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SOCIETAL LCA

Social Life Cycle Assessment in the construction sector: current work and directions for future research

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Abstract

Purpose While social aspects are considered as part of Life Cycle Sustainability Assessment (LCSA), the concept of Social Life Cycle Assessment (S-LCA) is relatively new in the construction sector, and more research is needed to comprehend its full potential and inform practice to deliver socially sustainable interventions. The paper aims to provide an account of current work in the field of S-LCA in the construction sector and presents an overview of the methodologies and frameworks that are currently used, with a focus on the critical analysis of impact categories applied to the construction sector.

Methods The paper adopts a systematic review of the literature with the objective to (a) provide a holistic and cross-disciplinary overview of the S-LCA methodologies and frameworks in the construction sector, (b) explore existing gaps, and (c) frame directions for future research.

Results and discussion Several gaps have been identified in relation to the S-LCA research landscape applied to the construction sector, which have, in turn, informed the formulation of recommendations for future research.

Conclusions The paper emphasises the importance and the need to intensify efforts to develop and reach consensus on the categories and criteria to deliver an S-LCA framework for Social Life Cycle Assessment of built environments. The framework, underpinned by a methodology, should involve an adaptable weighting system that considers the nature of the building as well as the type and profile of occupants. It should also factor in dynamic data to inform real-time adaptations to continuously deliver socially sustainable built environment interventions.

Keywords S-LCA · Social LCA · LCA · Construction · Buildings · Infrastructure

1 Introduction

The building sector is recognised as a key consumer of natural resources, also responsible for one-third of European waste and 22% of European hazardous waste production (EC 2013). Also, construction processes involve longer time scales than in other industries (EC 2013) and therefore face very different operational and environmental conditions. The recent special report on the impacts of global warming of 1.5 °C (Intergovernmental Panel on Climate Change (IPCC) 2021) was yet another call to implement measures to mitigate GHG emissions and to devise new adaptation scenarios.

In this context, Life Cycle Assessment (LCA) helps to quantify the environmental pressures, the trade-offs, and areas for achieving improvements considering the full life cycle of built assets from design to recycling. Conversely, Life Cycle Sustainability Assessment (LCSA) factors in the environmental, social, and economic aspects of built environment interventions (Ferrari et al. 2019; Barrio et al. 2021). It is an important instrument to help reduce the overall environmental burden of our buildings and provide insights into upstream and downstream trade-offs associated with environmental pressures, social considerations, including health and wellbeing, and the consumption of natural resources.

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Recent research has highlighted the potential of a new generation of LCA methods and tools that are model based, continuously learn from real-time data, while informing effective operation and management strategies of buildings and districts (Ghoroghi et al. 2022; Fnais et al. 2022). However, a major limitation is consistently highlighted in that traditional LCA methods do not factor in environmental impacts on health and well-being as well as many other social considerations (Skaar et al. 2013; Fnais et al. 2022).

Out of the 17 goals for sustainable development proposed by the UN, several social aspects are taken into consideration, from gender equality and reduced inequalities to good health and well-being (UN 2023). The relation, on the one hand, between buildings and people and, on the other, buildings' effects on human life are well documented in the literature and form the subject of increasingly growing research. As Evans and McCoy (1998) argued, we spend 90% of our lives inside buildings. Rohde et al. (2020), who highlighted three domains of comfort, health, and wellbeing, inspired by the three Vitruvian principles, sustained: Following their historical overview, Samet and Spengler state that 'A more comprehensive rethinking is needed on the physiological, sociological, ergonomic and psychological characteristics of the built environment that affect health and well-being'. Evans (2003) stated that buildings have direct or indirect impacts on people and their mental health. Backes and Traverso (2023) argued: 'Thus, there is also a growing need in the construction industry and for new trends in sustainable building to assess social impacts and integrate them into decision-making (Abowitz and Toole 2010)'.

S-LCA, by definition, is looking to integrate a sociological approach to the LCA methodology. According to the official guidelines by the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC), in 2009, and revised in 2020 (United Nations Environment Programme 2020): 'Social Life Cycle Assessment (S-LCA) is a methodology to assess the social impacts of products and services across their life cycle (e.g. from extraction of raw material to the end-of-life phase, e.g. disposal). [...] S-LCA employs some of the modelling capabilities and systematic assessment processes of Environmental Life Cycle Assessment (E-LCA) combined with social sciences methods'. Thus, the stakeholder categories, impact categories and subcategories are closely aligned with the purposes of S-LCA. Stakeholder categories include workers, local community, value chain actors, consumers, society, children, and impact subcategories include human rights, working conditions, health and safety, cultural heritage, governance, socio-economic repercussions. Hosseinijou et al. (2013) argued: 'Since no development can be stable at the long run without social justice, social life cycle assessment (S-LCA) has also to be developed and considered. [...] There is a need to assess social impacts of materials along the full life cycle, not only to be able to address the "social dimension" in sustainable material selection but also for potentially improving the circumstances of affected stakeholders'. Oladazimi et al. (2021) also observed how, despite social aspects being highlighted by several studies, the majority of them are not in the building industry.

Conversely, several authors have discussed the role of recent advances in information and communication technologies, including machine learning, in enhancing the consideration of social aspects in LCA (Anand and Amor 2017; Negishi et al. 2018; Fnais et al. 2022; Ghoroghi et al. 2022). Machine learning has the potential to enhance occupants' experience in buildings as well as their overall comfort through optimal configuration of the indoor environment (Fnais et al. 2022; Ghoroghi et al. 2022). However, there is a recognition that S-LCA in the construction sector is in its infancy (Fnais et al. 2022). While acknowledging that social aspects are considered as part of LCSA, this paper is aimed at establishing an inventory of S-LCA use in the construction sector, with a view to identify research gaps and formulate recommendations for future work, which may in turn inform future evolutions of LCSA. The paper is structured into seven sections. Following this introduction, Section 2 summarises the methodology that underpins the study. Section 3 describes S-LCA methodologies and frameworks across a wide range of domains, while Section 4 focusses the analysis on the construction sector. Section 5 presents the identified gaps in the S-LCA research landscape, followed by (Section 6) recommendations for future research. Lastly, Section 7 summarises and concludes the paper.

2 Methodology

The paper sets out to answer the following questions with a focus on the building and infrastructure sectors:

