MANAGEMENT OF CONSTRUCTION WASTE IN AN URBAN DEVELOPMENT USING BIM TECHNOLOGY

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ABSTRACT

Purpose: Evaluate the use of BIM technology in estimating RCC (Civil Construction Waste) in the design phase of residences.

Theoretical Framework: BIM (Building Information Modeling) has been considered an essential technology and has been gaining notoriety on the world stage in the area of construction and demolition waste management due to its compatibility with other advanced technologies. It presents itself as a viable alternative to reduce costs and waste in construction conglomerates by increasing transparency in the life cycle of civil construction projects.

Method/Design/approach: In the development of this study, a methodological structure with characteristics of a case study was used. The study was classified as descriptive due to the need to gather information on indicators of loss of materials related to RCC and methods of using BIM in order to estimate the amount of construction waste. As for the methodological procedures, it was characterized as bibliographic and simulation.

Results and conclusion: BIM modeling proved to be efficient in making an initial prediction of the volume of waste generated in the construction stage of single-family units. Therefore, it is undoubtedly a useful tool for engineers, technicians and managers to think properly about solid waste management. In the future, it is necessary for researchers, representatives of civil society, public agencies and industry to unite so that real estate projects are implemented following the tripod of sustainability, as advocated by the UN Sustainable Development Goals.

Research implications: The results of this work are of great relevance for the sustainable development not only of the municipality of Garanhuns, but of the entire rural region of Pernambuco, since most municipalities in the region do not have their own Solid Waste Management Plan, which is one of the documents indicated by the

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National Solid Waste Plan (PNRS) to be prepared and used by municipalities, and which can be created according to the needs of each reality. It is important to point out that if they do not follow the PNRS recommendations, they may be left without financial incentives from the Union. Furthermore, through this work, the aim is to popularize BIM modeling with public bodies, since the use of such technology has become mandatory in public works, as recommended by the BIM BR Strategy.

**Originality/value:** By using BIM modeling in undertakings from the Minha casa Minha vida program, it is expected to contribute in a relevant way to the problem that arises, because if on the one hand there is a real estate deficit, mainly affecting families in social vulnerability, on the other, it is imperative that such urban expansion occurs in a sustainable manner, as advocated by ONU Sustainable Development Goal 11 (Sustainable Cities and Communities).

**Keywords:** Modeling, National Solid Waste Policy, Urban Planning, Minha Casa Minha Vida.

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**GESTÃO DE RESÍDUOS DA CONSTRUÇÃO CIVIL EM UM EMPREENDIMENTO URBANO USANDO A TECNOLOGIA BIM**

**RESUMO**

**Objetivo:** Avaliar o uso da tecnologia BIM na estimativa do RCC (Resíduo da construção civil) na fase de projeto de residências.

**Referencial Teórico:** O BIM (**Building Information Modeling**) tem sido considerado uma tecnologia essencial e vem adquirindo notoriedade no cenário mundial na área de gestão de resíduos de construção e demolição devido à sua compatibilidade com outras tecnologias avançadas. Se apresenta como uma alternativa viável para reduzir gastos e desperdícios nos conglomerados de construção por aumentar a transparência no ciclo de vida dos projetos para construção civil.

**Método:** No desenvolvimento deste estudo foi utilizada a estrutura metodológica com características de estudo de caso. O estudo foi classificado como descritivo em função da necessidade de levantar informações sobre indicadores de perdas de matérias relacionadas ao RCC e métodos de utilização do BIM com a finalidade de estimar a quantidade de resíduos de construção civil. Quanto aos procedimentos metodológicos caracterizou-se como bibliográfico e de simulação.

**Resultados:** A modelagem BIM se mostrou eficiente em se fazer uma previsão inicial do volume de resíduos gerados na etapa de construção das unidades unifamiliares. Sendo assim, indiscutivelmente é uma ferramenta útil para engenheiros, técnicos e gestores para que se pense adequadamente na gestão de resíduos sólidos. Futuramente, é necessário que pesquisadores, representantes da sociedade civil, órgãos públicos e indústria se unam para que os empreendimentos imobiliários sejam implementados seguindo o tripé da sustentabilidade, como preconizam os Objetivos do Desenvolvimento Sustentável da ONU.

**Implicações da pesquisa:** Os resultados deste trabalho são de grande relevância para o desenvolvimento sustentável não só o munícipio de Garanhuns, mas sim para o agreste Pernambucano, já que grande parte dos municípios da região não possuem um Plano de Gerenciamento dos resíduos sólidos próprio, que é um dos documentos indicados pelo Plano Nacional de Resíduos Sólidos (PNRS) para ser elaborado e utilizado pelos municípios, e que pode ser criado conforme a necessidade de cada realidade.

