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Review

Social Life-Cycle Assessment in the Construction Industry: A Review of Characteristics, Limitations, and Challenges of S-LCA through Case Studies

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Abstract: The paper aims to examine how researchers have operationalized social impact assessment in construction projects over the last ten years. A systematic review was used to investigate case studies in the Social Life-Cycle Assessment (S-LCA) to analyze the application of the methodology. In total, 19 articles published between 2012 and 2023 were classified according to their scope, functional unit measure, S-LCA indicators used, and the main challenges. Our findings revealed limitations in both qualitative and quantitative aspects of measuring social indicators, primarily stemming from difficulties associated with scoring and assessment methodologies. Additionally, we observed deficiencies in social data within the S-LCA framework. This suggests that potential social impacts may be inadequately addressed and evaluated due to various challenges that have been highlighted in the existing literature.

Keywords: S-LCA; social impacts; literature review; challenges; operationalization

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1. Introduction

The construction industry is one of the major industries in any national economy, regardless of its level of development (Ilhan and Yobas, 2019 [1]). It is responsible for substantial material and resource consumption and its impact on climate change (Balasbaneh et al., 2018 [2]). In 2018, the building and construction sectors were responsible for 40% of global greenhouse gas emissions (Larsen et al., 2022 [3]), and 36% of final energy use contributed to climate change effects and negatively impacted health (UNEP, 2019 [4]). With a lack of consideration for waste management and waste reduction in the early phases of projects, there tends to be waste generated by construction and demolition through the life cycle of buildings (Esa et al., 2017 [5]), with a remarkable impact of 50% at the end of the life of a project (Kibert, 2016 [6]). It also has a reputation for its high consumption rate of natural resources, which generates between two and three billion tonnes of building waste per year (Jain, 2021 [7]).

Fortunately, the construction sector has started to adopt life-cycle assessments (LCA) to conduct environmental assessments. On the other hand, Social Life-Cycle Assessment (S-LCA) has not gained as much popularity despite being recognized as key in designing processes and sustainable products (Vitorio and Kripka, 2021 [8]). S-LCA is a methodology to assess the social impacts of products and services throughout their life cycle, from raw resource extraction to their final disposal. It is based on the UNEP/SETAC guidelines (UNEP, 2020 [9]). While LCA involves material, energy, and economic flows in production and consumption that impact stakeholders, S-LCA provides a systematic assessment framework combining quantitative and qualitative data to support social and socio-economic decision-making (UNEP, 2020 [9]). S-LCA comprises four phases: goal and scope definition, inventory analysis, impact assessment, and interpretation (Ramirez et al., 2014 [10]). It includes these steps: characterization, normalization, and weighting. According to Dong et al. (2016) [11], characterization is converting social information into interpretable indicators that reflect a list of impacts; normalization is rescaling the characterization results into a comparable range; and weighting is modifying the normalization results according to the importance of subcategories. The two strengths of the S-LCA are (1) its focus on the product and (2) the definition of social impacts, which encompasses a company's behavior and socioeconomic perspective (Zamagni et al., 2011 [12]).

However, little research focuses on S-LCA in the construction industry. Larsen et al. (2022 [3]) said that S-LCA is neither considered nor applied in the building industry to evaluate the impact of construction and refurbishing buildings on the social aspect. However, social value should be considered in the construction industry, as social value tends to increase or improve the social image of stakeholders (Daniel and Pasquire, 2019 [13]). Considering current challenges, there is a need to enhance social indicators within the building sector. While specific solutions have been identified with commendable social characteristics, it is crucial to acknowledge that studies might overlook the social advantages inherent in these solutions (Ostermeyer et al., 2013 [14]). Most research focuses on technology and neglects social and human needs (Fan et al., 2018 [15]). Tokede et Traverso (2020 [16]) pointed out that the challenge with S-LCA is defining wellbeing, which should provide a holistic understanding of the human condition and aspirations. It is worth noting that most studies in this field rely on qualitative and semi-qualitative data, which can present challenges when attempting to draw definitive conclusions from the obtained results. (Huertas-Valdivia et al., 2020 [17]). On the other hand, concerns revolve around the methodological operationalization and measurability of social indicators, which pose limitations on data gathering and stakeholder identification (Tokede and Traverso, 2020 [16]). Though the social aspect is important, no standardized methodologies exist for S-LCA (Larsen et al., 2022 [3]).

In this sense, this paper analyzes how the literature addresses the operationalization of S-LCA in the construction industry by assessing to what extent Social Life-Cycle Assessment has been reported in case studies in the last decade.

This paper tries to answer the following questions:

RQ1—What is the scope of the S-LCA case studies?
RQ2—What is the functional unit measure studied in the case studies?
RQ3—What is the nature of the S-LCA indicators used in the selected case studies?
RQ4—What are the main challenges of Social Life-Cycle Assessment in the literature in case studies presented in the construction industry?

The paper's structure is organized as follows: Section 2 serves as the methodological section, encompassing descriptions of data selection, the research protocol overview, the classification framework, and four key research questions. Section 3 delves into the presentation of our literature review findings, while Section 4 is dedicated to the discussion of these results. Finally, the paper reaches its conclusion in Section 5.

2. Methodology

This paper seeks to understand to what extent the operationalization of S-LCA has been reported by researchers in the literature. To do so, this research assessed articles published during the last ten years (2012–2023), focusing on case studies in the construction industry.

The research methodology in this literature review includes (1) the data collection protocol and (2) the classification of selected papers. Each part is described in detail in the following subsections.

2.1. Data Collection and Research Screening Overview

The search was based on bibliographic databases and electronic libraries such as Web of Science and Google Scholar. Web of Science was used as it has selective, balanced, and complete coverage of the world's leading research, covering around 34,000 journals (Birkle et al., 2020 [18]). On the other hand, Google Scholar was used as well, and it provides an instant method to build on a digital snowball to retrieve literature (Zientek et al., 2018 [19]). A systematic literature protocol was used to evaluate our findings. From these, four research questions were defined to pursue our research. To analyze the S-LCA literature, the inclusion criteria were as follows in Table 1: (a) the period was set between 2012 and 2023, inclusive, and focused on literature written in English; (b) documents were limited to journal articles; and (c) early access articles that had a focus on case studies of S-LCA in the construction industry were also included. Additional articles were added to our article.