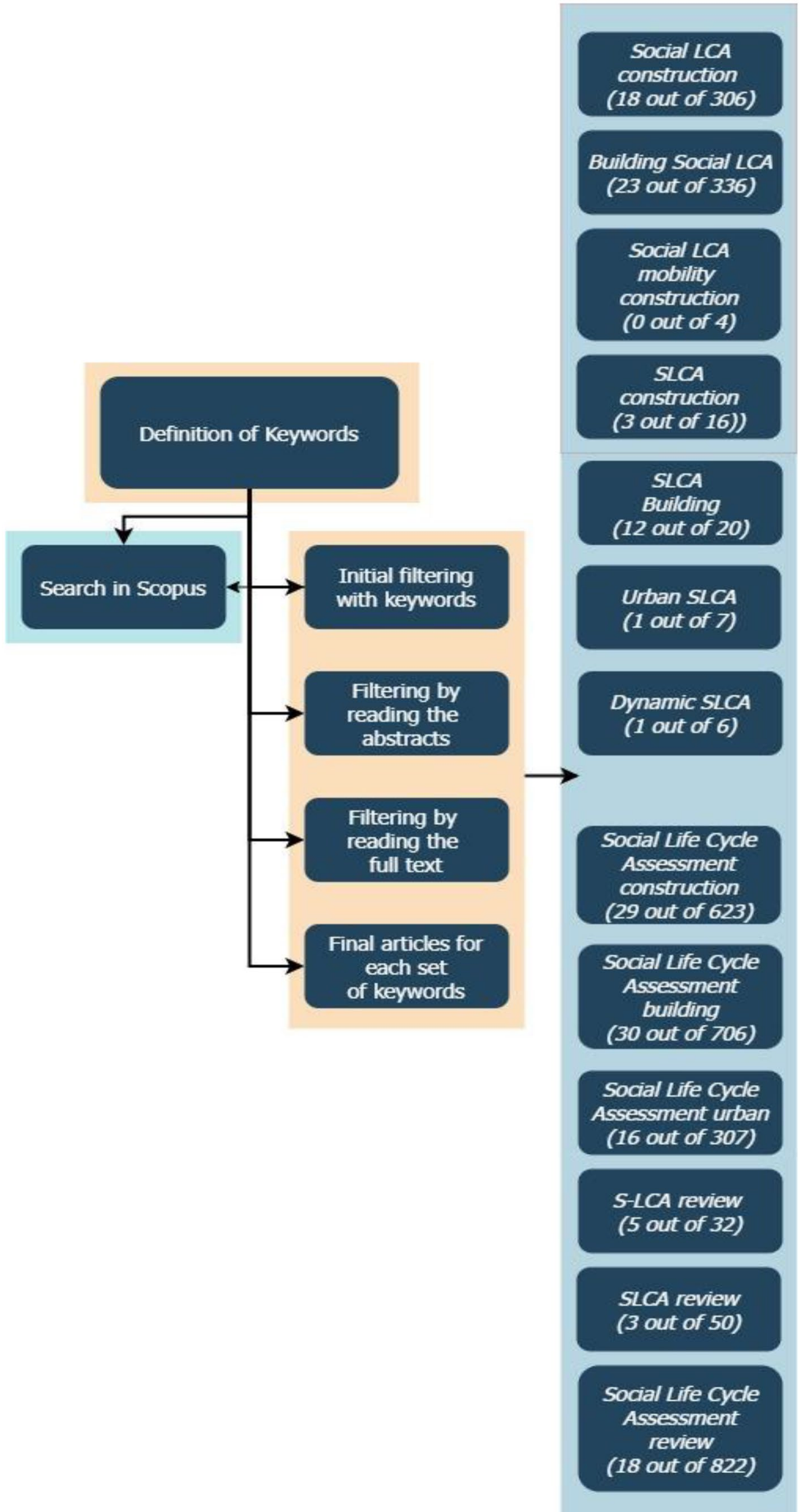
RQ1: What is the state of art of S-LCA, in the construction sector, including related frameworks and methodologies?
RQ2: What are current gaps in S-LCA, in the construction sector?
RQ3: What are proposed directions for future research in S-LCA applied to the construction sector?

The methodology used to address the above research questions involves the following phases and is illustrated in Fig. 1.

2.1 Planning phase

In this phase, scope, literature research questions, and databases were determined. Scopus was chosen for the search

Fig. 1 Visualisation of the filtering process of the results of the literature, via the use of keywords. The first number represents the final number of papers that were used, while the second number represents the total number of papers initially found in the search database. The review examined studies from 2013 to 2023 and focussed on those which were written in English



database. The publication years of studies were determined to be between the years 2013 and 2023.

2.2 Search phase

In this phase, the search process was developed to select appropriate studies. The keywords to conduct the search were informed from the above formulated research questions. Similar or interchangeable keywords were identified and connected using Boolean OR and AND operators. Table 1 lists the search keywords used.

2.3 Filtering phase

The filtering phase aims to identify authoritative (peer-reviewed) relevant sources that contribute to the understanding of SLCA and support the development of our posited research questions. As such, the filtering phase serves several purposes, including the following:

1. Identification of relevant literature: The primary purpose of the paper filtering phase is to identify relevant SLCA scholarly articles, books, reports, and other sources that are directly related to our posited research questions, thus focussing on the most pertinent literature and excluding irrelevant or tangential sources.
2. Quality control: Assess the quality and credibility of potential sources, by relying on criteria such as peer-reviewed journals, reputable publishers, to ensure that the selected literature meets certain standards of academic rigor and reliability.
3. Reduction of information overload: Manage information overload by narrowing down the pool of potential sources to those that are most likely to be useful and informative for the SLCA review.
4. Exclusion of duplicate or redundant sources: Identify and eliminate duplicate or redundant sources to avoid unnecessary repetition and ensure that each selected source contributes unique insights or perspectives to the SLCA literature review.
5. Inclusion of diverse perspectives: Ensure that the selected literature represents a diverse range of perspectives, methodologies, and theoretical frameworks. This helps avoid bias and ensures that the literature review reflects the breadth and depth of scholarship on the topic of SLCA applied to the construction industry.

Table 1 Keywords used to filter results

No.	Keywords
1	Social LCA construction
2	SLCA Construction
3	SLCA Building
4	Social LCA Mobility Construction
5	Dynamic SLCA
6	Urban SLCA
7	Social Life Cycle Assessment Urban
8	Social Life Cycle Assessment Building
9	Social Life Cycle Assessment Construction
10	Social Life Cycle Assessment Review
11	SLCA Review
12	S-LCA Review

2.4 Evaluation phase

The evaluation stage assesses the relevance, quality, and significance of the selected papers during the previous filtering stage and synthesise insights that contribute to the advancement of knowledge within SLCA applied to the construction industry. As such, the evaluation stage involved the following:

1. Assessing relevance: Each selected paper is evaluated to determine its re to SLCA and the posited research questions.
2. Critically analysing content: The content of each paper is analysed to identify strengths, weaknesses, limitations, and areas for further investigation.
3. Synthesising insights: Insights from the evaluated papers are synthesised to identify common themes, patterns, trends, contradictions, or gaps in the literature.
4. Contextualising findings: The context in which each paper was written is considered, including the historical, cultural, social, and political factors that may have influenced the research.
5. Forming conclusions: Based on the evaluation of the selected papers, conclusions are formed about the state of knowledge in SLCA applied to the construction industry, the strengths and weaknesses of existing research, and the gaps or unanswered questions that warrant further investigation.

Finally, a decision is made regarding the inclusion of the paper in a full review for this paper. Some papers may have been included for context or interest despite a lack of methodology. Overall, thirty-six journal papers were filtered out and analysed, concerning Social Life Cycle Assessment in the construction sector. In Table 2, the use or not use of the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) guidelines and the type of these papers is presented. This study builds on Backes and Traverso (2023) work, by examining the current

Table 2 Categorisation for studies of S-LCA in the construction industry: frameworks and methodologies

Names of authors	Case study	Model or framework proposal	Assessment process	Literature review	Methodology and frameworks used (direct quotes from the respective papers)	UNEP/SETAP guidelines
Larsen et al. (2022)				x	• Literature review, following four main steps: review of scientific literature, transparent method, replicability and updatability, and summary and synthesise main subjects in the research	x
Zheng et al. (2020)	x	x			• Proposal of S-LCA framework for pavement with four phases • Case study	x
Balasbaneh and Sher (2021)	x				• LCA • LCC and social survey • Analytic hierarchy process (AHP) • Multicriteria decision-making (MCDM: TOPSIS)	x
Aung et al. (2021)	x				• Literature review, following seven steps	x
Martínez-Blanco et al. (2015)		x			• Development of a conceptual framework for SOLCA	x
Toboso-Chavero et al. (2021)	x				• LCA • SLCA	x
García-Sánchez and Güereca (2019)	x				• LCA methodology, according to ISO 14040 • Followed the four phases of ISO 14040/44	x
Dong and Ng (2015)	x	x			• Development of SMoC (Social-impact Model of Construction), in three stages • A case study was applied, following the four-phase structure of S-LCA	x
Dong and Ng (2016)	x	x			• LCSA framework development • EMoC, CMoC, and SMoC	
Backes and Traverso (2021)				x	• Systematic literature review • Quantitative–qualitative content analysis	
Bezama et al. (2021)	x				• REgional SPecific cONtextualised Social life cycle Assessment (RESPONSA) • Combination of two life cycle methods	
Safarpour et al. (2022)	x	x			• LCSA • LCC • AHP method	x
Barrio et al. (2021)			x		• Comparative LCA and LCC • Qualitative social life cycle assessment • LCSA conducted by combining LCA, LCC, S-LCA • LCA framework consisting of four steps	x
Zheng et al. (2020)	x	x			• A four-step structure • S-LCA • A combined AHP and VIKOR model • Sensitivity analysis	

