviewing the literature on BIM–LCA integration methodologies, identified that most studies rely on manual data exchange workflows, in which the BIM model is used to generate Bills of Quantity (BoQ), which are subsequently imported into specialized LCA software. Although such workflows represent early advancements compared to conventional approaches, their dependence on human intervention limits the standardization, scalability, and consistency of results. Semi-automated integration, also commonly adopted, allows for partial export of information from the BIM environment to LCA tools, but still requires manual completion of data that are not always available in the original model. Fully automated integration, typically enabled by dedicated plug-ins, has proven effective in achieving results with greater efficiency. However, the use of custom scripts to promote interoperability between platforms, while effective, requires users to have advanced proficiency in computational logic and programming languages, which restricts applicability in less specialized contexts.

While advances in interoperability represent a desirable direction, such dependence reinforces the exclusion of actors with lower technical or institutional capacity. According to data released by BIM Forum Brasil, only 33.8% of construction professionals in the country have reached a stage of practical experience with BIM, while 56.7% are still in the phase of discovery and initial engagement (Castelo et al., 2024). This indicates the still incipient adoption of this methodology in the sector. Furthermore, authors such as Costa et al. (2019) and Tokede & Traverso (2020) point out that education and training in LCA methodologies are necessary to enhance local capacity to carry out such assessments. In this sense, the reality of developing countries lacks systematized, practical, didactic, and accessible methods and criteria to increase the applicability of LCA analyses within the BIM environment.

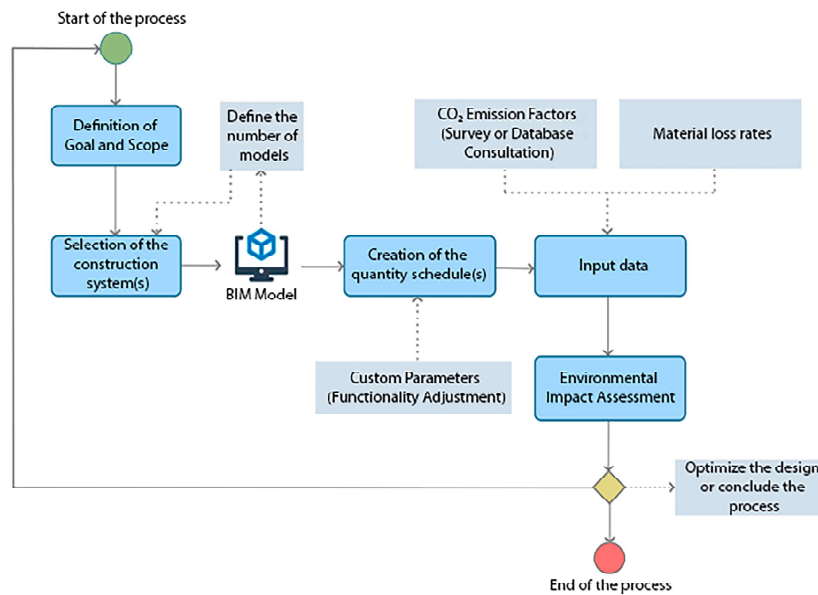
3 MATERIALS AND METHODS

The method proposed in this study is based on the recurrent approaches identified by Obrecht et al. (2020). However, it distinguishes itself by eliminating the need for interoperability with external software, centralizing the quantification of embodied CO₂ directly within Autodesk Revit®. This approach contrasts with conventional workflows, which rely on complementary platforms for environmental assessment. The developed method internalizes LCA logic within the information model, providing a simplified yet robust alternative for analyzing carbon emissions of construction materials. Focused on applicability within the BIM environment, it seeks to overcome technical barriers, particularly in contexts such as Brazil, where platform integration is limited.

The methodology applied in this study was adapted from Silva (2025b), who developed a framework for estimating environmental impacts of construction systems using BIM and simplified LCA. The process begins with defining the LCA goal and scope, establishing parameters such as system function and functional unit while adjusting contextual elements and selecting the construction systems, whose degree of similarity determines both the number and complexity of models to be developed in Autodesk Revit®. Following the modeling phase, quantity takeoff tables are generated—the core stage of the method—by adapting Revit® through the creation and configuration of custom parameters. Initially, input parameters are entered using data from bibliographic sources or manufacturer catalogs, followed by calculated parameters, which automate environmental quantification. The results allow the identification of the system with the lowest environmental impact; if performance is unsatisfactory, the process may be restarted with adjustments to materials or critical variables.

Figure 1 illustrates the sequential structure of the method.

