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Advancing Sustainable Development Through Environmental Performance Monitoring: The Organisational Life Cycle Assessment

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ABSTRACT

The growing importance of sustainability poses significant challenges to companies, particularly micro, small, and medium enterprises (MSMEs). Product life cycle assessment focuses on individual products, often leaving MSMEs without a complete picture of their overall environmental impact, especially within complex and long value chains. Organisational Life Cycle Assessment (OLCA) appears to be a valid approach to address these challenges by assessing all activities within an organisation. OLCA offers a comprehensive view of an organisation's sustainability performance, overcoming the challenges often faced by MSMEs, such as resource constraints and challenges within the value chain when adopting product LCA. By integrating OLCA with product LCA, companies can gain a more holistic understanding of their environmental impacts, improving both environmental assessments and ethical business conduct. The findings of this research assess OLCA's presence in literature and industry, exploring its content and practical applications demonstrated through case studies. It emerges that the adoption and use of the methodology have great potential especially for small and medium enterprises, as they are often left outside the comprehensive view of the life cycle of a single product, making it difficult for these companies to approach environmental performance monitoring. Therefore, the OLCA could address this gap, becoming a reference approach for companies that need to disclose about environmental impact. Due to its relatively recent nature, companies still struggle with its adoption. Scientific research on this, therefore, becomes crucial in its spread and adoption, stressing the benefits and limitations, as well as providing evidence of case studies. This paper aims to address this gap and pone itself as a cornerstone for future researchers to pursue on this path and for companies to foster a broader, offering a dual perspective with product LCA.

1 | Introduction

In the last decade, a notable shift has unfolded in the domain of organisational environmental analysis. The importance of sustainable development is a pivotal goal reaffirmed by the United Nations in Agenda 2030 (United Nations 2015) and the European Green Deal (European Commission 2019) in order to protect society and the environment from pollution and depletion of natural resources.

Current lifestyles and business models, as structural and strategic frameworks that define how organisations create, deliver, and capture value, urgently need to adapt in response to the pressing challenges posed by climate change and high resource consumption. These issues have direct, far-reaching consequences on people's lives, the economy, and the natural environment. Business models encompass aspects such as supply chain management, production processes, and customer engagement strategies, all of which must now integrate environmentally conscious practices to mitigate their broader environmental impacts. This shift not only responds to regulatory pressures and consumer demands but also reduces corporate activities' ecological footprints., which have direct consequences on people's lives, the economy, and the natural environment (Wafa et al. 2022).

Similarly, individual and community lifestyles significantly influence climate change through consumption patterns and daily practices. For instance, high consumption lifestyles prevalent in many developed nations lead to increased demand for energy, transportation, and goods all contributors to substantial greenhouse gas (GHG) emissions and resource depletion. In contrast, adopting sustainable lifestyles that prioritize low-carbon transportation, energy-efficient homes, and waste reduction can significantly mitigate these impacts. The dynamic interaction between lifestyles and business models is thus a critical area for intervention. Changes in both can drive significant environmental benefits, fostering a culture of sustainability and steering the global economy towards lower carbon emissions.

The Life Cycle Assessment (LCA) stands as a robust quantitative tool pivotal in environmental decision-making, originally crafted for product evaluation. Traditional Product LCA offers a detailed evaluation of the environmental effects associated with individual products from production to disposal, guiding material and design decisions within specific industries. The standardised methodology allows to reduce environmental impacts by intercepting hotspots and taking informed decisions according to it, and thanks to the comparability of different solutions, both for managers and policymakers (Liscio and Sospiro 2023), other than supporting informed products claims avoiding greenwashing (Alizadeh, Liscio, and Sospiro 2024).

Moreover, especially micro, small, and medium enterprises (MSMEs) sometimes struggle to adopt such tools, both for the requirement of resources and competencies in the field, but also due to the fact that in some cases, such as the fashion industry (De Ponte, Liscio, and Sospiro 2023), these companies are just in the early stages of the value chain; therefore, they cannot conduct such analysis on the entire life cycle of a product. In this sense, one high-potential approach can be recognised in the so-called "Organisational LCA". The International Organization for Standardization defines OLCA in the ISO/TS 14072 (ISO 2014), primarily based on the ISO standard for the product LCA, with the majority of ISO 14044 elements (ISO 2006) being the same as for the product LCA (Wafa et al. 2022).

The United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) in the Life Cycle Initiative released a Guidance in OLCA to support the practitioners in the interpretation of the standard and the main field of applications and benefits of it (UNEP - SETAC - LCI 2015). This Guidance document aligns with ISO/TS 14072, ISO 14040, and ISO 14044. It serves as a comprehensive resource, referencing and building upon existing works, aiming to unravel the capabilities and applicability of OLCA.