Table 2 (continued)

Names of authors	Case study	Model or framework proposal	Assessment process	Literature review	Methodology and frameworks used (direct quotes from the respective papers)	UNEP/SETAP guidelines
Jayawardana et al. (2022)		x		x	• Four stages • Development of conceptual framework based on stages of the ISO 14040	
Dinh et al. (2020)	x				• Development of a list of sustainability criteria • The list was sent to architects and designers for analysis • The importance weightings of Life Cycle Sustainability Assessment, using the Likert scale and the AHP method	
Balasbaneh and Marsono (2020)	x				• Four stages • LCA • LCCA • SLCA • MCDM approach • AHP method • Paper questionnaire following the UNEP/SETAC guidelines	x
Vitorio Junior and Kripka (2020)	x				• Two main phases • SLCA	x
Kono et al. (2018)	x				• Hotspot analysis and impact assessments by SLCA and LCA • PSILCA Product Social Impact Life Cycle Assessment database	
Santos et al. (2019)	x	x			• Model is based on UNEP/SETAC • Open participatory approach	x
Balasbaneh et al. (2021)	x				• LCA • LCC • S-LCA • MCDA approach	
Balasbaneh et al. (2018)	x				• Literature review • Pairwise comparisons among different social criteria have been made with interviews following UNEP/SETAC guideline	x
Ostermeyer et al. (2013)	x				• Multidimensional Pareto optimisation methodology • LCC, LCA combined with first stages of a social assessment	
Oladazimi et al. (2021)	x				• LCA • LCC • SLCA • LCA following ISO 14040 and ISO 14044 • S-LCA based on UNEP/SETAC	x
Hu et al. (2013)	x				• Five operational steps for LCSA framework • SLCA	x
Gulcimen et al. (2022)	x				• Framework following standards ISO 14040:14,044 on LCA • Analysis of each phase of the LCSA study, via LCA, LCC, and S-LCA	x

Table 2 (continued)

Names of authors	Case study	Model or framework proposal	Assessment process	Literature review	Methodology and frameworks used (direct quotes from the respective papers)	UNEP/SETAP guidelines
Hosseinijou et al. (2013)	x	x			• UNEP/SETAC 'guidelines for social life-cycle assessment of products'—four main phases • Comparative assessment • Analytic hierarchy process • For hotspot analysis • Impact assessment	x
Amini Toosi et al. (2022)	x	x			• LCSA model • LCA • LCC • SLCA • Model is enhanced with machine learning (ML) methods	
Fauzi et al. (2022)	x				• S-LCA followed the procedures of ISO 14040, 14,044 and UNEP guidelines • Multilevel analysis	x
Hossain et al. (2017)	x	x			• Twofold research approach - Expert interviews - Indicators based on the case-specific survey • Method following United Nations Programme Environment Society of Environmental Toxicology and Chemistry guidelines published in 2009 and the methodological sheets published in 2013 and guidelines provided by the Global Reporting Initiatives and ISO 26000	x
Backes and Traverso (2023)				x	• Literature review • SHDB	
Liu and Qian (2019)	x	x			• Framework for SLCA of buildings through stakeholder-based approach • The method was applied to a case study	
Ferrari et al. (2019)		x			• Definition of a set of environmental, economic, and social performance indicators • SHDB	
Janjua et al. (2019)				• x	• Literature review of 807 articles, from 2009 to 2019 • The following databases were used: Scopus, Web of Science, ScienceDirect and Compendex, with keywords use	
Larsen et al. (2022)		x			• Combination of life cycle thinking methodologies with evidence-based decision-making and design process • Based on a previous literature review of the same authors (Larsen et al. 2022)	
Amini Toosi et al. (2020)				x	• Literature review, following EN standards and guidelines	

state of S-LCA in the construction sector, generally, and uses a similar template in the categorisation of the material, as seen in Table 2. The focus is on frameworks and methodologies. Out of these selected papers, seven were literature reviews, twenty-six were focussing on case studies, thirteen are proposing new frameworks and models, and one study focussed on an assessment process solely.

3 Overview of Social LCA frameworks and methodologies

The United Nations Environment Programme differentiates environmental from social LCA. Environmental Life Cycle Assessment (E-LCA) is defined as 'a methodology for assessing environmental impacts associated with all the stages of the life cycle of a product, service or organisation' (United Nations Environment Programme 2020). Three decades ago, it was already recognised that social impacts are as significant as environmental impacts (McCabe and Halog 2018). Despite the efforts to include social aspects in ELCA, it was deemed inefficient, and therefore, the development of Guidelines for Social Life Cycle Assessment (S-LCA) was critical to address social aspects (Zheng et al. 2020).

In S-LCA, there are two main approaches and ways to assess impact, which are known as Type I and Type II (Huarachi et al. 2020). S-LCA involves impact categories (human rights, working conditions, health and safety, cultural heritage, governance, and socioeconomic repercussions) and subcategories, as well as stakeholder categories (workers, local community, value chain actors, consumers, society, and children), as highlighted by the official guidelines by the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC), in 2009, and revised in 2020 (United Nations Environment Programme 2020). As Vitorio Junior and Kripka (2020) argued, 'stakeholder categories are groups that have shared interests due to a similar relationship with the investigated product systems', while impact categories and subcategories are defined as 'those that may directly affect stakeholders positively or negatively during the life cycle of a product' (United Nations Environment Programme 2020).

In the landscape of S-LCA globally and throughout the years, a study conducted a thorough review of the literature classified the research into four main categories: the first steps towards Social Life Cycle Assessment (1996–2009), the uncertainty years (2009–2012), the development years (2013–2016), and the search for standardisation (2017–onward) (Huarachi et al. 2020). This study presented a thorough and methodical review of S-LCA, presenting a retrospective overview of frameworks used since its initial stages. The authors organised these into two sets. Four main studies were selected in the first set. First (Huarachi et al. 2020), it was analysed how Norris used a methodology which was named "life cycle attribute assessment" and looked at how health was affected. Secondly, a study by Weidema, which used the Quality Adjusted Life Years (QALY) to measure social impacts, was documented. Next, a study by Hunkeler, who employed what was called Societal LCA, and a study by Dreyer et al., which employed a methodology akin to the UNEP/SETAC guidelines, were presented.

From 2011 onward (Huarachi et al. 2020) another set of frameworks were presented, including fifteen studies. According to the categorisation (Huarachi et al. 2020), Reitinger et al. used a capabilities method, while Bauman et al. based their approach on the DALY (Disability-Adjusted Life Years). Smith and Barling looked into the workers stakeholder category specifically, while Weldegiorgis and Franks employed S-LCA in combination with technological assessment. Martinez-Blanco et al., were documented to create the Social Organisational Life Cycle Assessment (SOLCA), whereas Tsalis et al., looked into indicators related to social aspects. Peruzzini et al., focused on Areas of Interests, while Van Haaster et al., looked into Safety, security, tranquillity, Equality, Participation and influence). Wangel used the so-called Nussbaum capabilities method which focused on the necessity of products. Hossain et al, calculated social sustainability through the SSG (Social Sustainability Grading) model. Zimdars et al. used a framework which focused on three variables to assess social impact value. Fan et al. developed an evaluation system which integrated the AHP method. Souza et al. combined S-LCA and Input-Output Analysis approach, while Fontes et al. based their approach on S-LCA and developed the so-called Product Social Impact Assessment. The last study presented, by Fortier et al. used S-LCA as a means to assess energy justice.

Larsen et al. (2022) argued how S-LCA is still not well defined in scientific literature. It is significant to remember that the main aim for S-LCA, according to the official UNEP/SETAC guideline, is 'to promote improvement of social conditions and of the overall socio-economic performance of a product throughout its life cycle for all its stakeholders' (Balasbaneh et al. 2018).