Figura 1 – Proposed Method for Estimating Environmental Impacts of Building Envelope Systems

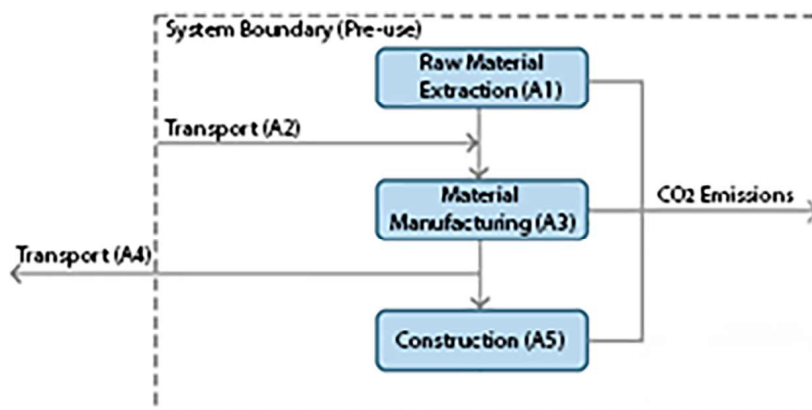


Source: Authors.

3.1 Definition of Goal and Scope

This research adopts a methodological simplification of LCA, suppressing specific stages to ensure operational feasibility. The scope definition follows a cradle-to-site logic, encompassing the phases of raw material extraction, industrial processing, and construction. However, among logistical processes, only the transport of raw materials to the manufacturing facility was considered, as it is already embedded in the Emission Factors (EF) associated with the pre-use phase. Transport from the factory to the construction site was excluded due to the generic nature of the analysis, which does not account for location-specific suppliers. Figure 2 presents the adopted system boundary, indicating the included stages. Additionally, a cut-off criterion was applied, excluding materials that represent 0.1% or less of the building's total mass.

Figura 2 – System Boundary



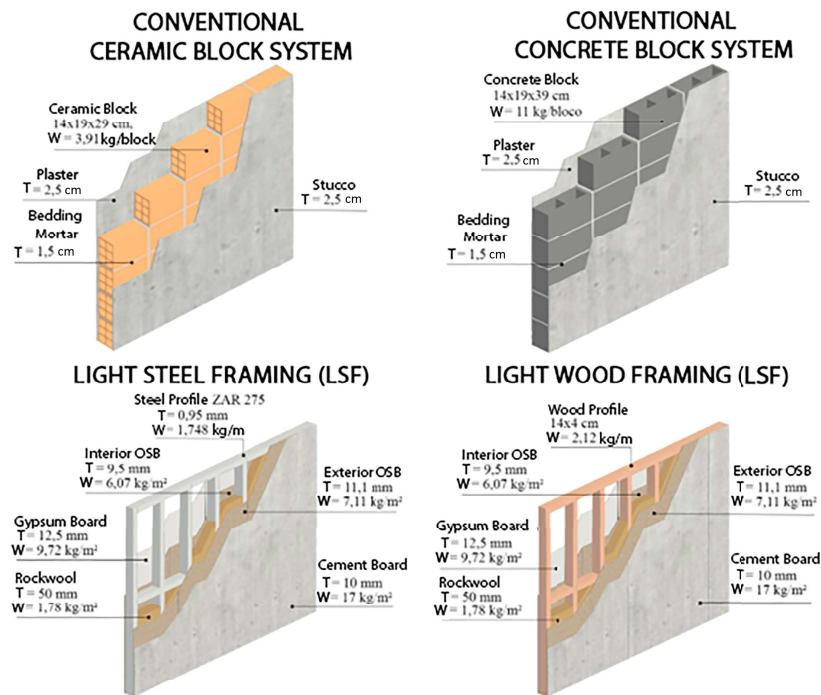
Source: Authors.

3.2 Analyzed Construction Systems

Figure 3 presents the four construction systems analyzed.

The products selected for analysis comprise the main inputs used in the construction of internal and external vertical partitions in residential buildings, including: (a) ceramic blocks; (b) concrete blocks; (c) mortar for laying and rendering; (d) galvanized steel studs; (e) OSB structural panels; (f) fiber-cement boards; (g) gypsum plasterboards; (h) rock wool insulation; and (i) timber studs. These components are integral to the four construction systems examined—conventional masonry with ceramic blocks, concrete block masonry, Light Steel Framing (LSF), and Light Wood Framing (LWF)—which constitute the comparative basis of the study. Quantification was initially carried out for a standard dwelling unit and subsequently converted to the functional unit of 1 m² of wall, in addition to being projected for the total development.

Figura 3 – Analyzed Construction Systems



Source: Authors.

3.3 BIM Model: Application in a Case Study

The application of the method was carried out through a case study of a completed social housing development (HIS) located in the municipality of Santa Rosa, in the northwestern region of the state of Rio Grande do Sul, Brazil, as shown in Figure 4.

Figura 4 – Location of the Analyzed Housing Project

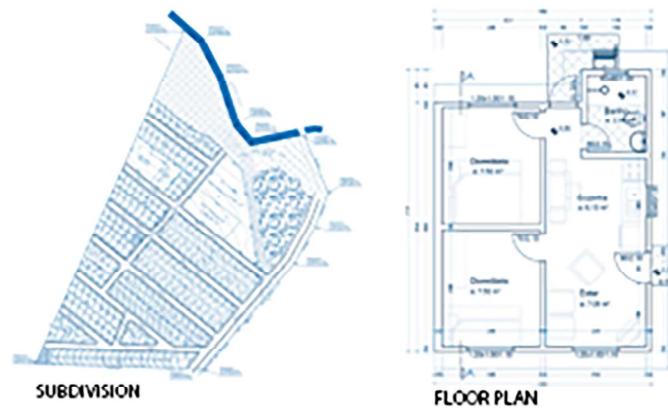


Source: Authors.

