# Building Information Modeling Integrated With Life Cycle Analysis in Plumbing Projects: A Preliminary Systematic Review

**Diogenes Oliveira Senna[1,2*], Larissa da Silva Paes Cardoso[1], Alex Álisson Bandeira Santos[1]**

*[1]SENAI CIMATEC University Center; Salvador; [2]State University of Feira de Santana; Feira de Santana, Bahia, Brazil*

**Many studies point out that the modeling of construction information (BIM) integrated with life cycle analysis (LCA) can be launched as an alternative, to identify and quantify the environmental impact generated by the construction industry. However, most studies are based on architectural and structural projects, there are few works in plumbing installations. The objective of this study was to evaluate, through a systematic literature review (SLR), the scientific contribution from 2015 to 2021 in articles on free access to BIM integrated with LCA in plumbing facilities projects. In the RSL, 128 articles were found, and we selected 5 articles for analysis and extraction of information that identified gaps and potential studies.**
**Keywords: BIM. LCA. Plumbing Project.**

## Introduction

The Industry of Architecture, Engineering, and Construction (AEC) accounts for a considerable portion of the Brazilian economy, generating several jobs, moving a considerable economic chain, and consequently consuming a high volume of natural and energy resources, thus generating a great environmental impact.

But in counterpoint, it is perceived that there are joint efforts to minimize and or mitigate this impact, promoted mainly by groups of national and international researchers bringing concepts, methodologies, tools, or directly, solutions that promote sustainability. One of these concepts/ methods is the use of bim integrated life cycle analysis (LCA), which proved to be powerful for the identification and quantification of these generated impacts [1-3].

Several studies have demonstrated in the last 7 years the potential to use the integration of BIM and LCA methodologies to promote sustainability in the various phases of projects and constructions.Santos and colleagues [4] surveyed the state-of-the-art BIM and LCA integration and concluded that while there are currently tools to do this integration, there are still gaps that make it difficult to use their results effectively.

It was perceived by Machado and colleagues [5] that the adoption of mitigating measures facilitated by BIM through the incorporation of solutions in the virtual model, taken from the results of a LCA increases the efficiency of the response to the reduction of environmental impact. In another work, the authors affirm that this integration has the potential for managing the built environment. However, most of these works are limited to methodologies application in architectural design and structural design, and few works on projects of construction systems, precisely, in hydrosanitary projects. The objective of this study is to evaluate through a systematic literature review (RSL) the scientific contribution in the period from 2015 to 2021 of open access articles on BIM integrated with LCA in hydrosanitary facilities projects identifying gaps and potential studies.

## Material and Methods

In the present study, the Systematic Literature Review (SLR) was used, according to Dresch and colleagues [6], to map, critically evaluate, consolidate and aggregate the results of relevant primary studies.

### Protocol for the Implementation of Systematic Literature Review

We used StArt, free software on the Windows platform, developed by the Software Engineering Research Laboratory (LaPES) of the Federal University of São Carlos (UFSCar) to facilitate the reference systematizations.

Figure 1 shows the flowchart of the protocol model proposed by Kitchenham and Charters [7] and adopted by the StArt tool to elaborate the RSL.

The following are the steps or phases for conducting the Systematic Literature Review:
(i)   Planning - Define the objective and plan the protocol of systematic review;
(ii)  Execution - Execute the RSL protocol; Quality Assessment and Data Extraction;
(iii) Summarization - Synthesize the information obtained through graphs and publish the results (report, articles, thesis, dissertation).

### Purpose of Systematic Review

The objective of the systematic literature review is directly the objective of the present study. Through a systematic literature review (RSL) the scientific production of the last 7 years on BIM integrated with LCA in plumbing facilities projects.

### Research Questions

Can the systematic literature review filter the free access scientific production from 2015 to 2021 on Building Information Modeling (BIM) and Life Cycle Analysis (LCA) in plumbing plant projects?

### Search Terms and Search String

For the execution of this work, terms were used for searches in the databases, in the English language and their respective acronyms: ***Building Information Modeling (BIM); Life Cycle of Analysis (LCA); Hydraulic and Sanitary Installations, Plumbing System, Hydraulic Facilities, Drainage Facilities.***

After defining the search terms in the databases, the generic search string was assembled ***(“bim”) AND (“lca”) AND (“project” OR “system”) AND (“plumbing” OR “hydraulic” OR “drainage” OR “sanitary”)***.

### Search Database

For the search for scientific articles, we used the Science Direct platform (www.sciencedirect.com) due to its multi-interdisciplinary character.

### Inclusion/Exclusion Criteria

Inclusion/exclusion criteria are necessary to delimit the search of databases related to the subject of the research and to ensure the specificity of the searches, thus reducing the document volume sought.