There is room for improvement towards the development of a concrete framework of action (Larsen et al. 2022). One challenge that S-LCA faces in comparison to the E-LCA is the difficulty of quantifying social data (Huarachi et al. 2020). There is a difference between E-LCA and S-LCA in that the latter does not follow the ISO standardisation that E-LCA follows (Liu and Qian 2019). In fact, it has been argued that S-LCA is lacking any standardisation, as a method (Hossain et al. 2017). The first standard for S-LCA was EN12643-3 (Balasbaneh et al. 2018). However, as Zheng et al. (2020) sustained: 'In E-LCA, the environmental impacts are assessed through a causal link to each process during the life cycle, where the exchange with the environment is measured, such as energy consumption and greenhouse gas emissions. Regarding S-LCA, the social impacts are not related to processes themselves, but associated with the stakeholders' interventions from the organisation and companies involved in the life cycle of product (Dreyer et al. 2006, 2010)'. Also, S-LCA usually limits its scope in examining single stages or parts of the life cycle, due to the methodology being overall not yet properly formulated (Zheng et al. 2020).

Furthermore, it has been reported that the S-LCA case studies that have been conducted so far do successfully evaluate the social performance of products (Martínez-Blanco et al. 2015). Also, it is usually during the use stage that social impacts are not studied in depth (Zheng et al. 2020).

4 S-LCA in the construction sector: methodologies and frameworks

The construction sector is currently under a lot of pressure, as it needs to align itself with the urgency of climate change and offer sustainable and effective solutions. The EU has made recommendations to use Life Cycle Assessments in the construction industry (Zheng et al. 2020). This section focusses on the construction sector and provides an in-depth account of S-LCA frameworks and methodologies used to date, organised by category, as illustrated in Table 2. Table 3 is a comparative table which presents previous literature reviews in the construction sector, their focus, and scope. The study also details the associated impact subcategories, organised by stakeholders, as illustrated in Figs. 2 and 3, found in the Appendix.

A study has used a methodology of comparing socioeconomic impacts linked to various stages in the production stage of life cycles, in order to address the impact assessment relations in S-LCA (Hossain et al. 2017). Backes and Traverso (2021) argue: 'The LEED certificate has a strong focus on ecological aspects; nevertheless, the LCA is not required to obtain certification […] It is, therefore, up to the user to decide whether to carry out an LCA for their project. The LCC and S-LCA are not considered any further'. It has been argued that social sustainability is of significance, so as to secure healthy and safe environments and that the conditions attached to social circumstances present a dynamic nature (Zheng et al. 2020). Also, LCA has been criticised as being too static, because as Larsen et al. (2022) argued, 'the results of the LCA are snapshots rather than trends'.

There is an increasing demand for S-LCA modelling approaches that can be initiated during the early-design stage and which can factor in uncertainty, including dealing with incomplete, unreliable, and unascertained data and information (Fnais et al. 2022). Conversely, there is a requirement to maintain adequate indoor air quality and occupants' comfort while reducing energy demand and prioritising clean energy consumption. As such, machine learning techniques, including model predictive control and optimisation algorithms, can be used to deliver actionable knowledge to inform various control strategies and corrective actions with a view to delivering socially acceptable built environment interventions. Machine learning models may be more easily integrated than other black box methods as more easily interpreted by users (Ghoroghi et al. 2022). However, the time and cost overheads for establishing machine-learning models should be considered for real-time use. The use of S-LCA has the potential to assist facility managers to enhance the experience of occupants in built environments, while having access to actionable knowledge to inform various control strategies and corrective measures to reduce the gap between predicted and actual social and environmental impacts.

The UNEP/SETAC Life Cycle Initiative provides a useful blueprint to deliver S-LCA as corroborated by the reviewed literature (Santos et al. 2019). This was used across different contexts and applications. However, in 2018, overall, the percentages were still low, as only 8% followed these guidelines (Larsen et al. 2022). Table 2 highlights the studies that have used the guidelines as part of their methodology. Overall, twenty-one have been identified, which have used the guidelines in various manners, which is more than half of the studies.

Larsen et al. (2022) used the guidelines in order to filter out the results for their literature review and identify the appropriate material for the study. Amini Toosi et al. (2020) relied on the

Table 3 Categorisation for studies on S-LCA in the construction industry: literature reviews

Authors	Scope and focus
Amini Toosi et al. (2020)	• LCSA applied to building retrofitting • S-LCA as part of the analysis, as one of the four categories along with LCA, LCC, and a multidimensional analysis
Backes and Traverso (2021)	• LCSA applied to sustainability assessment • S-LCA analysed alongside LCA, S-LCA, LCC
Jayawardana et al. (2022)	• LCSA applied to modular construction and introduction of a dedicated conceptual framework • S-LCA as one of the categories of analysis
Larsen et al. (2022)	• Integration of LCA, LCC and S-LCA into LCSA in the construction sector • Thirteen studies selected on LCSA and eight studies on S-LCA
Backes and Traverso (2023)	• S-LCA applied to concrete and carbon fibres • Detailed analysis of twelve selected studies

terms in the EN standards and guidelines, in order to conduct their review. Similarly, Balasbaneh et al. (2018) used the guidelines to conduct interviews, in order to assess social criteria. Dong and Ng (2015) proposed a S-LCA model for building construction in Hong Kong. The model is the SMoC (Social-impact Model of Construction). The methodology consisted of three stages and included the use of characterisation, normalisation and weighting, a questionnaire survey, and also, a use of a case study and the UNEP/SETAC guidelines. Zheng et al. (2020) proposed a S-LCA framework for evaluating social impacts of pavement, which integrated the UNEP/SETAP suggestions, while four stakeholders, twelve subcategories, and sixteen social indicators were used for the life cycle stages that were examined. The same approach was used by Hu et al. (2013) as part of their LCSA approach, where the UNEP/SETAP guidelines were used to identify indicators. Balasbaneh et al. (2018) used the UNEP/SETAC guidelines for conducting interviews as part of determining social criteria for the methodology. Gulcimen et al. (2022) included the guidelines for the S-LCA as part of the LCSA framework and proceeded with an online survey. The results were quantified, and a scoring system assessed quantitative and semi-quantitative social indicators. Fauzi et al. (2022) focussed on multilevel story buildings and applied the guidelines with the following four steps: goal and scope definition, data inventory, impact assessment, and interpretation. Multilevel analysis was also applied, which assisted in filling data gaps on indicators and filling data gaps on the product system's life cycle. Hossain et al. (2017) used S-LCA in order to assess social sustainability for recycled construction materials in Hong Kong. Their research design included expert interview, a survey, while the method is based on the UNEP/SETAP guidelines. Studies have also combined other approaches with the framework of the guidelines. Santos et al. (2019) combined them with an open participatory approach and a collaborative model, where stakeholders' groups played a key role. Oladazimi et al. (2021), for their case study and the evaluation of two construction frames (stell and concrete), applied S-LCA based on the guidelines. There are steps which certain studies have proposed. For example, Aung et al. (2021) followed the following steps to assess impacts: goal and scope definition, identification of stakeholder categories, identification of impact categories and subcategories, selection of a panel of experts for weighting of indicators, Social Life Cycle Inventory (LCI) data collection, questionnaire survey, and interviews, Social Life Cycle Impact Assessment (S-LCIA), and interpretation of results and conclusions (Aung et al. 2021). Other studies focus their approach and steps on stakeholders (Liu and Qian 2019). Hosseinijou et al. (2013) based their method for their study of materials on the guidelines and included their four main phases. Lastly, a study which focussed on Life Cycle Sustainability Assessment (LCSA) by conducting a comparative LCA and LCC of novel bio-based multilayer panel included as part of its methodology S-LCA, which aligned with the guidelines for defining impact indicators (Barrio et al. 2021).