Furthermore, the European Commission embraced the Organisational point of view, as it published the Organisational Environmental Footprint methodology, starting from the ISO/TS 14072 standard, which encompasses some procedural differences, compared to the OLCA (European Commission 2021).

Researchers estimate that less than 20% of used and waste textiles from households and industries are collected in the EU. And out of the waste effectively collected, only 30% is sent for recycling, and 50% is exported to third countries. It is time to mend the fabric of our textile industry.[1] The EU Textiles Strategy aims to reduce textile waste. According to the Pulse of Fashion report,[2] global clothing consumption could increase by 63% from 62 million tonnes to 102 million tonnes by 2030. This industry is estimated to be responsible for about 5000 million tonnes of CO2 per year, about 10% of global GHG emissions, as well as for one-third of the microplastics in the oceans, or 190,000 t, and 20% of the pollution of industrial waters. Waste from the sector is estimated at around 92 million tonnes per year, including unsold clothing.

Driven by the pressing need for sustainable practices, industries are facing heightened scrutiny regarding their environmental impact. OLCA emerges as a crucial methodology, offering a holistic assessment of a company's environmental footprint and aligning with the global push towards sustainable business models. Business model innovation for sustainability is limited by insufficient tools for environmental assessment at the business model level, where traditional LCA fails to integrate economic and sociotechnical aspects of business models. BM-LCA links (Goffetti et al. 2022) physical life cycle data with monetary flows within a business model, providing critical insights for evaluating business strategies and the environmental performance of various business models. In this light, a thorough examination of OLCA's implementation across various industries highlights considerable progress, making a compelling case for its adoption, especially in the ever-evolving landscape of the fashion industry.

OLCA emerges not only as a tool for immediate environmental impact scrutiny but also as a strategic approach steering industries towards authentic environmental stewardship. Product LCA and OLCA represent distinct approaches for evaluating environmental impacts, differing in several key aspects. The differences in both methodologies as outlined by the guidance can be seen in Table 1 as stated by UNEP - SETAC - LCI (2015).

TABLE 1 | Comparison of LCA and OLCA steps. Own elaboration.

	Product LCA	Organisational LCA
Goal and scope definition		
General	A sole product LCA, in itself, does not provide all the information to make decisions on an organisational level, as O-LCA does.	The granularity of O-LCA does not give information on how to improve the environmental performance of an individual product.
	Unit of analysis and consistent boundaries are mostly required for comparative assertions. Product LCA can also be used for performance tracking if it is embedded in the right technical and organisational manner.	Apart from transparency reasons (due to the large complexity of the system), the need of a unit of analysis and consistent boundaries is for environmental performance tracking of the organisation.
Unit of analysis	Functional unit and the reference flow are defined according to the main function/s of the product.	The reporting organisation defines the organisation per se (i.e., the unit of analysis) and the reporting flow ideally represents the quantification of its product portfolio (amounts, unit, revenue, etc.).
	The functional unit defines the specific function of the product that is used as a basis for comparison.	In the reporting organisation, it is specified which parts of the organisation are included, determining whether the whole organisation is considered and using the consolidation methods.
	The reference flow denotes the quantity of the product being assessed, specifically the number necessary to satisfy the functional unit.	The reporting flow often encompasses multiple products, corresponding to the range offered in the organisation's portfolio.
Timeframe	Very often, the environmental impacts are calculated according to the life span of the product.	The environmental results of the organisation are attributed to a specific reference period, which should be clearly defined by the reporting entity and is typically 1 year.
System boundary	The components of the life cycle, such as processes, materials, energy, and intermediate products, determine the units/steps involved. The system boundary is derived from the product type, and no distinction is made between direct and indirect impacts.	The units refer to the organisations within the value chain of the reporting entity. The definition of the reporting organisation is crucial in establishing the system boundary. Within this boundary, direct and indirect activities and their associated impacts are clearly distinguished.
Life cycle inventory analysis		
Inventory	Stakeholder involvement is encouraged in the peer review of the study, extending beyond the commissioners. While outcomes may be updated, periodic revisions are uncommon. Activities not directly related to production are typically excluded. The use of specific data for the assessed product is expected. System expansion is considered one method to circumvent allocation.	Suppliers should be involved extensively to provide specific operational data, including that of their suppliers. Enhancing data collection and quality is recommended. OLCA, designed for annual performance tracking, includes commonly excluded activities in product LCA such as business travel, leased assets, heating, and cleaning services. Big organisations with complex products often rely on generic or extrapolated data. Generally, system expansion is avoided to prevent inconsistent or unrepresentative substitution scenarios.
Life cycle impact assessment		
Impact	Once the inventory is compiled, the same methodologies are applied to both product and organisational LCA. In OLCA, it is common to use inventory-level indicators in addition to impact categories.	
Interpretation		
General information	Communication of results (e.g., through EPDs) is mainly targeted to consumers.	Organisational reporting (e.g., sustainability reporting) mainly aims to communicate stakeholders, facilitating sustainability reporting activities.

