BUILDING INFORMATION MODELING INTEGRATED WITH LIFE CYCLE ANALYSIS IN PLUMBING PROJECTS: A PREMILINARY SYSTEMATIC REVIEW

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

[a], *Senai-Cimatec, Brazil*

Abstract: Many studies point out that the modeling of construction information (BIM) integrated with life cycle analysis (LCA) can be launched with 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. Therefore, the objective of this study was to evaluate, through a systematic literature review (SLR), the scientific contribution from 2015 to 2021 in articles of free access on BIM integrated with LCA in plumbing facilities projects. In the RSL, 128 articles were found, and finally 5 articles were selected for analysis and extraction of information that identified gaps and potential studies.

Keywords: BIM; LCA; plumbing project.

MODELAGEM DA INFORMAÇÃO DA CONSTRUÇÃO INTEGRADA COM A ANÁLISE DE CICLO DE VIDA: UMA PRELIMINAR REVISÃO SISTEMÁTICA.

Resumo: Muitos estudos apontam que a modelagem da informação da construção (BIM) integrada com a análise de ciclo de vida (ACV), pode lançar-se com uma alternativa, para identificação e quantificação do impacto ambiental gerado pela indústria da construção. No entanto, a maioria dos estudos se detém a projetos de arquitetura e estrutural, há poucos trabalhos em instalações hidrossanitárias. Diante disto, o objetivo deste trabalho foi avaliar, por meio da revisão sistemática de literatura (RSL), a contribuição cientifica no período de 2015 a 2021 em artigos de acesso livre sobre o BIM integrado com ACV em projetos de instalações Hidrossanitárias. Na RSL foram encontrados 128 artigos, sendo finalmente selecionados 5 artigos para análise e extração de informações que identificaram lacunas e potenciais estudos.

Palavras-chave: BIM; ACV; projetos hidrossanitários.

1. INTRODUCTION

The Industry of Architecture, Engineering and Construction (AEC) accounts for a considerable portion of the Brazilian economy,generating several jobs, moving aconsiderable economicchain, 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 theseconcepts or methodologies themselves, which proved to be with a great potential for use for the identification and quantification of these generated impacts is the use of bim integrated life cycle analysis (LCA). [1,2,3]

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 et al. [4] they surveyed the state of the art on 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 et al. [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 increase the efficiency of the response to the reduction of environmental impact. In another work, the authors affirm that this integration has potential ities for the management of the built environment.

However, most of these works are limited to the application of methodologies in architectural design and structural design and as few works on projects of construction systems, precisely, in hydrosanitary projects. The objective of this work 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.

2. METHODOLOGY

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

2.1. Protocol for the Implementation of systematic literature review

To facilitate the work of systematization of the bibliography was used, StArt, a free software on the Windows platform, developed by the Software Engineering Research Laboratory (LaPES) of the Federal University of São Carlos (UFSCar).

Figure 01 shows the flowchart of the protocol model proposed by Kitchenham and Charters [7] and adopted by the StArt tool for the elaboration of the RSL.

ISSN: 2357-7592

Figure 01 – Flowchart of the protocol model adapted from Kitchenham and Charters (2007)

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).

2.1.1. 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.

2.1.2. Research question

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?

2.1.3. 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 Cicle of Analisys (LCA); Hydraulic and Sanitary Installations, Plumbing System, Hidraulic Facilities, Drainage Facilities*.**

Após a definição dos termos de buscas nas bases de dados, foi montada a *string* genérica de buscas **("bim") AND ("lca") AND ("project" OR "system") AND ("plumbing" OR "hidraulic" OR "drainage" OR "sanitary")**.

2.1.4. Search Database

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

2.1.5. Inclusion/Exclusion Criteria

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

The include listing 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 full text.

It is noteworthy that due to the pandemic and the difficulty of accessing educational institutions, full open access texts were used as a selection criterion and can be easily accessed in the residence.

2.1.6. 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 2nd filtering of them. Table 01 presents the quality criteria for reading prioritization.