Table 1. Inclusion criteria.

Inclusion Criteria
Studies published between 2012 and 2023
Articles addressing social impacts
Articles presenting case studies
Articles focusing on the construction industry

The following search strings and keyword combinations of terminologies and abbreviations were used: ("SLCIA" OR "Social life cycle impact assessment" OR "SLCA" OR "S-LCA" OR "Social life-cycle assessment" OR "Social LCA" (Topic) AND ("construction" OR "building" OR "AEC") (Topic) AND ("case studies" OR "case study" OR "use case") (Topic) AND between 2012 and 2023 (Publication Years) AND Article (Document Types) and Article (Document Types) AND Article or Early Access (Document Types) AND English (Languages).

The first screening of databases resulted in 32 publications and contained scientific publications (peer-reviewed journal articles). To ensure that the articles mentioned both case studies and S-LCA and the construction industry for the literature portfolio, all abstracts screened through Endnotes 20 and 19 were proven irrelevant based on the inclusion and exclusion criteria. After we screened out the articles, 13 were removed as 9 were not in the construction industry, and 4 were not on social assessment, leaving us with 19 relevant articles.

Figure 1 summarizes the research screening process and the criteria for classifying the articles. The following section describes the classification framework used to analyze the selected papers.

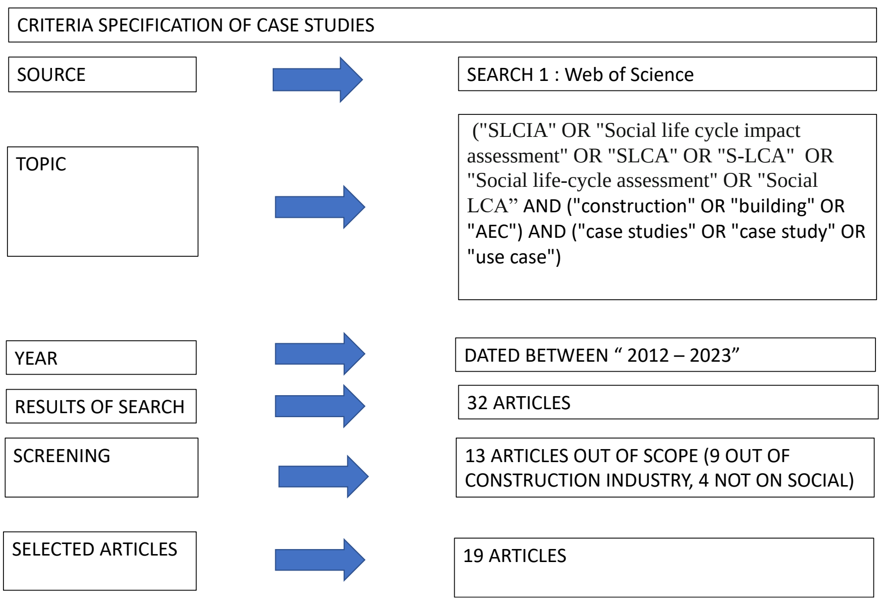

Figure 1. Research screening process.

2.2. Classification Framework

To classify our paper, we first categorized our articles according to their location, type of infrastructure, model, and the stakeholders involved. The location is the country where the research has been performed and studied. It is prescriptive and helps to understand if the results are biased and influenced because of their location in a specific part of the world. The type of infrastructure determines if it is a building, a part of the building, or a particular model. The actors involved help identify the types of stakeholders/individuals involved.

A specific classification scheme was then developed to answer each research question, as described in the following subsections.

2.2.1. Scope

A scope's objective is to identify and "define the object of the study and to delimit the assessment" (Jørgensen et al., 2008 [20]). According to the UNEP (2020 [9]) Guidelines, some elements are included or excluded depending on the study's goal. In those, we shall find (1) the definition of the object of the study (product, function, or service), the number of materials needed to produce the product or output, and the steps, activities, and organizations to comply with the functional unit; (2) the identification of parts of the production system in the assessment (the system boundaries); (3) the variable(s) to determine the importance of different activities in the product system; the stakeholders included and affected (workers, value chain actors, society, consumers, government, construction enterprises, real estate developments, community); the type of impact assessment method, and impact categories and/or subcategories included; the data collection strategies (inventory indicators, data type, and data collection) and data quality requirements.

To answer this question, we looked at the scope of the study presented in each article. Moreover, four elements' criteria were used: (a) the type of construction (building, route, etc.), (b) the scope of infrastructure studied (entire building or parts of buildings), (c) the type of case studies (single or multiple case studies), (d) the organizational type (public or private), and (e) the type of stakeholders involved (workers, local community, society, consumers, value chain actors).

2.2.2. Functional Unit and System Boundary

Functional units are the "quantified performance of a product system for use as a reference unit in a Life-Cycle Assessment study "(UNEP, 2009 [21]). Its purpose is to provide a reference to the relationship between inputs and outputs (Tokede and Traverso, 2020 [16]). It is a critical issue in S-LCA as it is difficult to identify (Fan et al., 2018 [15]). However, it needs to be consistent with the goal and scope of the study (UNEP, 2020 [9]) in which it is involved.

The system boundary "determines parts of the product system that will be included in the system assessed" (UNEP, 2020 [9]). They are defined according to the life cycle stages from upstream processes (i.e., resource use, purchase of goods, and services) to downstream processes (i.e., distribution use and end-of-life products). According to the guidelines (UNEP, 2020 [9]), it is defined as (a) the full life cycle of products and services (cradle-to-grave; from resource extraction to end-of-life); (b) the supply chain of the product (cradle-to-gate; exclude use phase and end-of-life); and (c) parts of the life cycle (gate-to-gate or gate-to-grave).

To answer this question, we separated the functional units for S-LCA, the boundary (cradle to grave or cradle to gate), and the functional units used for LCA.

2.2.3. S-LCA Indicators

Social indicators can be described as "evidence, subjective or objective, qualitative, quantitative, or semi-quantitative, being collected to facilitate concise, comprehensive, and balanced judgments about the condition of specific social aspects concerning a set of values and goals" (UNEP, 2020 [9]). It includes (a) approaches such as impact pathways (mentioned in Question 3), (b) social topics as stakeholders and impact categories, (c) characterization models and types of impact pathways used for assessment, and (d) the weighting approach (UNEP, 2020 [9]).