The Municipal Government provided the project's technical documentation, consisting of the complete architectural design in DWG format and a descriptive report detailing the construction specifications adopted. The housing complex comprises 189 lots, of which 185 are designated for single-story detached residential

units, two for institutional facilities, and two for green areas, as shown in Figure 5. Each dwelling unit has a built area of 36.35 m² and was constructed using perforated ceramic block masonry, finished with a mortar composed of cement, lime, and sand, applied at a thickness ranging from 1.5 to 2.5 cm.

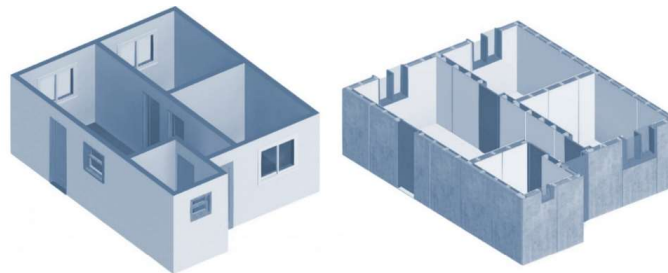
Figura 5 – Design of the Analyzed Housing Development



Source: Authors.

The floor plan of a dwelling unit was modeled twice in Autodesk Revit®, with the purpose of representing different construction systems. The first model incorporated conventional masonry solutions; the second was used to simulate the prefabricated LSF and LWF systems, as shown in Figure 6.

Figura 6 – Modeling of a Single Dwelling in Autodesk Revit® Conducted to Represent Conventional and Prefabricated Construction Systems



Source: Authors.

3.4 Development of Quantity Schedules

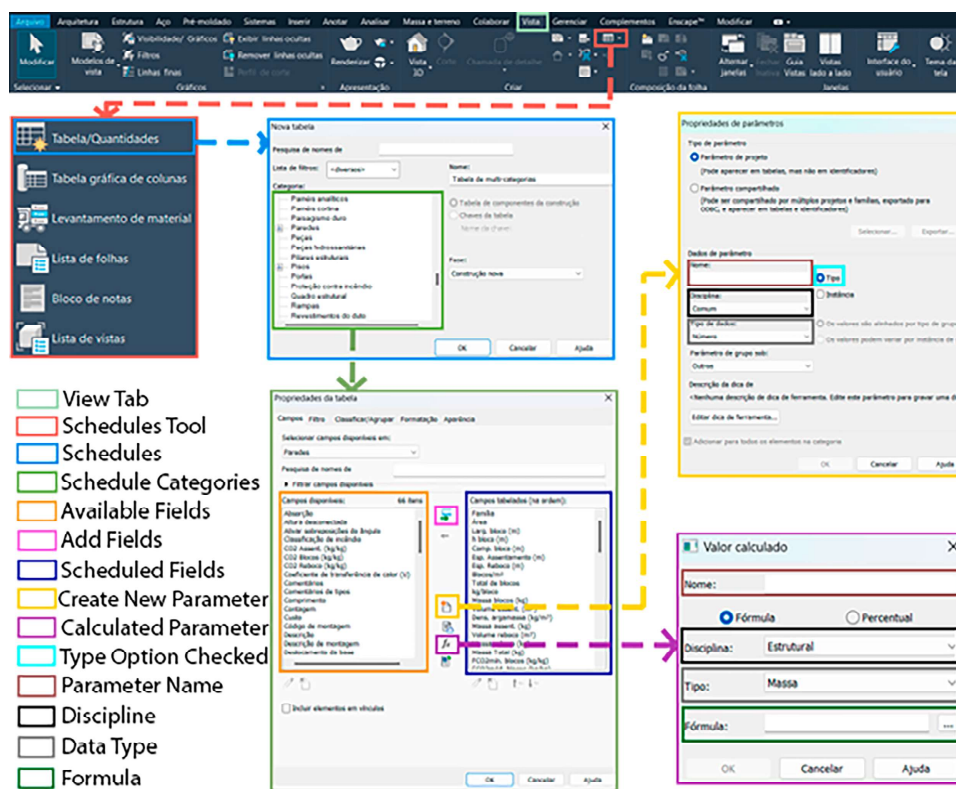
The quantity schedule in Autodesk Revit® was created using the dedicated tool available under the "View" tab. When activated, the software directs the user to an interface that lists the categories of modelable elements—such as floors, doors, and plumbing fixtures, among others. For the purposes of this research, the "Walls" category was selected, enabling the insertion of the desired fields to compose the schedule. Initially, two default fields — "Family" and "Area"— were selected, forming the initial columns of the tabular structure.

Subsequent columns were incorporated through the creation of custom parameters, enabled by the "Create New Parameter" and "Add Calculated Parameter" functions. The choice between these resources depends on the nature of the variable being added, distinguishing between input data and parameters derived through formulas.