Table 01 - Criteria for Quality Assessment of Scientific Articles

Identification	Quality Assessment Criteria
C1	The objectives of the selected article are clear as to how much the use of BIM integrated with LCA?={YES,NO}
C2	The methodological procedures are clear?={YES,NO}
C3	The descriptors appear inthe title, or 9intheabstract, or in thewords-keys?={YES,NO}

By the protocol used, data extraction is the final stage of the execution phase, which after the quality selection of the primary studies, we can extract the information desiredby means of extraction criteria elaborated as questions. From this foi proceeded a dynamic reading of the full text. Table 02 presents the Information Extraction Criteria.

Table 02 - 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 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 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

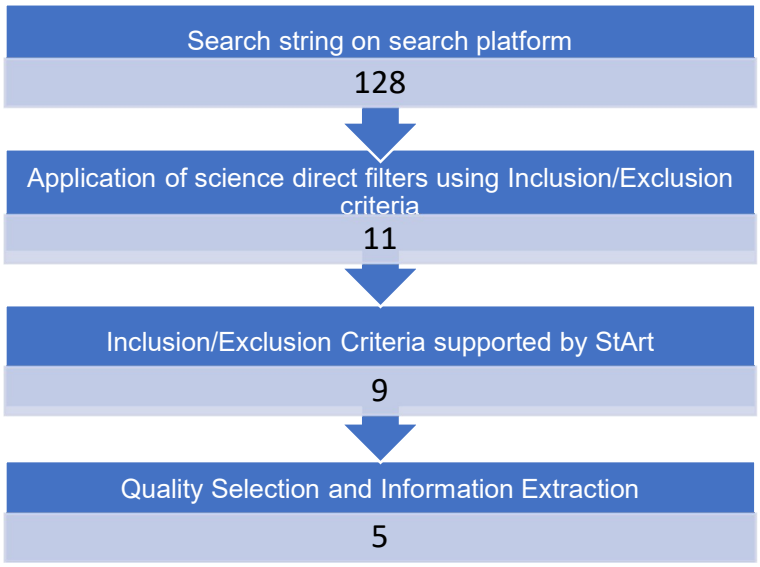
ISSN: 2357-7592

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

3. 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 02.

Figure02 – Flowchart of selection of studies on INTEGRATED ACV BIM in plumbing facilities projects



At 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, in view of the criteria presented in table 02,to evaluate the research potential of BIM integrated with LCA in facilities projects. Table 03 shows the consolidation of the result of this work.

Table03 - Analysis of articles in view of the criteria for extracting information

Authors	Analysis of information extraction criteria
Ahmad et al. [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 et al. [2]	This work is a case study that comems conventional constructions and green constructions in relation to GHG emission and energy incorporated in the design phase, presents an integrated BIM/LcA tool, but does not propose the development of another tool.
Holberg et al. [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 et al. [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.

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.

4. CONCLUSION

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

ISSN: 2357-7592

5. REFERENCES

[1]AHMAD, T.; AIBINU, A.; THAHEEM, M. J. **BIM-based Iterative Tool for Sustainable Building Design: A Conceptual Framework.** Procedia Engineering, [s. l.], v. 180, p. 782–792, 2017. 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, [s. l.], v. 12, n. 2, p. 1375–1383, 2021. Available at: https://doi.org/10.1016/j.asej.2020.11.002

[3]HOLBERG HOLLBERG, A.; GENOVA, G.; HABERT, G. **Evaluation of BIM-based LCA results for building design**. Automation in Construction, [s. l.], v. 109, n. May 2019, p. 102972, 2020. Available at: https://doi.org/10.1016/j.autcon.2019.102972

[4]SANTOS, R., NEVES, E., SILVESTRE, J. D., and COSTA, A. A. **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, F; SIMÕES, C.C; A. MOREIRA, L.C. S.O. **Potencialidades da lintegração 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, P. L.; ANTUNES JÚNIOR, J.A.V. **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, R. A. **Exploring the CO2-Impact for Building Height; A Study on Technical Building Installations**. Energy Procedia, [s. l.], v. 96, n. October, p. 5–16, 2016. 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, [s. l.], v. 6, p. 286–296, 2020. Available at: https://doi.org/10.1016/j.egyr.2020.01.008