On this note, with regard to the Life Cycle Sustainability Assessment framework, various researchers have been using it as part of their approach. LCSA includes LCA, LCC, and S-LCA and follows a methodology proposed by Klopffer: LCSA = LCA + LCC + S-LCA (Ferrari et al. 2019). As argued by Barrio et al., LCA + LCC + S-LCA follow the Life Cycle Assessment framework as it is described in the ISO 14040 and ISO 14044 standards (Barrio et al. 2021). Backes and Traverso (2021) conducted a systematic literature review by using qualitative and quantitative analysis methods, and S-LCA was found to mainly focus on the production. However, even for this model, more research of S-LCA is required (Dong and Ng 2016).

In fact, S-LCA is deemed necessary in LCSA for the built environment (Barrio et al. 2021). The idea of the integration of all three methodologies aims at balancing the environmental, social, economic aspects of sustainability and assessing of costs and value creation. Amini Toosi et al. (2020) included S-LCA in their study around LCSA for their assessment in building energy retrofitting. Dong and Ng (2016) created a framework based on LCSA by employing three life cycle models, the environmental model of construction (EMoC), cost model of construction (CMoC), and social-impact model of construction (SMoC). The goal was to evaluate sustainability of building construction, with satisfactory results which, however, pointed towards the need for significant refinement of LCSA as a framework.

Similarly, Safarpour et al. (2022) proposed an LCSA framework for assessing the sustainability of urban water and wastewater infrastructure. S-LCA was conducted by using the AHP method, and the UNEP/SETAC guidelines were taken into consideration. In the context of developing a framework for pavement LCSA, Zheng et al. (2020) also proposed a framework. To assess the positive and negative social impacts, S-LCA was employed, based on the UNEP/SETAC guidelines. Eventually, and through the application to the case study, a combined AHP–VIKOR method was employed to unify the three sustainability dimensions and, lastly, a sensitivity analysis using twenty-one case studies. Furthermore, Jayawardana et al. (2022) proposed a conceptual framework for LCSA via conducting a literature review for the assessment for modular construction, where S-LCA was part of the equation. In another recent review using LCSA approach, S-LCA was deemed to still be an emerging tool which 'needs a methodological breakthrough to be applied in the building industry' (Janjua et al. 2019). As Janjua et al. (2019) observed: 'There is not a single agreed approach to the selection of impact indicators, with UNEP/SETAC guidelines suggesting a top-down method for social LCI and some other studies suggesting a participatory approach to indicator selection. Stakeholder selection for S-LCA depends on the research objectives, stakeholder behaviour, and confidentiality agreements signed with the company' (Janjua et al. 2019). A study which proposed a new LCSA-machine learning-based optimisation model, targeting the design process of buildings and refurbishment scenarios, and which used S-LCA to identify indicators based on the case studies concluded that S-LCA presented a difficulty with regard to input data collection (Amini Toosi et al. 2020). Lastly, García-Sánchez and Güereca (2019) implemented the guidelines to assess the environmental and social impacts of sustainability in urban water systems, by following the ISO 14040/44 standard.

There have been studies, conducted in the construction sector, which touch on the economic implications of using S-LCA as a methodology (Vitorio Junior and Kripka 2020). Larsen et al. (2022) conducted a literature review with the intent of examining the role of S-LCA in LCSA. They argue that, when it comes to providing a model for circular economy, S-LCA in the built environment could be a particularly useful tool, specifically dealing with the use phase and the reuse/recycle phase (Larsen et al. 2022). However, its current state is not yet mature. Bezama et al. (2021), within the context of examining socioeconomic evaluations of value chains, used a combination of the 'Regional Specific contextualised Social Life Cycle Assessment (RESPONSA)' with LCA. They concluded that the results evidence that this collaboration of methods offers positive results, when it comes the use of indicators which are related to impacts of bio-based technologies. A study by which evaluated the S-LCA of various timber composite structure from timber house, by examining the stakeholder, looked into how it affected the economic development with regard to jobs and wages (Balasbaneh et al. 2018) The results showed a positive correlation between the two. In the context of studying fair wage potential within the construction sector and, more specifically, the building sector, in a study by Vitorio Junior and Kripka (2020), S-LCA was performed to evaluate the social aspect of the study. Case studies were used and the UNEP/SETAC guidelines were used to identify stakeholder categories and impact subcategories and focussed on the worker and on the fair salary. A study by Ferrari et al. (2019) which looked into construction materials, and more specifically ceramic tiles, used the LCSA framework. Another study, which examined LCSA in the construction material selection in Vietnam, included S-LCA to assess social criteria (Dinh et al. 2020). For that, a list of sustainability criteria was created and analysed. One more study, which applied hotspot analysis and impact assessment for its LCA and S-LCA, looked into six different countries and the PSILCA Product Social Impact Life Cycle Assessment database (PSILCA), making it one more study which made use of the UNEP/SETAC guidelines for their methodology (Kono et al. 2018). Lastly, Toboso-Chavero et al. (2021) also used the Social Hotspots Database to conduct S-LCA, on an urban level.

In the attempt to improve the S-LCA methodology, and depending on the scope, aims, and context of the study, several improvements/additions have been proposed. S-LCA has been also used as part of the MCDM (multicriteria decision-making), as one of the three pillars (LCA, LCCA, and S-LCA) to assess the sustainability performance of different flooring systems (Balasbaneh and Marsono 2020). Lastly, the most recent literature review conducted about S-LCA in the construction industry by provided an overview of the state of art and then focussed on carbon-reinforced concrete. It also used analysis for the Social Hotspot Database (SHDB) to identify the importance of CRC (carbon reinforced concrete) for each social category. In a study by Ferrari et al. (2019), S-LCA was conducted by consulting the Social Hotspots Database (SHDB) for the sustainability assessment. Furthermore, Backes and Traverso (2023) used SHDB for conducting their literature review. Oladazimi et al. (2021) proposed a multidimensional Pareto optimisation framework, which included only the first stages of S-LCA, for the sustainability choice of different materials (timber). Martínez-Blanco et al. (2015) proposed a framework for Social Organisational LCA (SOLCA), in a three-step methodology, where the guidelines for S-LCA and for OLCA (organisational LCA) were used. Another study proposed a framework which integrates participatory system thinking techniques (McCabe and Halog 2018). As mentioned previously, the AHP (Analytic Hierarchy Process) method has also been used by some studies, in order to determine weights (Zheng et al. 2020) and social indicators. A study implemented the combined analytic hierarchy process (AHP)–complex proportional assessment (COPRAS) technique (Balasbaneh and Marsono 2020). Furthermore, a study by Balasbaneh et al. (2021) used questionnaires as part of the AHP method. Safarpour et al. (2022) applied S-LCA by using the Analytic Hierarchy Process (AHP), where three main stakeholders were considered. Hosseinijou et al. (2013) also used AHP for their case study assessment, as well as a hotspot analysis for the analysis of the data that were gathered. Dinh et al. (2020) used AHP to assess weightings of LCSA. Lastly, AHP was also adopted by Balasbaneh and Sher (2021), by also using the UNEP/SETAC guidelines, for assessing different types of concrete buildings.