The character of assessment for social indicators is divided into three types: (a) qualitative, which is nominative and will use words (description); (b) quantitative, which will use a numerical description of the issue (physical units); and (c) semi-qualitative, which will have results expressed in a yes/no form or a scale (scoring system) (UNEP, 2020 [9]).

UNEP (2009) [21] defines the impact pathways as "social LCI results and/or social impact categories" and the impact categories as "logical groupings of S-LCA results related to social issues of interest to stakeholders and decision-makers". The impact pathway is an important part, as it provides an assessment framework. With the identification of indicators, it will give a better assessment of impacts throughout the life cycle (Tokede et Traverso, 2020 [16]). It can be qualitative, which will cover social topics and categories, or quantitative, which will focus on measurable numbers and targets (UNEP, 2020 [9]). It is referred to as a cause-and-effect relationship between the midpoint and endpoint (Jørgensen et al., 2008 [20]). The midpoint is the parameters in the social mechanism network (UNEP, 2020 [9]). The endpoint is the determined damage levels (UNEP, 2020 [9]). The impact is mostly linked to the midpoint and endpoint impact pathways. The impact categories cover specific social issues of interest to stakeholders and decision-makers. They can be grouped as subcategories results (UNEP, 2020 [9]). It is separated between additive and descriptive according to the criteria of their functional units in the case studies.

To answer this question, we looked at the stakeholder categories and their impact categories linked to their activities, the social indicators, the character of the assessment process through impact pathways, impact effects, and impact and stakeholder categories. The impact categories are linked to an indicator, and the indicator is a way to relate to the identified impact (Mathe, 2014 [22]). Indicators are direct measurements of social issues, and they act as a bridge to link the data with subcategories and impact categories to guide the data collection process (Wu et Chen, 2014 [23]).

2.2.4. Challenges

Jørgensen et al. (2008 [20]) described the impact assessment as the phase where inventory information is translated into impacts. Characterization considers the inventory results within the same impact category (Jørgensen et al., 2008 [20]). It is required to translate results into value for an impact indicator at the midpoint or endpoint (UNEP, 2020 [9]). This is the final stage of the S-LCA, where the results are checked and discussed. They are broken down into life cycle phases, impact categories, impact subcategories, and stakeholder categories (UNEP, 2020 [9]).

This section comprises data for stakeholders and impact categories. Three approaches are used to prioritize data collection: (a) conduct a literature review to highlight key potential social impacts to identify specific unit processes for which data should be collected; (b) explore the intensity of different unit processes in a product's life cycle and determine a variable; and (c) identify hotspots in the product's life cycle (UNEP, 2020 [9]). The approach to prioritizing data is to identify the hotspot. It highlighted that hotspots are linked to social issues, and impact subcategories cover these. Hotspots can generally be evaluated at the country's level, but for case-specific S-LCA, more precise geographic information is needed (Hosseinijou et al., 2014 [24]). Benoit et al. (2010 [25]) claimed that the impact assessment is underdeveloped as the guidelines provide a general structure with a set of categories and subcategories.

To answer this question, our approach involved a comprehensive examination of each article's methodology regarding data collection and its accessibility, impact assessment procedures, and the subsequent interpretation of results. Specifically, we scrutinized aspects such as data collection methods and availability (drawing from literature, assessing unit intensity, and identifying hotspots), the nature of impact assessment (whether midpoint or endpoint), and the nuances within result interpretations (considering life cycle phases, impact categories, and subcategories). This meticulous analysis enabled us to discern and identify the challenges elucidated across the 19 articles.

In our next section, we discussed our results and findings through the respective tables associated with each question.

3. Results

Our protocol brought 19 articles (Table 2). A numerical value is attributed to each article and will be used in the remaining tables and figures.

Table 2. Selected papers.

Paper	Authors	Paper Objective	Type of Construction	Location
1	Dong et Ng, 2015 [26]	Develop a S-LCA model for building construction projects	Precast Façade, Semi Precast Slab, and Precast Staircase	Hong Kong
2	Fan et al., 2018 [15]	Evaluate the social impact of a green building district within its designed service life	Green Building	China
3	Balasbaneh et al., 2018 [2]	Analyze the stakeholder toward contribution to economic development	Timber and Concrete structure	Malaysia
4	Dong et Ng, 2016 [11]	Develop a LCSA framework and a case study of LCSA	Building	Hong Kong
5	Hosseinijou et al., 2014 [24]	Assess and compare socio-economic impacts of materials in their life cycle.	Material (steel and iron)	N/A
6	Fauzi et al., 2022 [27]	Propose a method and case study based on the S-LCA framework and guidelines	Wood, Concrete, Steel, Gravel, Aluminum, Gypsum, and Brick	Ontario, Canada; Quebec, Canada; China
7	Santos et al., 2019 [28]	Collect and analyze information to assist the decision-making process	Construction and Demolition waste	Not specific
8	Balasbaneh et al., 2021 (Life cycle. . .) [29]	Assess three different construction techniques	Materials (concrete) and Single-story residential building	Malaysia
9	Zheng et al., 2020 [30]	Evaluate the social impacts on pavement	Hot-Mix Asphalt Pavement	China
10	Hossain et al., 2018 [31]	Assess the social implications and sustainability of construction materials with a comparative rating model	Recycled Materials	Hong Kong
11	Bezama et al., 2021 [32]	Compare two different demonstrator systems for lightweight wood-based concrete elements	Wood-Based Concrete Elements	Germany
12	Liu et Qian, 2019 (Towards) [33]	Propose an integrated building-specific sustainability assessment model	PPVC Project Semi-Prefab	Singapore
13	Liu et Qian., 2019 (Evaluation. . .) [34]	Develop a methodological framework for social life cycle assessment	Social Sustainability Projects	Singapore
14	Zheng et al., 2019 [35]	Compare LCSA	Pavement	China
15	Vitorio et Kripka, 2021 [8]	Verify the evolution of social indicators in the sectors	Single-Family Residences	Brazil
16	Balasbaneh et al., 2020 [36]	Evaluate carbon dioxide (CO_2) emissions and the cost and social impacts	Windows in School Building	Malaysia