The OLCA can be more manageable than the product LCA as it assesses the entire firm, and it is more feasible to get the overall inputs and outputs, rather than the specific ones for each product. Product LCA primarily targets specific products, services, or processes, examining their entire life cycle from production to disposal. In contrast, OLCA takes a broader organisational perspective, aiming to assess the environmental impacts across all products, services, and operations of the entire organisation considered, as it monitors and assesses the overall environmental performance of an organisation, considering all activities. LCA finds use in industries for product-focused environmental evaluations, guiding material, and design decisions.

In fact, as stated by the UNEP-LCI Guidance on OLCA (UNEP - SETAC - LCI 2015), this methodology's adaptability, which may be utilised in a range of circumstances, even in organisations that are unfamiliar with environmental analysis tools, is one of its best features. For organisations that have never carried out thorough environmental studies, this is extremely useful. OLCA can provide a fundamental grasp of how environmentally responsible an organisation is. This knowledge supports continuous improvement by assisting with goal setting and environmental action prioritization. At the organisational and product level, OLCA also aids in the decision of how to apply additional environmental assessment methods as explained in more details in the discussion. On the other hand, organisations employ OLCA for continuous monitoring of their overall environmental performance, supporting sustainable management practices, and facilitating environmental performance reporting (Martínez-Blanco, Inaba, and Finkbeiner 2015a).

The methodologies of OLCA and Product LCA share a foundational structure, with differences primarily reflected in their scope and specific applications, as highlighted in the bracketed texts in Figure 1. While LCA focuses on assessing the environmental impacts of a single product or service from raw material extraction to disposal, defining a "functional unit" as a reference for comparison, OLCA extends this approach to analyse the entire organisation. This broader scope includes defining "organisational boundaries" that specifies which parts of the organisation are under assessment, whether it encompasses entire operations or selective divisions.

In OLCA, the "reporting unit" plays a role similar to the functional unit in LCA but is adapted to represent the aggregate activities of the organisation, rather than a single product. This adjustment is crucial for capturing the complex interdependencies and operational scales within an organisation, thus guiding the scope of data collection and impact analysis. Organisational boundaries in OLCA are essential as they delineate the extent of the assessment, influencing how environmental impacts are measured, reported, and interpreted, ensuring that the findings align with organisational goals and stakeholder expectations.

Resta et al. (2016) contributed to the textile sector by proposing OLCA methodological approaches, while Martínez-Blanco, Inaba, and Finkbeiner (2015a) delved into OLCA's application in the packaging sector, presenting an initial implementation example. Jungbluth, Keller, and König (2016) displayed a full organisational environmental footprint for a Swiss operator overseeing 240 canteens, illustrating OLCA's practical application. Furthermore, Martínez-Blanco, Inaba, and Finkbeiner (2016) provided detailed insights into OLCA implementations by industry leaders like Accor and Unilever.

OLCA promotes the continuous monitoring of an organisation's environmental impacts by establishing an annual reference period. This approach allows organisations to systematically assess and document their environmental effects consistently each year, rather than on an ad hoc basis. Such ongoing monitoring ensures that data on the environmental impacts of all organisational activities are regularly updated and available. This practice is particularly vital as sustainability reporting requirements are set to become mandatory for an increasing number of companies across Europe in the near future. By maintaining a continuous, year-long cycle of environmental evaluation, organisations are better prepared to meet these upcoming regulatory demands and contribute effectively to the broader objectives of sustainability reporting due to the reference period corresponding to 1 year, allowing them to contribute to the realisation of the sustainability reports, which will be mandatory for a larger number of companies in the following years in Europe.

OLCA stands as a systematic methodology employed to assess the environmental consequences associated with an entire range of products within an organisation's portfolio. Given that many organisations offer a diverse set of goods and services, OLCA enables the simultaneous evaluation of the entire spectrum of activities necessary for their provision, following a life cycle perspective. This approach extends the benefits of life cycle thinking (LCT), holding the significant potential to aid corporations, authorities, institutions, and other organisations in improving