Configuring each parameter requires defining the discipline — such as common, electrical, energy, HVAC, infrastructure, piping, or structural — and the data type, which is constrained by the selected discipline. For this application, most input parameters were configured under the "common" discipline with the "number" data type, while the parameters used for mass calculations were defined under the "structural" discipline with the "mass" data type.

Additionally, a cross-check was performed between the inserted values and the modeled volumes to ensure the geometric consistency of the data. This process also involved standardizing the units of measurement to ensure compatibility with the LCA requirements. Finally, the resulting schedule was validated through preliminary tests using the different wall typologies. Figure 7 presents the methodological workflow in Revit® for developing and customizing the quantity schedule.

Figura 7 – Workflow for Creating Quantity Schedules in Autodesk Revit®



Source: Authors.

The quantification of the conventional masonry systems using ceramic and concrete blocks began with the creation of five specific parameters in the "Walls" category using the "New Parameter" tool. These parameters were defined under the "Common" discipline with the "Number" data type and represented the block dimensions (height – Pbh, length – Pbl, and width – Pbw), the thickness of the bedding mortar (Pbmt), and the

thickness of the plaster/stucco (Ppst).

Subsequently, using the "Add Calculated Parameter" function (discipline: "Common"; data type: "Integer"), a formula was implemented that combined the geometric parameters to estimate the number of blocks per square meter (Pb/m^2), as shown in Equation 1. The same logic was applied in Equation 2 to compute the total number of blocks (Ptb). The estimation of the bedding mortar volume was performed through a calculated parameter (discipline: "Common"; data type: "Volume"), as shown in Equation 3, and similarly, Equation 4 was used to determine the volume of plaster/stucco.

The estimation of material mass was based on technical data provided by manufacturers, which included the unit weight of ceramic and concrete blocks. To enable this calculation, the parameter P_{bwe} (block weight) was created under the "Common" discipline with the "Number" data type. Using this parameter, Equation 5 was inserted into a calculated parameter to multiply the total number of blocks (Ptb) by the unit weight. The mass of the bedding mortar was determined through Equation 6 by multiplying the estimated volume (P_{bmv}) by its density (P_{md}, mortar density), configured under the "Common" discipline with the "Mass Density" data type. The same procedure was adopted for calculating the mass of the plaster/stucco (Equation 7).

All mass-related parameters were defined under the "Structural" discipline with the "Mass" data type, ensuring compatibility of the results in kilograms. The block dimensions (14×19×29 cm for ceramic blocks; 14×19×39 cm for concrete blocks), coating thicknesses (1.5 cm for bedding mortar and 2.5 cm for plaster/stucco), and unit weights (3.91 kg and 11 kg, respectively) were manually entered into the model's type properties. These values were obtained from supplier catalogs and from the technical specification document provided by the Municipal Government of Santa Rosa. Equation 8 was used to consolidate the total wall mass (P_{tm}) by summing the contributions from blocks, bedding mortar, and plaster/stucco.

With the mass values computed, the environmental impacts of the systems were estimated by creating four additional parameters, all configured under the "Common" discipline with the "Number" data type: (1) PEFCO_{2b} (emission factor for blocks); (2) PEFCO_{2m} (emission factor for mortar); (3) PLOSS_b (loss factor for blocks); and (4) PLOSS_m (loss factor for mortar).

The values for the emission factors and loss factors were defined based on an extensive literature review and on national and international databases, totaling more than 50 entries for the analyzed materials. The arithmetic mean of the minimum and maximum values was adopted to represent each material. These data were manually entered either into the type properties or into the first row of the quantity schedules, allowing Revit® to automatically replicate them across the remaining rows.

The quantification of embodied CO₂ in the blocks (PECO_{2b}) was performed through a calculated parameter following Equation 9. Given the absence of a native discipline for CO₂ emissions, the "Structural" discipline with the "Mass" data type was adopted to ensure consistency with the unit of measurement (kilograms). The same procedure was applied for calculating the embodied CO₂ of the bedding mortar (PECO_{2bm}) and the plaster/stucco (PECO_{2ps}), according to Equations 10 and 11. Equation 12 synthesized the total emissions by summing the three components.

For the prefabricated systems — Light Steel Framing (LSF) and Light Wood Framing (LWF) — two separate schedules were required due to Revit®'s limitation in consolidating elements from the "Curtain Wall

Mullions"and "Walls"categories into a single tabular structure. The first schedule was dedicated to the quantification of tracks and studs, and the second to sheathing materials and insulation.

In the stud schedule, the default length parameter (Pl) was used, to which a custom column for linear mass was added. The mass of the metallic components (Psm) was then calculated using Equation 13, multiplying the stud length by the specific weight per meter (Pswem), configured under the "Structural"discipline with the "Mass" data type.

For sheathing and insulation materials, a similar approach was adopted: the area (Pa) was multiplied by the weight per square meter (Pwe/m²), obtained from supplier data, as shown in Equation 14. The parameter was defined under the "Structural"discipline with the "Mass per Unit Area" data type. Additionally, the schedules included parameters for emission factors (PEFCO2) and loss factors (PLOSS), with equations adapted from Equations 9 to 12 for each specific material.