Table 2. *Cont.*

Paper	Authors	Paper Objective	Type of Construction	Location
17	Ostermeyer et al., 2013 [14]	Address the potential of LCSA in the built environment	Refurbishment of Building	Europe
18	Balasbaneh et al., 2021 (Applying. . .) [37]	Evaluate the sustainability performance of different flooring systems	Flooring Systems	Malaysia
19	Osorio-Tejada et al., 2022 [38]	Analyze the social performance of companies involved in the supply chain of road transport	Road Freight service	Latin America, Europe, and Asia

3.1. Scope of the S-LCA Case Studies

For scope, we classified the articles as per their contribution to research. Table 2 showed that out of the 19 articles, three aimed to develop and assess, four were to evaluate, one was to collect, compare, and verify S-LCA, and two were to propose and analyze S-LCA. Studies were mostly performed on Asian countries, with Hong Kong (three), China (four), Malaysia (four), Singapore (two), and Asia in general (1). Four studied buildings, and fifteen were in built-in environments.

In Table 3, we review the types of case studies. They were mostly single-case studies rather than multiple. The organizational type was mostly public (16). For the different kinds of stakeholders, the focus was on workers, value chain actors, consumers, and the local community.

We can also note that authors focused on (1) developing a model and methodological or LCSA framework; (2) assessing social impacts and sustainability of building materials; (3) evaluating the social cost of carbon dioxide emissions in green buildings and their materials; (4) comparing LCSA and systems of construction materials; (5) verifying the evolution of social indicators; and (6) analyzing stakeholder's contribution and the social performance of companies.

Mathe (2014 [22]) highlighted the need to consider the range of actors and indicators chosen and the individuals concerned. As such, one category in Table 3 is the type of stakeholders involved. Stakeholders should be present during the development of the S-LCA analysis and are considered from the impact analysis's point of view (Arcese et al., 2013 [39]). However, although S-LCA aims to validate an assessment and its consequences, some factors are personal. In the sense that when a company carries out its activity, it focuses on the product and not on the "behavior" (Zamagni et al., 2011 [12]). Indeed, certain changes cannot be directly linked to the specific individuals affected, as noted by Jorgensen et al. (2013 [40]). For instance, consider the evaluation of forced labor, where its existence might be recognized but not quantified in relation to the number of T-shirts within the product system, as illustrated by the example provided in UNEP (2020 [9]).

3.2. Functional Units and System Boundaries in Case Studies

Among the 19 articles reviewed, the functional units employed in S-LCA exhibited significant variation, as shown in Table 4. These included assessments ranging from worst to best in two articles, percentages in three articles, square meters (m^2) in three articles, scoring ranging from unconcerned to very strong priority in one article, a linkage with national and international laws with scoring from strongly positive to strongly negative in one article, numeric values, categorical distinctions, yes/no indicators, and hours each featured in one article, while another article used weight as a specification. Furthermore, three articles utilized cost evaluation as their functional unit, one considered the level of risk, and finally, two articles did not specify the functional unit employed in their assessments.

Table 3. Review of the case studies.

Paper	Type of Case Studies		Organization Type		Type of Stakeholders Involved:				Methods and Models Used
	Single	Multiple	Public	Private	Workers	Value Chain Actors	Consumers	Local Community	
1	X		X		X			X	Questionnaires and surveys on social performance of environmental friendly practices
2	X			X			X	X	Questionnaires for green residential districts
3		X	X		X				Interviews and research assessment on contribution to economic development for numbers of job creation
4	X		X	X	X			X	Interviews on material stages
5	X		X		X	X	X	X	MFA (tool) to identify hotspots within communities, companies and employment
6	X		X		X	X	X	X	Multi-level Analysis on unit, company, sector and country
7	x		X		X	X	X	X	Model identifies stakeholders' perspectives, experiences in waste management.
8		X	X		X	X	X	X	Multi-criteria decision-making on sustainable Flooring (type of flooring)
9	X		X		X		X	X	Framework on raw materials, production, construction, use and maintenance
10	X		X		X	X	X	X	Interviews on challenges and recycled materials
11	X		X		X				RESPONSA model on indicators and organizational learning
12	X		X		X		X	X	Model on structural design and well-being of stakeholders
13	X		X		X		X	X	Interviews and indicators on cause-effect relationships (soundproof issue)
14	X		X		X		X	X	Interviews and questionnaires on social impacts for pavement
15	X			X	X	X	X	X	WFWP method-raw materials and workers' wages
16	X		X		X		X	X	Multi-criteria decision-making on user satisfaction and indoor noise and parameters
17	X			X			X		A multidimensional Pareto optimization methodology on Building materials, Workers and job conditions
18		X	X		X		X	X	Interviews and Multi-criteria decision-making on judgement of stakeholders on types of construction
19		X	X		X		X	X	Interviews on labor rights

Table 4. Functional units S-LCA, boundary, and functional unit LCA.

#	FU-S-LCA	Boundary	FU-LCA
1	Scale of −1 to 1, and −1 is the worst and 1 is the best social	Cradle to grave	Scale of 1 to −1
2	None	Cradle to gate	None
3	%	Cradle to grave	Cost per MYR
4	−1 to 1, with 1 being the best social performance; the score ranges from −5 to 5, with 5 being the best social performance	Cradle to grave	Kg
5	T, m^2	Cradle to grave	None
6	M^2	Cradle to grave	None
7	None	Cradle to grave	None
8	9 is unconcerned, 7 is moderate priority, 5 is strong priority, 3 is solid priority, and 1 is very strong priority	Cradle to grave	M^2
9	%	Cradle to gate	None
10	1.00 Strongly positive, fully agreed, very highly related, highly compatible 0.75 Mostly positive, moderately agreed, highly related, moderately compatible 0.50 Neutrally affected, agreed, neutrally related, compatible 0.25 Mostly negative, partially disagreed, moderately negative, negatively compatible 0.00 Strongly negative, fully disagreed, highly unrelated, incompatible	Cradle to grave	None
11	Number, category, percent, yes and no, hour	Cradle to gate	Kg, mm
12	Weights	Cradle to gate	none
13	Weights	Cradle to gate	Weight
14	HHCP, milli-DALYS eq, S, nox eq)	Cradle to gate	T, m^3
15	R$/month	Cradle to grave	Kg, m^2
16	Weight	Cradle to grave	US $
17	Cost	Cradle to gate	Investment cost
18	Cost	Cradle to grave	Cm
19	Low, medium, high, very high risk	Cradle to gate	None

In terms of the functional unit concerning LCA, the analysis of the 19 articles revealed diverse approaches. Specifically, two articles were cost-related, three utilized weight specifications, one employed centimeters (cm), one used kilograms (kg), one utilized cubic meters (m^3), another employed tons (T), one used square meters (m^2), and one adopted the worst and best criteria. Remarkably, seven articles did not specify the functional unit used.