**Originalidade/valor:** Utilizando a modelagem BIM em empreendimentos do programa Minha casa, Minha vida, espera-se contribuir de forma relevante para a problemática que se apresenta, pois se de um lado existe um déficit imobiliário, principalmente atingindo famílias em vulnerabilidade social, por outro, é imperativo que tal expansão urbana ocorra de uma forma sustentável, como preconiza o Objetivo do Desenvolvimento Sustentável 11 (Cidades e Comunidades Sustentáveis) da ONU.

**Palavras-chave:** Modelagem, Política Nacional de Resíduos Sólidos, Planejamento Urbano, Minha Casa Minha Vida.

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1 INTRODUCTION

In recent decades, there has been growing concern for transforming the globe into an environmentally balanced location. In this sense, global actions have emerged that reflect this concern, such as Agenda 21 (Brazil, 1992) and Agenda 2030 (Brazil, 2023). They have in common the fact that they are proposed for policies and actions, in the short term, aimed at human development on an environmentally sustainable basis and within the framework of the promotion of human rights. These tools help plan, develop and build a sustainable society, responsible consumption and production, coupled with innovation and economic growth. At the same time, actions aimed at mitigating climate change gain attention and mobilize society. In addition, sustainability has become the focus for the development of all nations.

One of the sectors that most generates impacts on the environment is the civil construction industry. This sector causes various problems as a result of its end activity, such as: massive use of natural resources, incorrect disposal, CO₂ emissions, artisanal workforce, slow evolution and resistance to change, little mechanized industry, among others (Tzortzopoulos, 1999; Pinto, 1999). This way, the construction sector needs to explore alternatives that reduce this impact already in the planning stage (Won; Cheng, 2017). On the other hand, construction represents one of the main sectors that help in economic development in Brazil. In 2019, the sector was responsible for 6.7 million jobs, or about 7.3% of all jobs in the country (Marcocci, 2020), in addition to being responsible for 3.7% of all Gross Domestic Product (GDP) generated in the year (Diese, 2022).

BIM (Building Information Modeling) has been considered a key technology and has been gaining notoriety in the world in the area of construction and demolition waste management due to its compatibility with other advanced technologies (Gupta, Jha & Vyas, 2020). For example, this technology offers great potential to provide stock material information for future demolition activities and properly managing demolition-related information (Rašković et al., 2020). It also presents itself as a viable alternative to reduce spending and waste in construction conglomerates by increasing transparency in the life cycle of construction projects.

Oliveira (2020) states that among the benefits of using BIM technology can be improved simulation and analysis, coordination and communication for collaborative work, assessment and management of lifecycle information and sustainable design at all stages that make up the project lifecycle. Despite this, the level of implementation is not yet widespread in the construction sector.

2 THEORETICAL FRAME

According to Miara (2020), civil construction is one of the main segments of Brazilian industry and is seen as indicative of economic and social growth. In 2017, according to the IBGE, the GDP of the construction industry represented 4.5% of the total Brazilian GDP.

However, even positively affecting the country's economy, it should be noted that an inconvenience is generated to the environment and to the sustainable balance of the city: Construction and Demolition Waste (CDW), increasingly in proportions. According to Barros and Hochleitner (2017), Construction and Demolition Waste is estimated to account for 26% to 57% of total Urban Waste.

Won & Cheng (2017) show that construction and demolition waste is usually a mixture of surplus materials arising from construction, renovation and demolition activities, including site cleaning, earth excavation, construction, road works, renovation and demolition (Shen et al. (2004). The amount of construction and demolition waste is enormous. For example, construction and demolition waste accounts for more than 25 percent of solid waste disposed
of from landfills in Hong Kong in 2014, 48 percent in South Korea, and 26 percent in the U.S. Therefore, efficient process minimization management for construction and demolition waste is extremely necessary.

Won & Cheng (2017) also warn that it is important to accurately quantify the building materials needed on site to perform each activity to eliminate one of the main causes of building waste generation, which is poor planning. If the project schedule is not considered in the quantification and delivery of building materials, it can lead to waste generation. For example, it is estimated that about 1.6% of the total volume of machined concrete ends up being wasted because of inaccuracies in the quantities ordered of materials and the inadequate timing of deliveries. In addition, poor procurement and planning can lead to additional generation of construction waste due to long storage periods of on-site materials and raw material.