It is noteworthy that in the sheathing and insulation schedule, Revit® organizes the data vertically, listing distinct layers in a single column. This allows multiple entries to be inserted sequentially and reduces the need for separate columns for each material — a behavior that differs from the schedules used for the conventional systems, where the structure requires segregated columns for every analyzed component.

Table 1 summarizes the equations used for each calculated parameter incorporated into the model.

Tabela 1 – Equations Used in the Calculated Parameters of the Quantity Schedules

Nº	Equation	Key Variable
1	$P_{b/m^2} = 1/((P_{bh}) + [P_{bml}] * ((P_{bl}) + [P_{bml}]))$	P_{b/m^2} = Number of Blocks per Square Meter P_{bh} = Block Height; P_{bl} = Block Length; P_{ml} = Bedding Mortar Thickness
2	$P_{tb} = (P_a / (1m * 1m)) * P_{b/m^2}$	P_{tb} = Total Number of Blocks P_a = Wall Area; P_{b/m^2} = Blocks per m²
3	$P_{bmv} = ((([P_{bl}] + [P_{bml}]) + [P_{bh}] * [P_{bml}]) * (1m * 1m * 1m)) * P_{tb}$	P_{bmv} = Bedding Mortar Volume P_{bl} = Block Length; P_{ml} = Mortar Thickness; P_{bh} = Block Height; P_{bm} = Block Width; P_{tb} = Total Number of Blocks
4	$P_{psv} = (P_a * 2) * [P_{pst}]$	P_{psv} = Plaster/Stucco Volume P_a = Wall Area; P_{pst} = Plaster/Stucco Thickness
5	$P_{bm} = (P_{tb} * 1kg) * [P_{bvw}]$	P_{bm} = Block Mass P_{tb} = Total Number of Blocks; P_{bvw} = Block Weight
6	$P_{bmv} = P_{bmv} * P_{md}$	P_{bmv} = Bedding Mortar Mass P_{bmv} = Bedding Mortar Volume; P_{md} = Mortar Density
7	$P_{psm} = P_{psv} * P_{md}$	P_{psm} = Plaster/Stucco Mass P_{psv} = Plaster/Stucco Volume; P_{md} = Mortar Density
8	$P_m = [P_{bm}] + [P_{bmv}] + [P_{psm}]$	P_m = Total Mass P_{bm} = Block Mass; P_{bmv} = Bedding Mortar Mass; P_{psm} = Plaster/Stucco Mass
9	$P_{ECO2b} = P_{bm} * [P_{EFCO2b}] * (1 + ((P_{LOSSb}) / 100))$	P_{ECO2b} = Embodied CO2 for Blocks P_{bm} = Block Mass; P_{EFCO2b} = Emission Factor of CO2 for Blocks; P_{LOSSb} = Loss Factor for Blocks
10	$P_{ECO2mv} = P_{bmv} * [P_{EFCO2mv}] * (1 + ((P_{LOSSm}) / 100))$	P_{ECO2mv} = Embodied CO2 for Bedding Mortar P_{bmv} = Bedding Mortar Mass; $P_{EFCO2mv}$ = Emission Factor of CO2 for Mortar; P_{LOSSm} = Loss Factor for Mortar
11	$P_{ECO2ps} = P_{psm} * [P_{EFCO2ps}] * (1 + ((P_{LOSSps}) / 100))$	P_{ECO2ps} = Embodied CO2 for Plaster/Stucco P_{psm} = Plaster/Stucco Mass; $P_{EFCO2ps}$ = Emission Factor of CO2 for Mortar; P_{LOSSps} = Loss Factor for Mortar
12	$P_{ECO2T} = [P_{ECO2b}] + [P_{ECO2mv}] + [P_{ECO2ps}]$	P_{ECO2T} = Total Embodied CO2 P_{ECO2b} = Embodied CO2 for Blocks; P_{ECO2mv} = Embodied CO2 for Bedding Mortar; P_{ECO2ps} = Embodied CO2 for Plaster/Stucco
13	$P_{sm} = P_l * P_{swem}$	P_{sm} = Stud Mass P_l = Length; P_{swem} = Stud Weight per Meter
14	$P_{sim} = P_a * P_{we/m^2}$	P_{sim} = Sheathing and Insulation Mass P_a = Wall Area; P_{we/m^2} = Weight per Square Meter

Source: Authors.