Regarding the system boundary, it was observed that eight articles focused on the cradle-to-gate perspective, while eleven adopted the cradle-to-grave approach. This distinction can be attributed to the fact that four of the 19 articles were exclusively concerned with the building itself, whereas the remaining articles encompassed broader project or material assessments.

We can see in Table 4 that the unit processes to fulfill the functional unit are set up for both S-LCA and LCA. However, even if so, this approach is not feasible in S-LCA as the measures are mostly on the socioeconomic impacts, which are related to the company's behavior instead of the product's function unit (Jørgensen, 2013 [40]). As such, if S-LCA is applied to assess a product by focusing on the product system itself, the behavior will not be caught because the supplier will be held responsible for only the part of production included in the product system (Zamagni et al., 2011 [12]). Thus, the impacts cannot be expressed through the functional unit. In addition, S-LCA works with data on attributes and characteristics of processes that cannot be expressed per unit (Hosseinijou et al., 2014 [24]).

Lagarde and Macombe (2013 [41]) also mentioned that the concepts used to describe the systems and the boundaries are unclear in the literature since authors do not clearly explain their models and criteria for making their choice. It has been pointed out that to support management decisions, it is sufficient to include only parts of the life cycle that are directly influenced by companies (Hosseinijou et al., 2014 [24]). In our study, the articles are from cradle to gate or cradle to grave, meaning that all life cycle stages were involved.

3.3. Nature of the S-LCA Indicators Used in the Selected Case Studies

We have organized five distinct stakeholder categories and aligned them with their respective impact categories, as outlined in the UNEP guidelines. This arrangement provides a structured overview of the relationships between stakeholders and the specific impact categories relevant to their interests and concerns.

As Chan and Oppong (2017 [42]) discussed, a stakeholder has different attributes (power, legitimacy, and urgency), and it is important to understand their effect on construction projects. For workers, the categories associated were fair salary, working hours, forced labor, equal opportunities, health and safety, and discrimination. For value chain actors, the subcategories of capacity for job creation and local employment were of paramount importance. Consumers, on the other hand, exhibited a distinct concern related to consumer privacy. The community stakeholder category was associated with a broader range of impact subcategories, encompassing local job creation, respect for indigenous rights, land use, cultural heritage, safe living conditions, community engagement, human health, public commitment, and technology development.

However, it is noteworthy that in our analysis of the 19 articles, we encountered challenges in obtaining certain data, primarily due to difficulties in identifying the relevant stakeholders. This observation is somewhat surprising, given that the UNEP (2020 [9]) guidelines emphasize that the initial step in the analysis should be the identification of stakeholders. Nonetheless, we identified a recurring pattern whereby specific impact categories were consistently linked to particular stakeholder categories, as illustrated in Figure 2.

The subcategories were capacity for job creation and local employment. For consumers, consumer privacy was one of their concerns. The community was linked to local job creation and respect for indigenous rights, land use, cultural heritage, safe living conditions, community engagement, human health, public commitment, and technology development.

In Table 5, our analysis of the 19 articles revealed diverse characteristics of the assessment approaches. Specifically, we found that nine articles employed a quantitative assessment methodology, five utilized a qualitative approach, and five adopted a semi-quantitative method. Regarding the consideration of midpoint and endpoint criteria, only three articles exclusively focused on midpoint (two) or endpoint (one), while the remaining sixteen articles considered both criteria. Additionally, seven articles assessed direct impacts, while eleven focused on indirect impacts. The majority of articles, precisely fifteen out of nineteen, presented descriptive assessments, while the remaining four followed an additive approach.

Furthermore, our examination of the impact pathways, which illustrate the cause-and-effect relationship between midpoint and endpoint indicators, revealed that many articles established links, particularly between fair wages (midpoint) and human health (endpoint). However, as noted by Hosseinijou et al. (2014 [24]), the precise measurement of this process remains a challenge. In line with the observations of Neugebauer et al. (2014) [43], it became evident that the boundaries between impact indicators and inventory indicators are not distinctly defined.