They include listing as follows:
• Theme - Works that use Building Information;
• Modeling (BIM) and Life Cycle Analysis (LCA) in the design phase and/or construction phase;
• Language - English, and Portuguese;
• Period - 2015 to 2021;
• Scope - National and International;
• Type of Article - Research article (primary study);
• Access to Article - Open access.
The following are the exclusion criteria:
• Document Types - Non-scientific (commercial) journals, SITES;
• Thematic Areas - Works that do not relate to the Architecture, Engineering, and Construction Industry - AEC;
• Theme - Works that do not relate to BIM and LCA;
• Full-text access - No free access to the full text.

**Figure 1 .** Flowchart of the protocol model adapted from Kitchenham and Charters (2007).

*Method for Evaluating the Quality and Extraction of Data from Selected Papers*

The RSL uses the expedient of evaluating the quality of the selected scientific articles as a 2$^{nd}$ filtering of them. Table 1 presents the quality criteria for reading prioritization.

By the protocol used, data extraction is the final stage of the execution phase, in which, after the quality selection of the primary studies, we can extract the information desired using extraction criteria elaborated as questions. We proceeded with a dynamic reading of the full text. Table 2 presents the Information Extraction Criteria.

**Results and Discussion**

The flow chart presents the result of the selected texts in the applied steps of the stArt protocol, and in the search platform (ScienceDirect), visualized in Figure 2.

**Table 1.** Criteria for quality assessment of scientific articles.

| Identification | Quality Assessment Criteria |
| --- | --- |
| C1 | The objectives of the selected article are clear as to how much they use BIM integrated with LCA?={YES, NO} |
| C2 | The methodological procedures are clear?={YES, NO} |
| C3 | Do the descriptors appear in the title, in the abstract, or in the words-keys?={YES, NO} |

**Table 2.** Research questions for analysis and extraction of information.

| Identification | Information Extraction Criterion | Selection Field in StArt |
| --- | --- | --- |
| CE01 | What is the BIM computational tool used in the article? (text) | Text |
| CE02 | What is the computational tool of LCA used in the article? (text) | Text |
| CE03 | What LCA inventory database is used? (text) | Text |
| CE04 | What design disciplines were used in the scientific article (Architectural, Structural, Electrical Installations, Hydrosanitary Installations, Other, Unidentified) | Pick on many |
| CE05 | What is the type of construction (single-family residential, multifamily residential, Commercial, Mixed, Industrial, Unidentified) | Pick on many |
| CE06 | Is the scientific article the kind that automatic data extraction is? (yes or no) | Pick on list |
| CE07 | The article is a proposal for The Development of a Computational Tool that integrates BIM/LCA? (yes or no) | Pick on list |
| CE08 | Does it present a model or framework for the development of the BIM and LCA integration tool? (yes or no) | Pick on list |
| CE09 | The article presented which stage of LCA?(Complete, Cradle - Gate, Tomb Gate, Unidentified) | Pick on list |
| CE10 | Stage/phase of the construction lifecycle={Complete,Planning/Design,Construction,Use,Post-use,Unidentified} | Pick on list |

**Figure 2.** Flowchart of selection of studies on INTEGRATED ACV BIM in plumbing facilities projects.
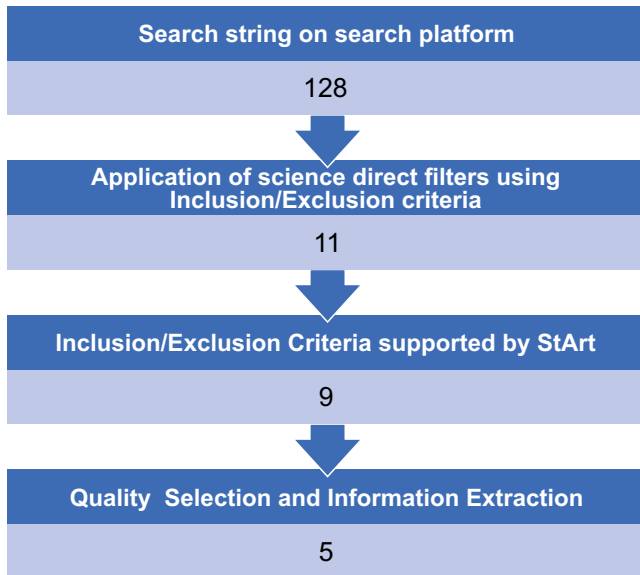


The end of the process of selecting the quality of the articles found, recommended in the StArt protocol, resulted in the selection of 5 articles that after a reading of the full text was extracted the information, because of the criteria presented in Table 2, to evaluate the research potential of BIM integrated with LCA in facilities projects. Table 3 shows the consolidation of the result of this work.