4 RESULTS AND DISCUSSION

Figura 8 – Embodied CO2 Estimation for the Conventional Ceramic Block Construction System Obtained Using Autodesk Revit®

Conventional Ceramic Block System								
A	B	C	D	E	F	G	H	I
Family	Area	Width Block (m)	Height Block (m)	Length Block (m)	Thk. Bedding Mortar	Thk. Plaster/ Stucco	Blocks/ m ³	Total Blocks
Basic Wall	15.751 m ²	0.14	0.19	0.29	0.015	0.025	16	252
Basic Wall	6.140 m ²	0.14	0.19	0.29	0.015	0.025	16	98
	77.201 m ²							1235

J	K	L	M	N	O	P	Q
kg/Block	Block Mass (kg)	Vol. Bedding Mortar	Density Mortar	Bedding Mortar Mass	Vol. Plaster/ Stucco	Plaster/ Stucco Mass	Total Mass
3.91	985.32 kg	0.2620 m ³	1900.00 kg/m ³	497.71 kg	0.7876 m ³	1496.37 kg	2979.40 kg
3.91	383.18 kg	0.1019 m ³	1900.00 kg/m ³	193.55 kg	0.3070 m ³	583.30 kg	1160.03 kg
	4828.85 kg	1.2838 m ³		2439.19 kg	3.8601 m ³	7334.12 kg	14602.16 kg

R	S	T	U	V	W	X	Y
EFCO2 Blocks	LOSS (Blocks)	EFCO2 Mortar	LOSS (Mortar)	ECO2 Blocks	ECO2 Bedding Mortar	ECO2 Plaster/ Stucco	Total ECO2
0.2025	15.5	0.195	15	230.45 kg	111.61 kg	335.66 kg	677.63 kg
0.2025	15.5	0.195	15	89.62 kg	43.40 kg	130.81 kg	263.83 kg
				1129.41 kg	546.99 kg	1644.68 kg	3321.07 kg

Data Input
 Automatic Results

Source: Authors.

The analysis of embodied CO2 data in the assessed construction systems highlights significant variations in the environmental performance of different construction techniques, reflecting the sensitivity of total emissions to the geometric, material, and operational characteristics of each solution. Such discrepancies, primarily associated with the production stage and the nature of the inputs used, directly affect design guidelines and technical specification decisions. The proposed method enables the quantification of these impacts in a fully parameterized manner executable entirely within Autodesk Revit®, eliminating the need for interoperability with external platforms and establishing a reproducible protocol for incorporating environmental criteria from the early design stages.

As illustrated in Figure 8, the masonry system using ceramic blocks totals 3,321.07 kgCO2 per dwelling, with the blocks alone accounting for 1,129.41 kgCO2 — approximately 34% of the total. This contribution underscores the environmental significance of this material in conventional buildings. According to Vinhal (2016), these emissions are associated with the use of biomass — particularly wood — as an energy source in industrial kilns. On a global scale, Del Rio et al. (2022) estimate that brick production accounts for roughly 2.7% of annual carbon emissions. To mitigate this impact, the authors propose integrated strategies beyond energy efficiency gains, including waste recycling, rationalization of raw material use, and progressive substitution with lower-carbon materials, requiring technological restructuring and regulatory adjustments throughout the production chain.

The conventional concrete block system, shown in Figure 9, has a total embodied carbon (EC) of 4,437.35 kg per dwelling, making it the system with the highest environmental impact. The largest contribution comes from the blocks themselves (2,299.69 kg, or 51.82%), whose high EC is associated with Portland cement production, responsible for approximately 8% of global emissions (Proaño et al., 2020). These data highlight the need for environmental mitigation strategies. In this context, Damineli (2013) emphasizes optimizing concrete mixes to reduce cement consumption. Plaster contributes significantly to total EC (1,644.68 kg, or 37.06%), followed by mortar for laying (492.98 kg, or 11.11%), with impacts also linked to cement use.

Figura 9 – Embodied CO2 Estimation for the Conventional Concrete Block Construction System Obtained Using Autodesk Revit®

Conventional Concrete Block System								
A	B	C	D	E	F	G	H	I
Family	Area	Width Block	Height Block	Length Block	Thk. Bedding Mortar	Thk. Plaster/ Stucco	Blocks/m²	Total Blocks
Basic Wall	15.751 m²	0.14	0.19	0.39	0.015	0.025	12	189
Basic Wall	6.140 m²	0.14	0.19	0.39	0.015	0.025	12	74
	77.201 m²							926

J	K	L	M	N	O	P	Q
kg/ Blocks	Blocks Mass	Vol. Bedding Mortar	Density Mortar	Bedding Mortar Mass	Vol. Plaster/ Stucco	Plaster/ Stucco Mass	Total Mass
11	2079.00 kg	0.2362 m³	1900.00 kg/m³	448.70 kg	0.7876 m³	1496.37 kg	4024.06 kg
11	814.00 kg	0.0925 m³	1900.00 kg/m³	175.68 kg	0.3070 m³	583.30 kg	1572.98 kg
	10186.00 kg	1.1570 m³		2198.37 kg	3.8601 m³	7334.12 kg	19718.49 kg

R	S	T	U	V	W	X	Y
EFCO2 Blocks	LOSS (Blocks)	EFCO2 Mortar	LOSS (Mortar)	ECO2 Blocks	ECO2 Bedding Mortar	ECO2 Plaster/ Stucco	Total ECO2
0.214	5.5	0.195	15	469.38 kg	100.62 kg	335.56 kg	905.56 kg
0.214	5.5	0.195	15	183.78 kg	39.40 kg	130.81 kg	353.98 kg
				2299.69 kg	492.98 kg	1644.68 kg	4437.35 kg

Input Data
 Automatic Results

Source: Authors.