According to Gnecco (2018), waste management has a practical and applied character, more focused on the actions carried out in the management of solid waste, since the management is more focused on the search for strategies for correct management. Nascimento et al. (2022), diagnosed the solid waste management carried out in the companies operating at Moda Center Santa Cruz and concluded that the management of these materials on site occurs in a limited way, requiring the expansion of activities related to waste. In addition, companies had little knowledge about public policies for solid waste management.

According to Miara & Scheer (2019), BIM can be classified as a set of policies, processes and technologies that, combined, generate a methodology to manage the design process of a building, testing its performance and managing its information and data throughout its lifecycle.

Guerra et al. (2020) state that Building Information Modeling (BIM) is endorsed as one of the key developers in the fields of Architecture, Engineering and Construction in recent years. In the last decade, BIM has gained popularity and applications are growing; examples include waste reduction (Liu et al., 2015), automated estimate of construction waste (Guerra et al., 2019) and planned disposal (Cheng & Ma, 2013).

3 METHODOLOGY

The research was developed in the municipality of Garanhuns, which is located in the Northeast region of Brazil, in the Southern Agreste of Pernambuco, between latitudes 08° 50’ 0"S and longitude 36° 40’ 0"W, encompassing a total area of 458,552 km². It is located in the Borborema Plateau, where the differentiation of the climate system of its surroundings stands out. (Azambuja & Correia, 2015).

In the development of this research was used the methodological structure with case study characteristics, which according to Gil (2022), consists in the deep and exhaustive study of one or more objects, in a way that allows its broad and detailed knowledge. The research was classified in descriptive according to the need to collect information on indicators of losses of materials related to the civil waste (CCR) and methods of use of the BIM with the purpose of estimating the amount of civil construction waste. As for the methodological procedures, the research was characterized as bibliographic and simulation, due to the preparation of the systematic literature review (RSL) following the guidelines proposed by Comforto, Amaral e Silva (2011), with the objective of seeking evidence in the literature that serve as a basis for the development of the research theme, and evaluate a procedure to quantify the RCC through simulations, using BIM software.

Once the methodological concepts and procedures used to conduct this research are presented, the steps that allowed the research to be operationalized will be presented (Figure 1).
Once the loss indices have been collected, the estimate of waste generation will be obtained using Equation 1. (Miara, 2020):

\[ W = P \times IP \]  

Where:

- \( W \) = Amount of waste generated (kg or m\(^3\))
- \( P \) = Quantity of material specified in the project (kg or m\(^3\))
- \( PI \) = Loss of material per activity/application in %

### 4 RESULTS AND DISCUSSION

As shown in Figure 1, the research question that led to the realization of this step was: "What is the method for estimating the quantitative RCC?" The objective of selecting the main methods of waste quantification was then proposed. As previously explained, a bibliographic survey was conducted through a systematic literature review and 8 articles were selected that used BIM modeling in their methods to estimate RCCs. Methods related to BIM modeling, and other relevant information such as the software used, in addition to their applications and life cycle stages of the project were used in the selected works. Of the eight articles analyzed, seven used the Revit® software as a tool for carrying out their modeling. In this way, for the development of this work, the Revit® Software was chosen, because in addition to offering the necessary tools a free license is available for students.

After the choice of the software, the next step was to answer the question: "What are the main rates of losses for the various types of RCC?", and as previously done, the following specific objective was outlined: "Search the various rates of losses in the literature available". To do so, a preliminary bibliographical survey was carried out and afterwards a systematic review of the literature. In this research, we looked for articles that presented in their research rates of losses of materials related to the Civil Construction Residue.

Once the enterprise was chosen, the author had access to the floor plan of the single family housing unit used as a model, made up of two bedrooms, living room, kitchen, bathroom,
pavement and garage. In possession of the floor plan and the information contained in the memorial, the model was developed in the chosen software. Once the project was in the Revit® software, the next step was to generate the tables with the quantitative and areas for the floors and walls, both made of concrete. The specifications can be viewed in Chart 1.

**Chart 1.** Single-family unit elements and their specifications.

<table>
<thead>
<tr>
<th>Element</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floors</td>
<td>Enameled ceramics</td>
</tr>
<tr>
<td>Masonry</td>
<td>Concrete wall coated with plaster</td>
</tr>
</tbody>
</table>

*Source: Prepared by the authors.*

The software directly provided the dimensional parameters for the materials that make up the floors and masonry. Available values refer to floor and wall areas and the material family/type. Therefore, the estimation of the quantity of waste occurred by multiplying the quantitative presented by Revit® by the previously defined loss index, as explained in Equation 1 presented in the methodology.