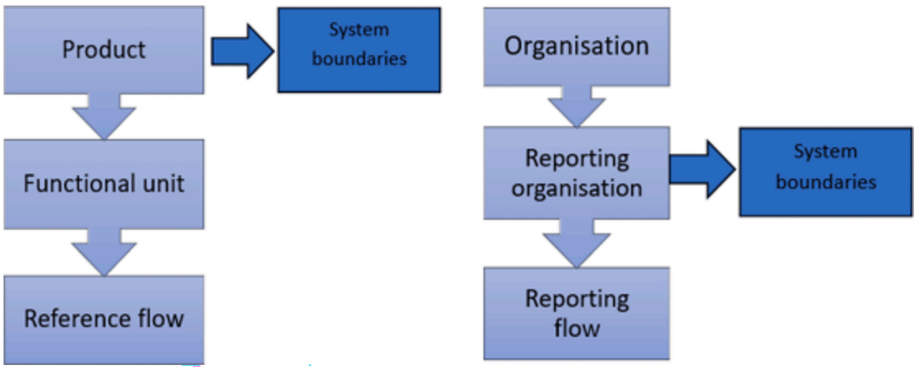

FIGURE 1 | Product LCA and organisational LCA comparison. Own elaboration based on UNEP - SETAC - LCI (2015).

their environmental performance by providing credible and comprehensive information (UNEP - SETAC - LCI 2015).

This study aims to rigorously explore and evaluate the literature surrounding OLCA to identify its benefits and limitations, thereby illuminating its potential to aid MSMEs in adopting more sustainable business models and improving their communication strategies. By systematically reviewing OLCA applications, this research seeks to understand how OLCA can be effectively implemented across various organisational contexts, particularly focusing on MSMEs which often face unique sustainability challenges. The benefits of OLCA include providing a comprehensive view of an organisation's environmental footprint by assessing impacts across all products, services, and operations. This holistic approach helps organisations to identify significant environmental impacts and inefficiencies across their entire operation, rather than in isolated products, facilitating strategic decisions that enhance overall sustainability. Additionally, OLCA supports organisations in achieving compliance with increasing regulatory demands for environmental reporting and can improve stakeholder communication by transparently demonstrating a commitment to environmental stewardship. The findings are expected to contribute to the broader discourse on sustainable business practices, offering insights into how OLCA can be tailored to meet the needs of smaller enterprises and thus enabling them to engage more effectively in sustainable operations and communications.

2 | Methodology

To methodically delve into the role of OLCA across diverse industries, a systematic literature review was initiated under the research scope of "OLCA in the scientific literature." The review process adhered to the protocol delineated in the Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) by Paul et al. (2021). Following this structured framework, as outlined in Table 2, facilitated a comprehensive exploration of existing literature, aiming to elucidate OLCA's presence within various industrial contexts.

Through this methodological approach, the review sought to identify both the benefits and limitations of OLCA within several contexts, especially underlining insights from real-world examples documented in scholarly literature. Conducting a literature review on OLCA faces limitations including its relative novelty since ISO 14072 was introduced in 2014, leading to fewer comprehensive studies compared to product LCA. The requirement for extensive, organisation-specific data presents a significant challenge, especially for MSMEs lacking resources for such data collection. Reliance on high-quality sources like Scopus may overlook relevant research published outside these databases or in non-English languages, and the strict criteria for selecting studies can introduce bias, potentially excluding significant findings. Additionally, the thematic review approach, focusing on broad trends and themes, might miss nuanced insights or emerging practices, limiting the generalizability of the results to various industries and regions. By systematically analysing available knowledge, this study aimed to contribute to a deeper understanding of OLCA's applicability and impact across diverse sectors, paving the way for informed decision-making and strategic environmental management practices.

TABLE 2 | SPAR-4-SLR scheme applied to this research.

Assembling	Identification Research domain: Organisational Life Cycle Assessment in the scientific literature. Research questions: benefits and limitations of OLCA. Source: Scopus.
	Acquisition Search period: 2014–2023. Search mechanism and material acquisition: Scopus. Search keywords: Boolean search using combination of words in Title, Author keywords and Abstracts.: ("organisational life cycle assessment" OR "organisational lca" OR "organisational-lca") OR ("organisational life cycle assessment" OR "organisational lca" OR "organisational-lca") OR (olca OR o-lca)RESULTS: 78
Arranging	Organisation Organising codes: (i) language – (ii) documents type – (iii) source type – (iv) title and abstract analysis.
	Purification (i) English – (ii) research and review articles and book chapters – (iii) Journals – (iv) correlation with the research domain. RESULTS: 57
Assessing	Evaluation Analysis method: content analysis. Agenda proposal method: case studies, benefits, and gaps of OLCA.
	Reporting Reporting convention: words. Limitation: related to data type and topic considered.

The process involved three key steps: assembling, arranging, and assessing.

Within the assembling phase, a total of 78 results were yielded. In the identification phase, the domain, the research question, and the source for the research have been identified, while in the acquisition phase, keywords, and Booleans for the initial research for documents have been selected, as well as the timespan of the research (2014–2023). At this point, the first research was conducted on the designated database. To ensure source quality, the Scopus database was selected, recognised for its comprehensive coverage and broader category indexing, as advised by Paul et al. (2021). For the same reason, in the Acquisition, Scopus served as the primary search tool and material source, due to the extensive integrated and advanced research tools.