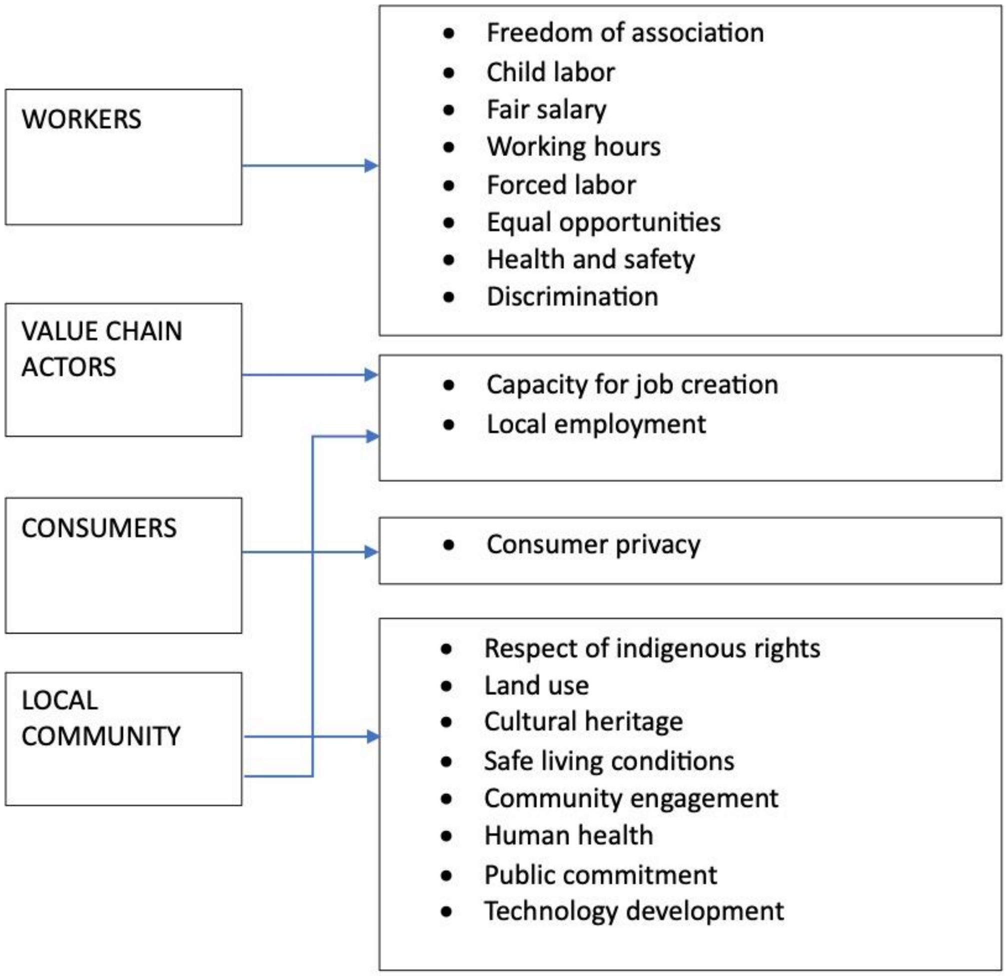

Figure 2. Stakeholders' categories and subcategories from UNEP guidelines.

3.4. Main Challenges of Social Life-Cycle Assessment

Addressing research question 4, this section categorizes methodological challenges into four distinct types: data quality, data uncertainties, data measurement, and missing data. We found that six studies employed surveys, five relied on interviews, two used literature reviews, two employed models, three utilized multi-criteria decision-making approaches, and five employed statistical methods and matrix analysis.

Within the data quality category, Dong and Ng (2015 [26]) emphasized that data quality is a significant concern, particularly because certain indicators cannot be effectively measured, rendering it impossible to estimate scores accurately. Furthermore, the scoring method itself is problematic, given the absence of a widely accepted and standardized scoring system, as noted by Fan et al. (2018 [15]).

Concerning data uncertainties, despite the collection of information via questionnaires, it was recognized that these data may still exhibit uncertainties. Additionally, Balasbaneh et al. (2020 [36]) highlighted the difficulty in identifying certain stakeholders, particularly in governance, making it challenging to collect data from them.

In the context of data measurement, the quantification of social impact was deemed challenging overall. Sustainability, as highlighted in Article 5, was described as an underdeveloped aspect. Moreover, Vitorio and Kripka (2021 [8]) underscored that the construction industry still lacks comprehensive social data inventories.

Addressing missing data, it was noted that some stakeholders were excluded due to data gaps, especially in the case of value chain actors and governance, where obtaining information proved difficult (Balasbaneh et al., 2018 [2]; Balasbaneh et al., 2020 [36]).

Table 5. Character of assessment, impact assessment, and result interpretations.

Paper	Assessment Process			Impact Assessment						Result Interpretations			
	Qualitative	Qualitative	Semi-Qualitative	Midpoint	Endpoint	Classification	Characterisation	Normalization	Weighting	Impact Effects		Impact Categories	
										Direct	Indirect	Addictive	Descriptive
1			X	X	X	X		X	X	X		X	
2	X			X	X	X	X		X	X		X	
3			X	X	X	X	X				X		X
4				X	X	X	X	X	X		X	X	
5		X	X	X	X	X	X		X		X	X	
6	X	X		X	X	X				X			X
7		X		X	X	X	X			X			X
8	X			X	X	X	X	X	X	X			X
9	X	X		X	X		X			X			X
10		X		X	X	X	X	X	X		X		X
11	X	X		X	X	X	X	X	X		X		X
12	X	X		X	X		X	X	X		X		X
13		X	X	X	X	X	X	X	X		X		X
14	X		X	X	X	X	X	X	X		X		X
15	X			X	X	X	X		X	X			X
16	X	X		X	X		X	X	X		X		X
17	X	X		X	X		X	X	X		X		X
18	X			X	X	X	X	X	X		X		X
19		X		X	X	X	X	X	X		X		X

Lastly, we observed that among the studies, eight focused on the cradle-to-gate perspective, while eleven adopted the cradle-to-grave approach. This choice of system boundary in life cycle analysis was influenced by the challenges associated with missing data, as highlighted in Table 4.

As pointed out by Fauzi et al. (2022 [27]), it is crucial to encompass the entire product life cycle because impacts occurring throughout various phases are frequently overlooked due to missing data. This underscores the need for comprehensive data collection and analysis across the entire life cycle of a product.

Moreover, Ostermeyer et al. (2013 [14]) emphasize that these missing data represent essential information gaps that should be addressed through future research efforts, highlighting the importance of ongoing data generation to enhance the effectiveness of S-LCA. Zanchi et al. (2018 [44]) have also identified several key elements that can significantly influence the application of S-LCA. These elements encompass the perspective from which affected stakeholders are considered, the methodology's selection and prioritization of indicators, the critical role of the functional unit linked with social inventory information, the definition of system boundaries that may not always encompass all relevant unit processes, and the potential disparities in data collected when assessing social impacts on-site within a company compared to data collected at a national or geographic level. These considerations underscore the complexity and multifaceted nature of social life-cycle assessment.

In summary, Social Life-Cycle Assessment continues to pose significant challenges within the construction sector. These challenges (In Table 6) are primarily driven by issues related to missing data, difficulties in measurement, uncertainties, and the inconsistent quality of available data. Addressing these challenges is essential to advancing the effectiveness and reliability of Social Life-Cycle Assessment in construction projects.

Table 6. Challenges in data collection.