5 Gaps in Social LCA

SLCA is important in the construction industry due to a wide range of reasons, including its reliance on materials for the green transition, such as rare earth, which involve unethical work practices, such as child labour, as sourced from third countries. As such, while SLCA can provide valuable insights into the social aspects of construction projects, it also involves several challenges and limitations (Zheng et al. 2020; Balasbaneh and Sher 2021; Safarpour et al. 2022; Backes and Traverso 2023), including the following:

1. Subjectivity and stakeholder involvement: SLCA tends to be based qualitative and often subjective assessments as well as stakeholder involvement to define relevant social aspects, indicators, and impact assessment methods (McCabe and Halog 2018). This can sometimes lead into biases and inconsistencies in the assessment process, especially

when stakeholders have conflicting interests or priorities as is the case with the imperative to decarbonise our buildings and the reliance on renewables with constituent materials sourced from third countries without legislation protecting worker rights and thus engaging into exploitative practices, including imposing excessive work hours, or engaging in child labour or forced labour.
2. Data availability and quality: Gathering comprehensive and reliable data for SLCA in the construction sector can be a challenging task as social impacts tend often to be qualitative and context-dependent, rendering benchmarking across projects difficult (Grubert 2018). Limited data availability may lead to inaccurate or incomplete assessments, which can affect the accuracy and credibility of the results (Fnais et al. 2022).
3. Scope and boundaries: Defining the scope and boundaries of SLCA in the construction sector can be complex due to the interconnected nature of social impacts with environmental and economic factors (Subramanian et al. 2018). Determining which social issues to include such as labour rights may vary depending on the project context and value chain key priorities (Subramanian et al. 2018).
4. Time and resource intensiveness: Delivering a comprehensive SLCA for construction projects is often a complex and time-consuming process (Grubert 2018). It requires interaction with the entire value chain through surveys or interviews and making sense of the resulting qualitative data. This is often overlooked on projects as considered not a priority by clients. Consequently, SLCA may result in various limitations, such as missing on important social impacts (Kühnen and Hahn 2019).
5. Lack of standardisation and consistency: SLCA lacks a standardised and widely accepted framework and agreed procedures on impact assessment methods, which makes it difficult to benchmark results or ensure consistency across construction projects (Costa et al. 2019).
6. Interpretation and communication of results: Interpreting and communicating SLCA outcomes in a meaningful and actionable way, given their qualitative nature, can be difficult. Social impacts are often multifaceted and context-dependent, hindering their effective interpretation and communication to stakeholders (Parent et al. 2013).

The literature on frameworks and methodologies for S-LCA applied to the construction points to a lack of systematic and concrete methodologies. Several limitations have been identified, corroborated by the recent literature (Backes and Traverso 2023), including the following:

- Lack of a formal method to quantitatively social indicators and relate them to the functional unit of the system
- Lack of structured approach on how to obtain specific regionalised data
- Lack of guidelines and support to decide among the large set of indicators
- Lack of benchmark at sector level as well as the associated reference values
- Lack of rigorous approach to properly evaluate the S-LCA results

Furthermore, there are some fundamental gaps, which need addressing to create a common blueprint of action. To begin with, several studies have pointed out that S-LCA lacks clear definitions (Larsen et al. 2022). Also, in terms of methodology, there is no basis for S-LCA and that constitutes a significant gap to be addressed in the construction sector (Larsen et al. 2022). Furthermore, Larsen et al. (2022) argued that, when it comes to circular economy, the social aspects need to be explored and that entails the appropriate use of evaluation tools and stakeholders.

Concerning data, it has been observed how dealing with different types of data proves to be a difficult task in S-LCA (Dong and Ng 2015). Backes and Traverso (2023) argue that 'Especially for the S-LCA, mainly the production phase has been considered so far, though the use phase and the service lifetime are of great importance in the building sector. A more intense focus might be of relevance for the building sector'. Backes and Traverso conducted, to the best of the authors' knowledge, the latest review on S-LCA in the construction sector, with a focus on CRC-concrete and carbon fibres (Backes and Traverso 2023). One observation that emerges from their analysis is that the construction sector 'represents a highly intertwined input–output system, making material flows difficult to determine'. They highlighted the complexity of the stakeholder dynamics in the sector and argued that it constitutes a barrier for S-LCA adoption (Backes and Traverso 2023). With regard to impact subcategories, Backes and Traverso (2023) identified gaps of indicators in the subcategories of labour rights, health, and safety, when it comes to carbon reinforced concrete. Vitorio Junior and Kripka (2020) also highlighted a gap regarding the wage of workers.

We have hereafter filtered out the results and identified the studies which explicitly discuss the use of impact subcategories in the construction sector. This resulted in a categorisation of the subcategories and eventually gives an overview of which ones have mostly been used, as well as which ones have been barely addressed. Figures 2 and 3 provide a detailed analysis of all the studies and subcategories, organised by stakeholder categories. These are colour-coded for readability, and, also, in red are the impact subcategories which are new and introduced by the studies. More specifically:

- The blue colour signifies the 'worker' stakeholder category.
- The dark orange colour signifies the 'local community' stakeholder category.

- The deep yellow colour signifies the 'value chain' stakeholder category.
- The green colour signifies the 'consumer' stakeholder category.
- The grey colour signifies the 'society' stakeholder category.
- The pink colour signifies the 'children' stakeholder category.

Overall, 172 categories have been explored, across the span of all the studies, which have been presented in Figs. 2 and 3. For reference, the numbers represent the studies as presented in Table 4.

The detailed analysis is presented in Fig. 2 and 3, in the Appendix. It was observed that the most frequently used (over ten studies) subcategories were the following:

1. Fair salary (worker)
2. Health and safety (worker)
3. Safe and healthy living conditions (local community)
4. Technology development (society)

Then, the analysis showed that several categories were used by less than ten studies; however, were still used by several studies (up to nine). These are the following:

1. Freedom of association and collective bargaining (worker)
2. Child labour (worker)
3. Working hours (worker)
4. Forced labour (worker)
5. Equal opportunities/discrimination (worker)
6. Access to material resources (local community)
7. Access to immaterial resources (local community)
8. Safe and healthy living conditions (local community)
9. Community engagement (local community)
10. Local employment (local community)
11. Health and safety (children)
12. Public commitments to sustainability issues (society)
13. Contribution to economic development (society)
14. Corruption (society)

Lastly, the subcategories which present notable gaps (zero studies) are the following:

1. Sexual harassment (worker)
2. Smallholders including farmers (worker)
3. Ethical treatment of animals (society)
4. Poverty alleviation (society)
5. Education provided in the local community (children)
6. Health issues for children as consumers (children)
7. Children concerns regarding marketing practices (children)

Overall, indicators present gaps which need to be addressed. There seems to be an incoherence and lack of consistency between LCA and S-LCA indicators, which adds to the confusion and creates difficulties for solidifying impacts categories (Backes and Traverso 2021). Also, quantification of S-LCA indicators is not currently properly developed (Dong and Ng 2016). There is a challenge in identifying and quantifying social criteria and indicators (Backes and Traverso 2021). However, Gurmu et al. (2022) pointed towards Social Sustainability Performance Indicators (SSPI), as a way to quantify social impacts, taking into consideration context and policies. It is important that this quantification uses indicators which address the entire life cycle (Hossain et al. 2017). One limitation with regard to indicators is that impact categories are mostly site specific, and it is suggested that S-LCA in the building sector become more holistic, to provide a better overview for decision-makers (Larsen et al. 2022).

Table 4 Studies which are presented in Figs. 2 and 3—numbers represent each study in the two figures

1	Zheng et al. (2020)
2	Dong and Ng (2015)
3	Bezama et al. (2021)
4	Zheng et al. (2020)
5	Vitorio Junior and Kripka (2020)
6	Oladazimi et al. (2021)
7	Hossain et al. (2017)
8	Liu and Qian (2019)
9	Ferrari et al. (2019)
10	Gulcimen et al. (2022)
11	García-Sánchez and Güereca (2019)
12	Toboso-Chavero et al. (2021)
13	Safarpour et al. (2022)
14	Santos et al. (2019)
15	Balasbaneh and Sher (2021)
16	Balasbaneh et al. (2021)
17	Balasbaneh and Marsono (2020)
18	Zheng et al. (2020)
19	Hosseinijou et al. (2013)
20	Kono et al. (2018)
21	Fauzi et al. (2022)
22	Barrio et al. (2021)
23	Aung et al. (2021)

6 Directions for future research in Social LCA

Following on the gaps and limitations discussed in the previous section, there is a need to pave the way to a (near) real-time S-LCA capability that exploits a wide range of digital resources and which leverages intelligence (in the form of machine learning and optimisation algorithms) to assess the whole life cycle social and environmental impacts of buildings.