Search keywords, agreed in collaboration with other academics, were searched in the Title, Author keywords, and Abstract using Boolean operators and wildcards in searching for the following terms:

("organisational life cycle assessment" OR "organisational lca" OR "organisational-lca") OR ("organisational life cycle assessment" OR "organisational lca" OR "organisational-lca") OR (olca OR o-lca)

The subsequent arranging phase encompassed Organising and Purification, where the outcomes underwent screening. Particularly, organising codes have been selected and, therefore, applied, to obtain more reliable and on-the-point results. The organising codes were the following: (i) language (i.e., English), (ii) document type (i.e., research and review articles), (iii) source type (i.e., Journals), (iv) Title and abstract analysis (i.e., exclusion based on off-topic results such as papers containing the same acronym "OLCA" referred to another meaning). At this point, the results were 57, and they were reviewed and discussed.

This filtering aimed to streamline outcomes, ensuring greater relevance to the research questions, while excluding areas less pertinent to the topic following a comprehensive review of the title, abstract, and full paper. Focusing solely on research articles published in journals, the review excluded editorials and conference papers to maintain a focus on empirical and comprehensive results.

Lastly, the assessing phase, consisting of the evaluation and reporting subphases, scrutinized the sources and information gathered, culminating in the reporting of results. In this phase, our study embraced a thematic lens, aimed at discerning the advantages and drawbacks of OLCA within the industry landscape.

However, it is essential to acknowledge certain constraints. Our focus was on the merits and demerits of OLCA within the broader industry. This entailed examining the articles for information on the results obtained, the added value derived from the implementation of OLCA, and the limitations encountered, so some elements characterising some articles may have been missed.

For the purpose of this article, which aims to provide a general analysis of the methodology, and its application and to inform researchers and companies on the potential and limitations of OLCA by providing scientific references on the subject, this limitation does not have a negative impact. The categories were decided according to the main purpose of the papers reviewed, resulting in three areas: those about a review of the literature, those related to the analysis and adoption of the methodology, and finally those to explain the results of specific case studies.

The study embraced a thematic lens, aimed at discerning the advantages and drawbacks of OLCA within the industry landscape. The paper explains how OLCA can be a key element in an organisation for environmental performance and decision-making based on the sustainability report. The results obtained through this process allowed us to search for the benefits and limitations of OLCA in the industry with real-life examples from companies.

3 | Results

The findings have been categorised into three distinct groups. The first category encompasses papers that provide an overview of OLCA's presence in both literature and industry. The second category comprises methodological papers, which delve into the content, application, and synergies of OLCA with other methodologies. Lastly, the third category pertains to papers that demonstrate the practical application of OLCA through real case studies.

The number of publications reviewing OLCAs has remained consistently low up to the year 2023, indicating limited academic focus on critiquing or summarizing existing OLCA research. Despite this, there has been a significant rise in research exploring OLCA methodologies and their applications from 2020 to 2023. This increase suggests a growing academic and industry interest in how OLCA can be integrated into sustainability practices. Furthermore, the practical implementation of OLCA in real scenarios is becoming more prevalent, as evidenced by a rising number of case studies (Figure 2). This trend underscores the expanding recognition of OLCA's value in conducting sustainability assessments across diverse industries and sectors.

The volume of review papers dedicated to OLCA remains concentrated within EU countries, particularly in terms of the territory of affiliations involved. A closer examination of complementary work related to OLCA methodology reveals a higher number of publications, especially in Germany and Italy, with 12 and 10 documents, respectively. Additionally, the practical application of OLCA methodologies follows a similar trend, indicating a significant focus and advancement in these countries (Figure 3).

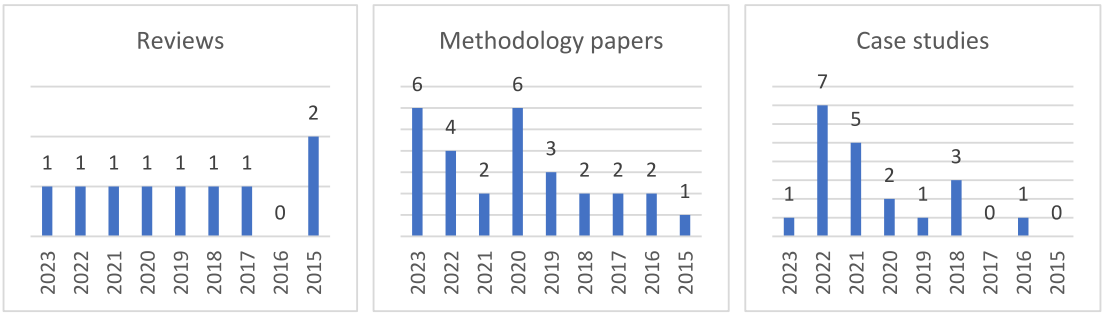

FIGURE 2 | Documents by year, per category. Own elaboration.