Paper	Challenges of Data Collection			
	Data Quality	Data Uncertainties	Data Measurement	Missing Data
1	X	X	X	
2	X	X	X	X
3			X	X
4	X		X	X
5		X		
6		X	X	X
7				X
8	X			
9				X
10	X		X	
11		X		X
12	X	X	X	X
13	X		X	X
14		X	X	
15		X	X	
16		X	X	
17			X	X
18	X	X		X
19	X			

4. Discussion

This paper had the overarching goal of examining how researchers have put social impact assessment into practice within construction projects over the past decade. The study encompassed various facets, including the development, assessment, evaluation, comparison, and verification of methodologies and frameworks. These encompassed activities such as (1) the creation of models and methodological frameworks for Life Cycle Sustainability Assessment (LCSA); (2) the assessment of social impacts and sustainability concerning building materials; (3) the evaluation of the social cost associated with carbon dioxide emissions in green buildings and their materials; (4) the comparison between LCSA and construction material systems; (5) the verification of the evolution of social indicators; and (6) the analysis of stakeholder contributions and the social performance of companies.

The study predominantly featured single-case studies rather than multiple-case studies, with a focus on evaluating and assessing a total of three private organizations and sixteen public organizations. In terms of stakeholders, the research centered on workers, value chain actors, consumers, and the local community, shedding light on the intricate dynamics and implications of social impact assessment in the construction sector.

Furthermore, in terms of functional units, the measurements and scoring employed varied widely, encompassing scales such as worst to best in two cases, percentages in three cases, square meters (m^2) in three cases, scoring from unconcerned to very strong priority in one case, linkage with national and international laws with scoring from strongly positive to strongly negative in one case, numeric values, categorical distinctions, yes/no indicators, and hours each featured in one case, with weight used as a specification in one case. Additionally, three articles utilized cost evaluation as their functional unit, one considered the level of risk, and finally, two articles did not specify the functional unit employed in their assessments.

These diverse scoring methods, as pointed out by Jørgensen (2013 [40]), raise questions about the appropriateness of measuring socio-economic impacts based on a company's behavior rather than focusing on the product's functional unit. Zamagni et al. (2011 [12]) similarly argued that behavior may not be adequately captured, as suppliers are held responsible only for the part of production included in the product system. Moreover, S-LCA often deals with data on attributes and characteristics of processes that cannot be expressed per unit, as highlighted by Hosseinijou et al. (2014 [24]). This complexity arises from the fact that social impacts are intricately linked to human well-being, making it challenging to establish a direct connection to a specific physical unit, as noted by Zheng et al. (2020 [30]). These considerations underscore the complexity and nuances associated with the choice of functional units in Social Life-Cycle Assessments.

Thirdly, the nature of indicators within the case studies spanned five stakeholder categories. These case studies were characterized as quantitative in nine instances, qualitative in five cases, and semi-quantitative in five instances. As outlined by Zanchi et al. (2018 [44]), various elements can significantly influence S-LCA applications, with a particular emphasis on the perspective of affected stakeholders. Stakeholders possess distinct attributes, including power, legitimacy, and urgency, and comprehending their impact on construction projects is vital, as noted by Chan and Oppong (2017 [42]). Consequently, for management decision support, it may be sufficient to consider only those parts of the life cycle directly influenced by companies, as highlighted by Hosseinijou et al. (2014 [24]).

Within the context of the case studies, the impact on affected stakeholders became evident. Workers were associated with indicators related to fair salaries, working hours, forced labor, equal opportunities, health and safety, and discrimination. Value chain actors were concerned with indicators related to capacity for job creation and local employment, while consumers prioritized indicators such as consumer privacy. The local community was linked to a broad range of indicators, including local job creation, respect for indigenous rights, land use, cultural heritage, safe living conditions, community engagement, human health, public commitment, and technology development.

It is noteworthy that the articles in our study encompassed a cradle-to-gate or cradle-to-grave perspective, indicating the involvement of all life cycle stages in the assessments. This comprehensive approach allows for a holistic understanding of social impacts throughout the entire life cycle of construction projects.

Additionally, the authors noted that the predominant challenges revolved around data quality and uncertainties. There exists an intricate interplay between scope, assessments, and measurements, rendering methodological evaluation challenging. Notably, S-LCA exhibits deficiencies in terms of comparability and transparency, as highlighted by Pollok et al. (2021) [45]. It is important to acknowledge that assessing the same item produced in different locations can yield disparate impacts, thereby influencing the indicators, as discussed by Zamagni et al. (2011 [12]). Furthermore, collecting data on-site within a company or at a country level within geographical zones introduces additional complexities, as underscored by Zanchi et al. (2018 [44]).

Connecting the inventory results of the social dimension to functional units is another challenge (Zheng et al., 2019 [35]; Dong and Ng, 2015 [26]). For the impact assessment, the weighting and scoring of social issues remain a challenge (Hosseinijou et al., 2014 [24]). For example, in the study of Dong et al. (2016 [11]), interviewees suggested leaving the choice of weighting to the users. In the study of Hossain et al. (2018 [31]), an indirect scoring system is used based on indirect weighing based on respondents' opinions as ratings. In Liu and Qian (2019 [22]), equal weights were assigned to four stakeholders because of experts' opinions regarding ethical issues. Knowing that, when the weighting of any criteria is higher, there is a chance for the related criteria to over-influence decision-making (Balasbaneh et al., 2021 [37]). As such, an uncertainty analysis of the scoring and weighting models is needed. Since social impacts are mostly associated with human well-being, there is a risk of inevitable subjectivity (Zheng et al., 2020 [30]). Characterization models should be able to translate inventory results into impacts in a comparative way (Hosseinijou et al., 2014 [17]). Still, there is a knowledge gap with the social indicators to characterize social issues (Liu et Qian, 2019 [34]). Dong et al. (2015 [26]) said that calculation is no longer part of characterization, while normalization and weighting are the quantification steps. Characterization models are not able to link the impact results to the functional unit (Hosseinijou et al., 2014 [24]). Therefore, the process of the scoring system usually includes normalization, which is a quantifying process with a lack of scientific method (Dong et al., 2015 [26]). Therefore, a specific set of indicators needs to be developed depending on the goal and scope definition as well as data accessibility (Liu et Qian, 2019 [22]). An international and multidiscipline expert panel could help solve these issues (Zheng et al., 2019 [35]).

We have identified and analyzed the specific methods that authors have employed to operationalize Social Life-Cycle Assessment (S-LCA) in construction projects. Our findings have unveiled numerous issues within the S-LCA assessment process. These challenges have been categorized into four distinct types: data quality, data uncertainties, data measurement, and missing data. Notably, the primary concern that emerged from our study pertains to the quality of the data, with certain indicators proving difficult or impossible to measure accurately. Therefore, it becomes nearly impossible to estimate the score (Dong and Ng, 2015 [26]).