Such values have been exported to Google spreadsheets, as well as the loss indexes found in the previous step. As the objective of this work to evaluate the functionality of the method, as well as to make an initial estimate, were chosen, for this, the elements made from concrete to structure. In addition, for Hernandes & Vilar (2004), the materials most present in the rubble extracted from construction sites were those belonging to Class A (mortar, concrete, soils, sand and red ceramics).

After the completion of the modeling and extraction process of the necessary data, the complementary worksheet for the calculation procedure was accessed. Consolidated values can be viewed in Chart 2. The classification of the materials that give rise to the waste was based on the criteria laid down in Resolution CONAMA No 307/2002.

**Chart 2.** Quantification of materials and estimation of waste generation for a single household unit.

<table>
<thead>
<tr>
<th>Constructive element</th>
<th>Material</th>
<th>Rating</th>
<th>Quantity of material incorporated into the building</th>
<th>Quantity of waste generated due to the execution of the construction service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service performed from which construction waste is generated (Categories of digital model)</td>
<td>Specification of required materials for each service or category</td>
<td>Waste class generated according to parameters established by CONAMA (2002)</td>
<td>Quantity of material required to perform the service</td>
<td>Expected amount of waste generated due to the execution of the construction service</td>
</tr>
<tr>
<td>Walls (100mm)</td>
<td>concrete</td>
<td>A</td>
<td>8.976 m³</td>
<td>0.809 m³</td>
</tr>
<tr>
<td>Floors (5mm)</td>
<td>concrete</td>
<td>A</td>
<td>2.845 m³</td>
<td>0.256 m³</td>
</tr>
<tr>
<td>Floors (10mm)</td>
<td>concrete</td>
<td>A</td>
<td>5.319 m³</td>
<td>0.479 m³</td>
</tr>
<tr>
<td>Floors (15mm)</td>
<td>concrete</td>
<td>A</td>
<td>20.432 m³</td>
<td>1.839 m³</td>
</tr>
</tbody>
</table>

*Source: Prepared by the authors.*

Automated, rapid and accurate estimates can also be observed in studies developed by Oliveira *et al.* (2020) and Kim *et al.* (2017). Both used strategies similar to those developed in this work, using Revit® to obtain the quantity of materials for performing the services.
According to information obtained from the construction company, the initial proposal was the construction of 533 houses. Therefore, the estimation of the generation of waste for the chosen building elements can be found in Chart 3.

**Chart 3. Estimation of waste generation in the construction process of family units.**

<table>
<thead>
<tr>
<th>Total amount of Class A waste</th>
<th>Number of single-family units</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.383 m³</td>
<td>533</td>
<td>1,803.139 m³</td>
</tr>
</tbody>
</table>

**Source:** Prepared by the authors.

According to Santos (2022), class A waste should be reused or recycled in the form of aggregates or sent to landfill of class A waste material for future use. However, the municipality of Garanhuns does not yet have its own solid waste management plan, which is not in line with the provisions of the National Solid Waste Policy. If they do not follow the recommendations, they may be without financial incentives from the Union (Silva et al., 2021).

Just considering two building elements, it is inferred that the value of waste generated is expressive. It is important to point out that this study did not take into consideration the residues generated in the stages of earthworks, cuts, landfills, construction of recreational areas, paving among others. In the light of all the laws, resolutions and norms, it is clear that the current concern is with the administration and final destination of the waste coming from the construction industry, however, the ideal would be to reduce the waste at the generating source. Although the construction sector uses large amounts of non-renewable natural resources, it has ample potential to reuse the waste produced in construction sites, by incorporating the waste in the manufacture of new construction materials (Kochem & Possan, 2016).

In this way, aiming at reducing construction waste, BIM modeling presents itself as a proven beneficial tool for waste management. When BIM is used for waste reduction in the early stages of a project, such as planning, design and even in construction management, the changes are greater than when applied directly to the operation of the already built work, since the surplus materials come from the preliminary stages (Gnecco, 2018). Liu et al. (2017) also proposed a BIM system to automatically calculate the waste generation potential of a work, with the generation of graphs, such as that of sectors, so that designers could evaluate the most economically, technically and environmentally viable design solutions.

**5 CONCLUSION**

BIM modeling has proved to be efficient in making an initial forecast of the volume of waste generated in the stage of construction of single family units. Therefore, it is undoubtedly a useful tool for engineers, technicians and managers to think properly about solid waste management.

In the future, researchers, representatives of civil society, public bodies and industry will need to come together to implement real estate developments in a sustainable manner, as advocated by the United Nations Sustainable Development Goals (SDGs/UN).

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