FIGURE 3 | Documents by country, per category. Own elaboration.

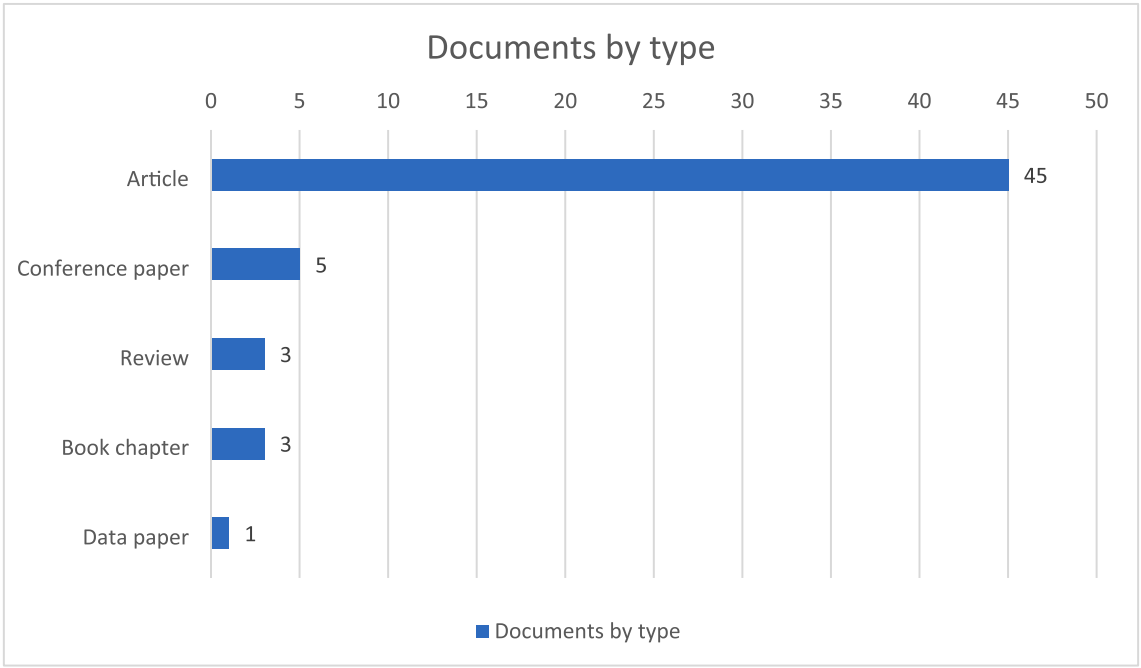

FIGURE 4 | Number of documents according to the type of source considered. Own elaboration based on Scopus data.

Figure 4 shows the types of documents retrieved in the literature analysis, highlighting the distribution across various scholarly types. The chart shows a predominant number of articles, totalling 45, which significantly exceeds other types of documents. Additionally, the chart includes 5 conference papers, 3 review papers, 3 book chapters, and 1 data paper. This visualization underscores the prevalence of articles in the dataset, indicating that articles are the primary medium through which relevant information on this topic is published and accessed.

As for the subject area, while environmental science dominates as the field most interested in OLCA due to its focus on sustainability, this chart highlights the broader applicability of this methodology. Other subject areas such as engineering and computer science can leverage OLCA's framework to analyse and improve their practices (Figure 5).

Considering the recent development of OLCA, the available literature includes only a limited selection of case studies. In 2017, the life cycle initiative evaluated 12 case studies across various sectors, 3 years after the publication of ISO/TS 14072:2014, following a call for testing of the methodology (UNEP-SETAC-LCI 2017). Therefore, the literature review reveals a total of 30 documented case studies, including 12 from (UNEP-SETAC-LCI 2017).

Regarding the case studies category, it is worth delving into the effective number of case studies. Indeed, two studies refer to the UNEP road testing report (UNEP-SETAC-LCI 2017). This includes research related to OLCA across various fields such as services, institutions, manufacturing, and agrifood. These findings will be discussed in further detail in the discussion section (see Figure 6).

4 | Discussion

As stated in the introduction, the aim of the paper is to investigate the OLCA topic to provide a clear overview on the state of the art in the scientific literature, providing a basis for further application in the research field and, therefore, in the companies, especially MSMEs.