In general, the extraction criteria CE04 (plumbing project), CE07, and CE08 were not found, specifically, gathered in the articles evaluated in the RSL strategy, allowing evidence of research gaps and potential studies in BIM integrated to LCA in plumbing projects.

## Conclusion

The systematic literature review of the present study sent the identification of possible gaps and

**Table 3.** Analysis of articles given the criteria for extracting information.

| Authors | Analysis of information extraction criteria |
|---|---|
| Ahmad and colleagues [1] | This paper can highlight the development of a conceptual framework of a Bim/ACV (SimulEIcon)(C07)(C09) interaction tool for decision making taking into account the dimensions of sustainability (economic, social, and environmental). |
| Ahmed and colleagues [2] | This work is a case study that comems conventional constructions and green constructions with GHG emission and energy incorporated in the design phase and presents an integrated BIM/LCA tool, but does not propose the development of another tool. |
| Holberg and colleagues [3] | The article aims to build an integrated tool BIM/ACV (C07)(C09) for automatic extraction of material quantity (C06 using Revit/Dynamo (CE01) and the swiss database LCA(C03)/ Ecoinvent V2.2 (C02) in a commercial building (CE05) during the architectural design phase. |
| Kaspersen and colleagues [8] | The authors made a cradle-gate LCA (CE08) using SIMAPRO (CE02) in the hydrosanitary, electrical, and other (CE04) facilities of a commercial building (CE05), evaluating the influence of height and concluded that in buildings up to 21 floors this impact on GHG generation is negligible. The use of BIM was evidenced, but without identifying the software used, and there was also no proposal to develop a BIM-LCA integration tool. |
| Sozer and Sozen [9] | The work does not propose to develop a BIM-LCA(C07) integration tool but does ACV (e-QUEST/TUIK)(CE02/C03) of the tomb gate (CE08) in the construction, use, and post-use phases of multifamily residential buildings evaluating effluents and solid waste and demolition. The BIM tool (C01) has not been identified. |

potential studies related to the construction of computer tools or integrated BIM-LCA frameworks applied in hydrosanitary projects. As noted, the articles selected in the information extraction process do not present an integrated BIM-LCA constructor specifically applied in projects of medical facilities. It is recommended for future work to expand the RSL using more databases and accepting articles of any kind of access.

## References

1.  Ahmd T, Aibinu A, Thaheem MJ. BIM-based iterative tool for sustainable building design: A conceptual framework. Procedia Engineering 2017;[s. l.]180,:782–792. Available at: https://doi.org/10.1016/j.proeng.2017.04.239.
2.  Ahmed N et al. Impact of sustainable design in the construction sector on climate change. Ain Shams Engineering Journal 2021;[s. l.]12(2):1375–1383, 2021. Available at: https://doi.org/10.1016/j.asej.2020.11.002.
3.  Holberg A, Genova G, Habert G. Evaluation of BIM-based LCA results for building design. Automation in Construction 2019;[s. l.]109;May: 102972. Available at: https://doi.org/10.1016/j.autcon.2019.102972.
4.  Santos R, Neves E, Silvestre JD, Costa AA. Integração de BIM com Avaliação ACV: Análise do estado da arte e das ferramentas disponíveis. 16º Congresso de Inovação na Construção Sustentável. Available at:www.researchgate.net/publication/309733082_Integracao_de_BIM_com_Avaliação_do_Ciclo_de_Vida_analise_do_estado_da_arte_e_das_ferramentas_disponiveis. accessed Oct 10, 2019.
5.  Machado D, Simões CCA, Moreira LCSO. Potencialidades da Iintegração do BIM ao Método de Avaliação do Ciclo de Vida das Edificações. In: 9th Brazilian Symposium on Construction Management and Economics and 6th Latin American Meeting on Construction Management and Economics (Sibragec and Elagec, 2015, São Paulo.
6.  Dresch A, Lacerda PL, Anrunes Jr. JAV. Design Science Research: Método de pesquisa para avanço da ciência e tecnologia. Porto Alegre: Bookman, 2015.
7.  Kitchenham B, Charters S.. Guidelines for performing systematic literature reviews in software engineering. 2007.
8.  Kaspersen B, Lohne J, Bohne RA. Exploring the $CO_2$-impact for building height; A study on technical building installations. Energy Procedia 2016[s. l.];96 October:5–16. Available at: https://doi.org/10.1016/j.egypro.2016.09.089.
9.  Sözer H, Sözen H. Waste capacity and its environmental impact of a residential district during its life cycle. Energy Reports 2020;[s. l.]6:286–296. Available at: https://doi.org/10.1016/j.egyr.2020.01.008.