The scoring method is also problematic, as there is a lack of a well-accepted scoring system (Fan et al., 2018 [15]). Concerning data uncertainties, even though information is gathered through questionnaires, it may still exhibit certain degrees of uncertainty. This inherent uncertainty complicates the identification of some stakeholders, particularly those involved in governance, making it challenging to gather data from them, as highlighted by Balasbaneh et al. (2020 [36]). As highlighted by Backes et Traverso (2021 [46]), the principal challenges identified revolved around the selection and quantification of social criteria and indicators.

Regarding data measurement, the quantification of social impact remains a challenging endeavor and is still underdeveloped in terms of sustainability, as noted by Hosseinijou et al. (2014 [24]). The complex and multifaceted nature of social impact assessment presents difficulties in precisely quantifying these impacts, particularly within the context of sustainability.

Concerning missing data, challenges persist, and some stakeholders are omitted due to data gaps, especially among value chain actors and governance, where obtaining information proves to be particularly challenging, as highlighted by Balasbaneh et al. (2018 [2] and 2020 [36]). Inventory data collection also presents a hurdle due to the limited availability of databases, as noted by Zheng et al. (2020 [30]). These data limitations underscore the ongoing issues associated with social impact assessment in the construction sector, where comprehensive and reliable social data inventories remain lacking, as highlighted by Vitorio and Kripka (2021 [44]).

Furthermore, the absence of international consensus on the social life cycle impact assessment method is a noteworthy challenge, as indicated by Fan et al. (2018 [15]). The lack of standardized criteria, particularly in the domain of social culture, further complicates the development and implementation of a cohesive approach, as observed by Balasbaneh et al. (2018 [2]). These challenges highlight the need for continued research and standardization efforts in the field of Social Life-Cycle Assessment. Pollock et al. (2021 [45]) even argued that the complication is in the complex testing and verification of social impact pathways and social issues' facets that connect to different disciplines and theories.

To sum up, the limitation of the implementation of the S-LCA is the selection of different stakeholder categories, impact subcategories, indicators, and weighting methods (Hossain et al., 2018 [31]). Upon juxtaposing our discoveries with those of Pollock et al. (2021 [45]), it becomes evident that analogous concerns have surfaced in other industries, notably in the automotive sector. Furthermore, we touched upon the behavioral dimension as a noteworthy factor, stemming from the inherent challenge of quantifying social aspects. The authors of the study similarly acknowledged this challenge, emphasizing its role as a causal factor for uncertainty, particularly in relation to Environmental Life Cycle Inventory (E-LCI) data. Although they addressed issues related to indicators, our selected case studies did not center on a specific site or location. In contrast, Backes and Traverso (2023 [46]) meticulously curated a list of indicators and linked them to a subsequent hotspot analysis focused on production countries. This approach introduces the possibility of variations in data collection, whether conducted on-site at individual companies or aggregated per country, especially within distinct geographic zones, as noted by Zanchi et al. (2018 [44]).

5. Conclusions

This paper conducted a comprehensive scoping review of case studies published in the past decade to gain insights into the current trends in Social Life-Cycle Assessment within the construction industry. Our primary objective was to explore the operationalization of S-LCA (Social Life-Cycle Assessment). The review encompassed various aspects, including the scope, functional unit, system boundaries, nature of indicators used, and challenges encountered in S-LCA applications. However, it is important to acknowledge that we cannot encompass every aspect of operationalization comprehensively. Notably, we did not delve into specific details such as the individuals responsible for conducting the analyses, the requisite skill sets, or the software tools employed, among other factors. These particulars are infrequently documented in the articles we reviewed. As such, it is important to acknowledge that there are numerous other facets of operationalization that warrant further investigation. Nevertheless, the findings from this review shed light on several noteworthy observations:

Flaws in S-LCA: It became evident that S-LCA faces certain shortcomings related to the quality of measurement, scoring methods, and the availability of social data. These deficiencies are not exclusive to the construction sector but are prevalent across various industries.

Measurement Challenges in Construction: Particularly within the construction industry, there is a pressing need to develop more suitable measurement approaches for construction output. The assessment of impacts in this context can be complex and challenging.

Focus on Products: The majority of S-LCA assessments focus on the product level, which may not adequately capture behavioral aspects (social) that are integral to understanding social impacts. Social impacts are often attributed primarily to companies rather than individual processes and materials.

Materials-Centric Assessments: A significant portion of the reviewed articles primarily focused on materials rather than the construction of buildings themselves. This emphasis on materials could contribute to the prevalence of flaws and challenges encountered in S-LCA within the construction sector.

Standardization and Quantification Challenges: The field of social culture in S-LCA lacks standardization, and quantifying social impacts remains a complex task. This subjectivity is particularly pronounced in scoring and weighting during assessments.

In summary, this review underscores the need for continued research and development efforts to enhance the effectiveness and reliability of S-LCA, both within the construction industry and across other sectors. Addressing measurement challenges, standardizing social culture aspects, and considering the broader behavioral context are key steps in advancing the field of social impact assessment.

This research has its limitations, primarily stemming from the constraints imposed during the article selection process. The main limitations include:

Limited Article Pool: The study's scope was narrowed down by focusing exclusively on scientific articles within the construction sector that feature case studies. This approach excluded potentially valuable insights from non-academic sources and gray literature, which may contain relevant case studies conducted by industry professionals. Consequently, the findings may not provide a comprehensive view of all relevant S-LCA case studies in the construction industry. The decision to exclude gray literature, while upholding academic rigor, may have inadvertently omitted valuable real-world case studies and practical applications of S-LCA conducted by non-academic stakeholders in the construction sector.

Confidentiality and Ethical Considerations: Some case studies or industry-specific data may be subject to confidentiality agreements or ethical constraints, limiting their inclusion in the analysis. These constraints can potentially result in an incomplete representation of available S-LCA case studies within the construction industry.

Despite these limitations, the research provides valuable insights into the current state of S-LCA within the construction sector based on the available academic literature. Future research endeavors may seek to address these limitations by exploring a broader range of sources and considering alternative methodologies to capture a more comprehensive view of S-LCA case studies and applications in the field.

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