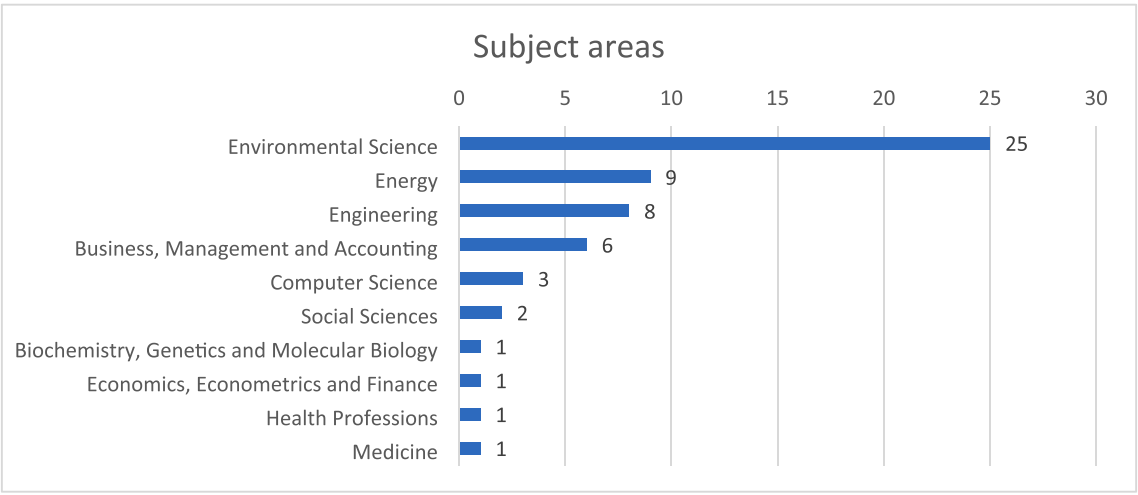

FIGURE 5 | Documents per Subject area. Own elaboration.

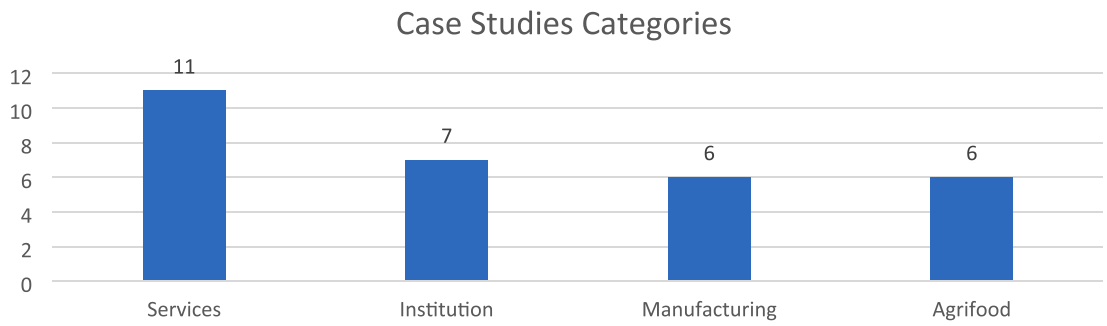

FIGURE 6 | OLCA case studies per sector. Own elaboration.

4.1 | Reviews on OLCA

The first part of the Discussion is dedicated to the review articles retrieved by the analysis, to offer an overview of review papers that embedded specific aspects related to the topic.

According to Curran (2015), LCA is a valuable tool for evaluating the environmental impact of products, processes, and activities as it involves establishing clear goals, defining study boundaries, collecting data, and enabling decision-makers to identify environmental hotspots and improve industrial systems without shifting burdens elsewhere. OLCA is therefore recognised as a complementary and effective way to booster LCA application at organisational level, also by Gnansounou (2017). Particularly, UNEP - SETAC - LCI (2015) plays a crucial role in the spreading of OLCA, as recognised by Junior et al. (2021), with the study that prioritizes case studies that apply the UNEP/SETAC guides in analysing OLCA methods and their applicability. Wafa et al. (2022) effectively implemented the OLCA framework as part of a broader Life Cycle Sustainability Assessment (LCSA) to analyse product sustainability. By adhering to UNEP guidelines, they conducted a systematic review of the literature, specifically focusing on the application of LCSA within university settings. Their findings highlighted a notable gap: There was a distinct lack of studies specifically assessing the LCSA of organisations. This integration of OLCA within the LCSA framework underscores the potential for OLCA to inform more comprehensive sustainability assessments. By contributing environmental insights, OLCA enhances the depth of LCSA studies, which also consider social and economic factors, thereby enriching the strategic, policy, and operational decisions aimed at sustainability. This discussion suggests that while OLCA provides valuable environmental data, its full potential is realized when incorporated into the wider LCSA context, supporting a more holistic approach to assessing sustainability across various dimensions. Agyei Boakye et al. (2023) acknowledge ISO 14072 as a beneficial instrument for establishing distinct boundaries for organisational inventories. This allows for comprehensive coverage of the life cycle of products as they progress through operational processes, emphasizing the significance of LCA in GHG accounting.