As illustrated in Figure 10, the CO2 factor for steel (2.32 kg/kg) is the highest among all materials analyzed. However, the track and stud system showed a value of 1,118.23 kg per dwelling, lower than that of ceramic and concrete blocks. This evidence aligns with the report by Silva & Damineli (2025a), regarding the lightness of LSF compensating for steel’s high emissions. Furthermore, as noted by Hao et al. (2020), the adoption of prefabricated buildings contributes to reducing CO2 emissions through more precise production and decreased waste generation. The authors indicate that using 50% prefabricated components in a construction can reduce emissions by approximately 15% during the materialization phase.

The presence of negative values for wood (-179.02 kg per dwelling) evidences biogenic carbon sequestration, a central aspect in discussions on emissions accounting in life cycle assessments of biomass-based products. This phenomenon underscores the need for clear and transparent regulatory criteria for validating biogenic carbon credits (Hoxha et al., 2020), such as the lack of guidelines on the minimum growth period of trees for harvest. Although the IPCC (2021) recognizes the importance of long-term carbon storage in

up to 69% during the cooling season (Akan & Akan, 2021).

In the two prefabricated systems analyzed, gypsum contributes 352.69 kg of CO₂ per dwelling, while cementitious boards total 879.23 kg of CO₂, reflecting the high impact associated with the production of these materials. Gypsum, widely used in internal partition systems, is highlighted in the literature for its high energy intensity and the use of non-renewable resources in its production (Esan, 2024). Cementitious boards, despite their good technical performance and durability, have their environmental impact amplified by the use of Portland cement, whose manufacturing is one of the largest industrial sources of CO₂ emissions, accounting for approximately 8% of global emissions, as previously noted by Proaño et al. (2020).

Figura 11 – Estimated Embodied CO₂ in the Finishes and Insulation of Prefabricated Light Steel Framing (LSF) and Light Wood Framing (LWF) Systems Obtained via Autodesk Revit®

OSB Panel						
B	C	D	E	F	G	H
Type	Area	Weight	Mass	EFCO ₂ (kg/kg)	LOSS (%)	ECO ₂
OSB Exterior	2.500 m ²	7.11 kg/m ²	17.78 kg	0.4755	7	9.04 kg
OSB Interior	1.415 m ²	6.07 kg/m ²	8.59 kg	0.4755	7	4.37 kg
	162.970 m ²		1071.88 kg			545.36 kg

Rockwool						
B	C	D	E	F	G	H
Type	Area	Weight	Mass	EFCO ₂ (kg/kg)	LOSS (%)	ECO ₂
Rockwool	0.562 m ²	1.78 kg/m ²	1.00 kg	1.0125	0	1.01 kg
Rockwool	0.562 m ²	1.78 kg/m ²	1.00 kg	1.0125	0	1.01 kg
	42.283 m ²		75.26 kg			76.20 kg

Gypsum Board						
B	C	D	E	F	G	H
Type	Area	Weight	Mass	EFCO ₂ (kg/kg)	LOSS (%)	ECO ₂
Gypsum Board	2.367 m ²	9.72 kg/m ²	23.01 kg	0.3335	7	8.21 kg
Gypsum Board	3.677 m ²	9.72 kg/m ²	35.74 kg	0.3335	7	12.76 kg
	101.682 m ²		988.35 kg			352.69 kg

Cement Board						
B	C	D	E	F	G	H
Type	Area	Weight	Mass	EFCO ₂ (kg/kg)	LOSS (%)	ECO ₂
Cement Board	2.886 m ²	17.00 kg/m ²	49.07 kg	0.8655	4.5	44.38 kg
Cement Board	2.100 m ²	17.00 kg/m ²	35.70 kg	0.8655	4.5	32.29 kg
	57.183 m ²		972.11 kg			879.23 kg

Input Data
 Automatic Results

Source: Authors.

To broaden the scope of the discussion, provide quantitative environmental indicators, and validate the

practical application of the proposed method, the results were converted to units of 1 m² of wall and to the total development, considering the 185 residential lots, as presented in Table 2.

Overall, the analysis of the results obtained for the LSF system, with emissions estimated at 41.15 kg CO₂/m², shows consistency with the values reported by Altmann et al. (2022), who identified 34.07 kg CO₂/m². Although a slight difference exists, the decarbonization rate of 33.03% compared to the concrete block system remains in line with the 33% estimate presented by the same author when comparing light steel constructions with conventional masonry. Meanwhile, the LWF system demonstrated an even more pronounced performance, with a 62.27% reduction in emissions, a result close to the 73.1% decarbonization reported by Teng et al. (2018) in educational timber buildings, corroborating the potential of this material as a strategic mitigation vector in the construction sector. The average of 25.23 kg CO₂/m² in LWF also aligns with the range of 26 to 40 kg CO₂/m² identified by Skullestad, Bohne & Lohne (2016), reinforcing the consistency of the obtained data.