Five main avenues for future research have been identified, namely, (a) reaching consensus on a Social LCA framework and associated weighting system; (b) conferring a dynamic and real-time dimension to S-LCA; (c) addressing the lack and uncertainty of data needed for S-LCA; (d) using Social LCA to inform decision- and policy-making; and (e) ensuring consistency in the impact subcategories used in S-LCA.

6.1 Reaching consensus on a S-LCA framework and associated weighting system

Research is needed to firm up a robust and comprehensive methodology for S-LCA in the construction sector that considers its complex supply chains and life cycle phases. There is a general consensus that S-LCA needs to develop methodologically in order to improve its application (Dong and Ng 2015). This should use a consensus-based approach involving multidisciplinary experts drawn from a wide range of disciplines, including social sciences, architecture, and urban planning. Conversely, research is needed to identify more subcategories and indicators, as corroborated by Dong and Ng (2015). Also, indicators aimed at the use stage, such as connectivity index and access of community destinations, need to be further developed (Zheng et al. 2020). A key challenge is to allocate the right weightings for all the categories and criteria within them. As such, further research is needed to refine and develop further the scoring and weighting models to factor in uncertainty analysis, as corroborated by Zheng et al. (2020). The S-LCA weighting system should be adapted to the type of buildings and profile of occupants. In fact, a factory should involve a weighting system different from a care home. These adaptations should be supported as part of a scalable framework and underpinning S-LCA methodology.

6.2 Conferring a dynamic and real-time dimension to S-LCA

Research is needed to assess the impact of utilising dynamic data on the accuracy of S-LCA results throughout different project stages, such as construction and operation. This involves researching approaches to delivering real-time accounts of social life cycle performance of buildings using multiaspect sensory data, including indoor and outdoor environmental data. The collection of dynamic data will require identification of necessary instrumentation and data capture technologies while leveraging existing building management system and information and communication technology (ICT) infrastructure. This needs to provide context to the sensed data via semantics (Fnais et al. 2022). In addition, a systems approach should be adopted, whereby the social performance and environmental impact of physical artefacts, such as a building, involve the assessment of each constituent subsystem. Toboso-Chavero et al. (2021) offered a set of suggestions for the future: 'To progress in social assessments and make the assessments more dynamic to perform, we recommend further research aiming to (a) prioritise social indicators, as S-LCA presents multiple indicators; we advocate for centralising efforts in the most common and widespread indicators, such as gender inequality, labour rights, and health and safety, or SDGs indicators; (b) increase the data availability of disaggregated sectors in databases such as the SHDB and PSILCA targeting to easily perform social assessments; and (c) promote among companies the control of social data to generate open-source databases to be used for researchers and organisations'.

6.3 Addressing the lack and uncertainty of data needed for S-LCA

Research is needed to devise rigorous approaches to source qualitative and quantitative information needed for S-LCA, including the collection of primary data, while ensuring these are accurate and complete. There is also a further need to comply with GDPR (General Data Protection Regulation) and FAIR (Findable, Accessible, Interoperable, Reusable) principles. There is a potential to leverage on machine learning techniques to address this data and information gap as elaborated below.

6.4 Using S-LCA to inform decision- and policy-making

Research is needed to evaluate the impact of real-time S-LCA in the decision-making process by non-experts, which should explore a wide range of options and scenarios with the least (social) environmental impacts, while advising on corrective measures through actionable machine learning. Future research should focus on using machine learning technologies in real-time S-LCA applications to monitor, optimise, and control the built-environment systems. Furthermore, hybrid ML applications may expand on the benefits of ML models and overcome limitations to case-specific scenarios for optimising S-LCA through their interpolation and extrapolation capabilities. Advanced stochastic metaheuristics should be used in refining ML model training parameters to maximise their accuracy and reliability. Evidence suggests that ML methods can match the LCA results within the accuracy of typical LCA studies and correctly predict the trends (Ghoroghi et al. 2022).

6.5 Ensuring consistency in the S-LCA impact subcategories

As mentioned in Section 5, the literature pointed at impact subcategories which are frequently used, while others have not been addressed at all. The categories that are explored include fair salary (for the worker), health and safety (for the worker), safe and healthy living conditions (for the local community), and technology development (for society). For these categories, and as one of the main outcomes of this study, certain observations arise. For the fair wage category, a few studies looked into how it was influenced by several factors. Oladazimi et al. (2021) argued that fair salary for the workers is the highest in significance, when steel frame is involved, and that it is more significant than when concrete frames are involved. However, Vitorio Junior and Kripka (2020) argued that steel was not ideal and had negative social effects during the extraction phase. On the other hand, Dong and Ng (2015) explained how precast concrete can potentially cause social problems, with regard to fair salary. Furthermore, as noted by Hossain et al. (2017), recycled aggregates presented lower score than natural aggregates. According to a study by Toboso-Chavero et al. (2021), perlite performs well concerning fair wage, whereas coir did not perform well. Kono et al. (2018) argued that geographical region representation is critical with regard to categories, such as fair salary. For example, it was observed that Thai products did not perform well. It is therefore suggested that a focus should be placed in improving fair wage for the worker, as an impact subcategory, while at the same time maintaining a positive performance from other impact subcategories as well.

Health and safety, for the worker, is another category which is well documented in the literature. In fact, Dong and Ng (2015) sustained those local experts in their study and placed this subcategory in the first place of importance, with regard to social aspects. Similarly, Balasbaneh and Marsono (2020) stated that, in the context of the study, health and safety were among the most important subcategories. Oladazimi et al. (2021), on the other hand, observed how health and safety held the least significance, according to the experts involved in the study, when it comes to steel frames. There are instances where solutions have been developed, in order to ensure health and safety for workers. Ferrari et al. (2019) sustained that, in Italy, there is an 'Avant-garde regulatory framework', with regard to ceramic, so much so that it has been promoted as an example for other countries, too. Gulcimen et al. (2022) argued for the need of ensuring health and safety for workers in a university campus level. This would take place, if all the potential risks are being considered. Furthermore, for safe and healthy living conditions (for the local community), Safarpour et al. (2022) had some observations to make, concerning quality of wastewater. Safe and healthy living conditions for the community were at the top of concerns.

On the other hand, sexual harassment (for the worker), smallholders including farmers (for the worker), ethical treatment for animals (for society), poverty alleviation (for society), education provided in the local community (for children), health issues for children as consumers (for children), and children concern regarding marketing practices (for children) have not been adequately addressed. It is significant to note that these categories were introduced to the UNEP/SETAC guidelines, in the updated version of 2020 (Environment U 2023). Huertas-Valdivia et al. (2020) observe that 'consumers and value chain actors and society are often overlooked as stakeholder categories, while workers and local communities appear to be frequently included in studies' [25] (p. 32). Therefore, these subcategories are relatively new additions and could be argued that there has not been enough time for them to be properly integrated in the construction sector. Nevertheless, Vitorio Junior and Kripka (2020) stated: 'Also, construction has associated social impacts on the workers involved in the sector; there are issues related to low wages, child labour, forced labour, excessive working time, wage assessment, poverty, migrant labour, gender discrimination and sexual harassment (Sala 2020)'. Therefore, there is a need to understand and explore why these categories are not addressed since 2020, what are the barriers and potential difficulties in doing so and the benefits from engaging with these impact subcategories.

7 Conclusions

The paper provided an overview of the S-LCA research landscape in the construction sector. Through a systematic literature review, which looked into both the building and the infrastructure sector, frameworks and methodologies are critically presented. Referring to our three posited research questions, (a) there is a general consensus that S-LCA in the construction sector presents a fragmented landscape and there are key challenges that need to be overcome. More than 50% of the studies relied on the UNEP/SETAC guidelines for their methodology and for the development of their frameworks; (b) several gaps have been identified in relation to (i) the S-LCA frameworks and methodologies employed, (ii) their support for dynamic data, (iii) reliability and completeness of data which involves a level of uncertainty, and (iv) the application of S-LCA to support decision- and policy-making through reliance on machine learning techniques; and (c) recommendations for future research have been proposed in line with these gaps. It is hoped that these recommendations will inform future enhancements of the social dimension of LCSA in the construction sector and beyond.