Regarding conventional systems, the values found for ceramic blocks (43.01 kg CO₂/m²) and concrete blocks (57.48 kg CO₂/m²) can be compared with the ranges reported by Caldas & Carvalho (2018), between 40 and 60 kg CO₂/m², highlighting the significant impact of traditional systems on emission intensification. These results reflect the resource-intensive nature of these materials' production, which still operates with low environmental efficiency. The convergence between the data of this study and the international literature reinforces the robustness of the proposed methodology and the validity of the generated indicators.

By eliminating the need for interoperability with external software, the proposed methodological approach represents a relevant advance in operationalizing Life Cycle Assessment within BIM environments, making it more accessible and feasible during the early design stages. This methodological innovation helps overcome technical barriers frequently faced in developing countries, although the absence of complementary analyses — such as cost assessments and other construction subsystems — imposes limitations on the decision-making scope. Nevertheless, the consistency of the results with international studies demonstrates the potential of the national model to engage with global sustainability practices and to promote the integration of LCA into the decision-making process in the construction sector.

Finally, the aggregated data for the total development offer an expanded perspective on the magnitude of emissions associated with vertical enclosures, serving as a basis for strategic decisions in larger-scale projects. However, it is important to highlight that these results represent only a fraction of total embodied carbon, considering that, according to Röck et al. (2020), walls account for between 24% and 30% of emissions in residential buildings. Furthermore, as these are estimates based on sectoral averages, it is essential to consider the influence of contextual variables — such as material origin, production technology, logistical conditions, and regional parameters — in the interpretation of results and their application in different construction scenarios.

Tabela 2 – Scenarios of Embodied CO2 in Construction Systems, Considering Different Functional Units

Material	Embodied CO2 (kg/m ²)	Embodied CO2 (kg/dwelling)	Embodied CO2 (Development)
Conventional Ceramic Block System			
Ceramic Block	14,63	1.129,41	208,940
Bedding Mortar	7,08	546,99	101,193
Plaster/Stucco	21,30	1.644,68	304,265
Total	43,01	3.321,07	614,397
Conventional Concrete Block System			
Concrete Block	29,79	2.299,69	425,442
Bedding Mortar	6,38	492,98	91,201
Plaster/Stucco	21,30	1.644,68	304,265
Total	57,48	4.437,35	820,909
Light Steel Framing (LSF)			
Steel Profiles	13,72	1.118,23	206,872
OSB	6,70	545,36	100,891
Rockwool	1,80	76,20	14,097
Gypsum Board	3,56	352,69	65,247
Cement Board	15,37	879,23	162,657
Total	41,15	2.971,71	549,766
Light Wood Framing (LWF)			
Wood Profiles	-2,20	-179,02	-33,118
OSB	6,70	545,36	100,891
Rockwool	1,80	76,20	14,097
Gypsum Board	3,56	352,69	65,247
Cement Board	15,37	879,23	162,657
Total	25,23	1.674,46	309,775

Fonte: Dados da Pesquisa.

5 CONCLUSION

The present study aimed to develop and apply a simplified method for integrating BIM and LCA that could be operated directly within Autodesk Revit®, aligning environmental assessments with the actual practices of the construction industry. The analysis demonstrated that when incorporated into Revit’s native BIM workflow, embodied CO2 metrics become more accessible, reproducible, and compatible with common professional routines, corroborating the initial hypothesis that the effectiveness of environmental analyses depends on adherence to the real operational conditions faced by designers, managers, and public institutions.

The results revealed significant differences among the construction systems evaluated, showing that LWF and LSF have substantial decarbonization potential compared to conventional solutions. The method enabled the quantification of these variations directly within the BIM environment, demonstrating that the environmental performance of each system is closely linked to its geometric, manufacturing, and material characteristics. The decarbonization rate of up to 62.27% observed in LWF, as well as the consistency of the findings with international studies, reinforces the method's ability to generate reliable and useful indicators for design decisions.

Although the method performed satisfactorily, several limitations must be acknowledged. The exclusive focus on vertical enclosure systems restricts the extrapolation of the results to the overall environmental performance of buildings. Moreover, the manual input of emission factors and waste rates may introduce variability into the results, especially among users with different levels of technical proficiency. Future research could enhance the method by incorporating multiple impact categories, extending its application to additional building subsystems, and exploring automated interfaces that reduce the reliance on manual data entry.

Despite these limitations, the study offers a meaningful contribution by providing an operational, transparent, and replicable alternative for environmental assessment within the BIM context. By eliminating the need for interoperability, the method becomes particularly relevant in contexts where technological resources, time, and specialized expertise constitute barriers to the adoption of advanced sustainability practices. In this sense, the work expands the reach of environmental analyses and strengthens the integration of sustainability into the design process from its earliest stages.

In summary, the study reaffirms that decarbonizing the construction sector requires methodological solutions aligned with the practical realities of design offices and public agencies. By demonstrating that environmental assessments can be conducted within a single software platform widely used in the market, this work helps bring sustainability closer to everyday professional practice, transforming it from a desirable concept into an effective tool for decision-making in architectural design and project management.

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