Overall, S-LCA seems to hold significant potential to improve the social impact of the construction sector. It is suggested by the authors that future work should include the implementation of the unexamined impact categories, as well as the development of methodologies which could resolve the barriers and challenges that are currently present.

Appendix

Stakeholder Categories	Impact Subcategories	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	sum
Worker	Freedom of Association and Collective Bargaining	x	x							x										x		x	x		6
	Child Labour		x						x	x			x							x		x			6
	Fair Salary					x	x		x			x	x							x	x	x	x	x	10
	Working Hours	x			x			x	x			x		x					x			x	x		9
	Forced Labour		x					x	x	x										x	x	x			7
	Equal Opportunities/ Discrimination	x							x		x									x		x	x	x	7
	Health & Safety	x			x			x	x		x	x		x	x				x	x		x	x	x	13
	Employment Relationship							x				x												x	3
	Sexual Harassment																								
	Smallholders Including farmers								.																
	Professional Growth & Development	x			x							x													3
	Training & Education							x																	1
	Excessive Working Hours												x												1
	Fatal Injuries												x												1
	Non - Fatal Injuries												x												1
	Gender Inequality												x												1
	Performance Monitoring Programs													x											1
	Transparency														x										1
	Access to Immaterial Resources														x										1
	Promotion of Social Responsibility														x										1
	The Employment of Child/Juvenily Labour																							x	1
	The Employment of Forced Labour																							x	1
	Freedom of Association and Collective Bargaining																							x	1
	Decent Hours of Work																							x	1
	Respect for Freedom of Association																x	x							2
	Occupational Accidents																x	x							2
	Living/Non-Poverty Wages																x	x							2
	Professional Growth																		x						1
	Working Time																				x				1
	Social Benefits/Social Security																					x			1
Local Community	Access to Material Resources	x			x			x			x				x				x	x		x	x		9
	Access to Immaterial Resources							x							x							x	x		4
	Decolonization and Migration																						x		1
	Culture Heritage										x									x					2
	Safe abd Healthy Living Conditions	x			x			x	x		x			x					x	x		x	x	x	11
	Respect of Indigenous Rights		x							x											x	x			4
	Community Engagement							x						x	x							x	x	x	6
	Local Employment	x					x	x	x						x					x		x	x	x	9
	Secure Living Conditions																					x		x	2
	Public Opinion on the Concerned Materials							x																	1
	Integration and Interaction								x																1
	Accessibility								x																1
	Hospital Beds												x												1
	Children out of School												x												1
	Drinking Water												x												1
	Satisfaction with the Performance of the WWCN													x											1
	Promotion of Social Responsibility														x										1
	Transparency														x										1
	Health / Safety														x										1
	Contribution of Economic Development														x										1
	Prevention and Mitigation of Conflicts														x										1
	Decolonization and Migration/Land Confiscation																							x	1
	Respect to Cultural Heritage																							x	1
	Respect to Ethnic Minorities																							x	1
	Access to Electricity																							x	1
	Access to Immaterial and Material Resources																							x	1
	Land Use																x	x							2
	Level of Industrial Water Use																x	x							2
	Extraction of Material Resources																x	x							2
	Pollution Levels																x	x							2
	Waste Genetations																x	x							2
	Job Creation																x	x							2
	Use of Local Labour																x	x							2
	Contribution of Product to Economy (GDP)																x								1
	Technology to Generate Employment																	x							1
	Presence of Complaints by Local Communities																	x							1
	Presence of Cultural Heritage																	x							1
	Local Community Acceptance																			x					1
Value Chain Actors	Fair Competition							x												x			x	x	4
	Promoting Social Responsibility							x															x		2
	Supplier Relationship							x												x			x		3
	Respect of Intellectual Property Right							x															x		2
	Wealth Distribution	x																							1
	Promoting Corporate Social Responsibility																							x	1
	Corruption																				x				1
Consumers	Health and Safety				x		x				x				x				x	x					6
	Feedback Mechanism										x			x											2
	Consumer Privacy										x														1
	Transparency										x				x										2
	End of Life Responsibility														x										1
	Demand Satisfaction													x											1
	Effluent Quality													x											1
	Expenses													x											1
	Consumers' Total Satisfaction													x											1

Fig. 2 Detailed analysis of all the studies and impact subcategories, organised by stakeholder categories

	Prevention and Mitigation of Conflicts														x										1
	Contribution to Economic Development														x										1
	Local Employment														x										1
	Promotion of Social Responsibility														x										1
	Cleaning Comfort																x								1
	Less Sound Producing																x								1
	More Beauty																x								1
Society	Public Commitment to Sustainability Issues	x			x			x	x		x								x				x	x	8
	Contribution to Economic Development							x			x									x	x	x	x	x	7
	Prevention and Mitigation of Armed Conflicts																							x	1
	Technology Development	x			x			x	x		x							x	x	x		x	x	x	11
	Corruption	x	x							x												x	x		5
	Ethical Treatment of Animals																								
	Poverty Alleviation																								
	Support from the Government							x																	1
	Child Labour												x												1
	Gender Inequality												x												1
	National Poverty Line												x												1
	GDPC(PI)												x												1
	ES(PI)												x												1
	FFC																							x	1
	EI																x								1
	LWDSU																x								1
	FA																x								1
	NTF																x								1
	D																x								1
	MCF																x								1
	TT																	x							1
	RD																	x							1
	CPE (GDP)																	x							1
	SNS																	x							1
	SD																			x					1
	H&S																				x				1
	CSI																					x			1
	SB																						x		1
Children	Education Provided in the Local Community																								
	Health Issues for Children as Consumers																								
	Children Concerns Regarding Marketing Practices																								
	Excessive Working Time		x							x															2
	Injuries and Fatalities		x							x															2
	Toxins & Hazards		x							x															2
	Poverty Wage 2		x							x															2
	Poverty Wage 1		x							x															2
	Migrant Labour		x							x															2
	Gender Equity		x							x															2
	High Conflict		x							x															2
	Legal System		x							x															2
	Drinking Water		x							x															2
	Improved Sanitation		x							x															2
	Hospital Beds		x							x															2
	Inadequate Social Benefits		x							x															2
	WORKERS			x												x									2
	OCCUPANT															x									1
	VALUE CHAIN ACTOR															x									1
	LOCAL COMMUNITY			x												x									2
	SOCIETY															x									1
	Local Community Acceptance						x																		1
	Extraction of Material Resources						x																		1
	Materials (Use of Natural & Recycled Materials)							x																	1
	Energy and Water Consumption							x																	1
	Emissions to Air, Water and Soil							x																	1
	Solid Wastes and Effluent Treatment							x																	1
	Biodiversity (Effects on Local Biodiversity)							x																	1
Relevant Stakeholders (So	Health and Safety							x																	1
	Use Stage Responsibility							x																	1
	Product and Service Labelling							x																	1
	End of Life Responsibility							x																	1
	User Satisfaction (based on quality)							x																	1
Producer of the Concerne	Fair Salary							x																	1
	Functionality and Usability								x																1
	Health and Confort								x																1
	Accessibility								x																1
	Feedback Mechanism								x																1
	Public Commitment to Sustainability Issues														x										1
Occupant	Prevention and Mitigation of Conflicts														x										1
	Contribution to Economic Development														x										1
	Health and Safety														x										1
	End of Life Responsibility														x										1
Municipal Services	Community Engagement														x										1
	Local Employment														x										1
	Access to Immaterial Resources														x										1
	Access to Material Resources														x										1
	Promotion of Social Responsibility														x										1
User	Health & Safety																					x			1
	Feedback Mechanism																					x			1
	End of Life Responsibility																					x			1
Supplier	Fair Competition																					x			1
	Promoting Social Responsibility																					x			1

Fig. 3 Detailed analysis of all the studies and impact subcategories, organised by stakeholder categories

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Declarations

Conflict of interest The authors declare no competing interests.

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