Rimano et al. (2019) further develop LCA's extension to organisational factors by analysing the Organization Environmental Footprint (OEF) and OLCA. Martínez-Blanco, Forin, and Finkbeiner (2020) emphasise the challenges associated with OLCA, such as the selection of the reporting organisation, defining system boundaries, categorising inventory, and assessing impacts.

Another crucial point individuated in the literature is the social aspect of OLCA. Martínez-Blanco et al. (2015b) proposed a novel approach called Social OLCA (SOLCA) to address challenges encountered in Social LCA (SLCA). SOLCA focuses on the

organisational perspective, streamlining allocation, data collection, and practical application. Moreover, Zanchi et al. (2018) discuss the need for a structured approach to guide practitioners in the critical application of SLCA, particularly in the automotive sector. They suggest redefining the framework and approach of SLCA according to the organisational perspective, aligning it with recent developments in OEF and OLCA. In this case, social aspects are evaluated in relation to the organisation behaviour and of the basket of products, bridging the gap between the conduct-of-a-company perspective and the product-oriented approach.

4.2 | Methodology Papers on OLCA Applications

Numerous articles emphasise the importance of organisations becoming more sustainable due to their significant impact on the environment.

Alejandrino, Mercante, and Bovea (2022) explore the integration of OLCA within circular economy strategies, addressing the challenges organisations face in transitioning to sustainable development models. They proposed a methodology that evaluates and prioritizes circular economy initiatives based on their environmental and economic performance. This approach not only aids in the effective adoption of circular principles but also showcases the application of OLCA in guiding organisations towards greater sustainability. Finogenova et al. (2019) highlighted the necessity for a universal inventory analysis approach in the context of OLCA. They developed a hybrid method that combines three distinct accounting techniques, enabling organisations to select the most suitable method for assessing indirect activities based on data availability. This innovation enhances the flexibility and accuracy of OLCA by providing a more comprehensive view of an organisation's environmental impacts. Additionally, Fritsch (2020) discusses the critical role of Sustainable business process management in understanding and improving the social, environmental, and economic impacts of organisational activities. He proposes a modelling method that incorporates OLCA concepts into business process management, aiming to identify and manage impact hotspots within organisational operations. This approach underscores the utility of OLCA in integrating sustainability into everyday business practices, ensuring that organisations can achieve and maintain high standards of environmental stewardship.

Martínez-Blanco, Inaba, and Finkbeiner (2015a), in one of the first scientific papers on the OLCA, define the OLCA and introduce its four-phase approach: while there are scope-level differences between product and OLCA, most principles, requirements, and guidelines of product LCA apply to OLCA. Furthermore, Martínez-Blanco and Finkbeiner (2017) highlight that OLCA requires some adaptations in the scope and inventory phases. It encompasses organisation's facilities and activities upstream and downstream in the value chain and serves multiple goals, such as identifying environmental hotspots, tracking environmental performance, supporting strategic decisions, and informing corporate sustainability reporting.

Büdel, Fritsch, and Oberweis (2020) discuss the need for organisations to manage their impacts for sustainable development. They propose a tactical management dashboard based on OLCA methodology which allows nonexperts to explore, analyse, and interpret OLCA study results. In fact, OLCA proves useful in monitoring and evaluating the environmental performance of companies across various sectors, as evident in the paper by Notarnicola et al. (2023). It describes a project by a multisector business group that quantified the environmental profile of their production activities using OLCA.

OLCA can be used to analyse the environmental performance of a specific sector: Resta et al. (2016) propose a decision-making process for the textile sector using OLCA methodology. They conducted interviews with stakeholders and evaluated the process in a spinning company case study, demonstrating benefits in reducing environmental impact and promoting sustainability. Another important sector is presented by Forin, Mikosch, et al. (2020), who propose a methodological approach to assess the water footprint at the organisational level. A further sector is discussed by Nemecek et al. (2022), and they analysed the shortcomings of current field emission modelling and toxicity characterisation of pesticides in LCA. The OLCA-Pest project proposes an approach to integrate pesticide emissions into LCI databases. The article provides recommendations for the implementation of default initial distribution fractions into LCI databases and for modelling pesticide residues in food along the supply chain, allowing for an assessment of eco and human toxicity and the modelling of the removal of pesticide residues in food during processing.

Toniolo, Marson, and Fedele (2023) aim to assess the environmental improvements of a steel mill in a circular economy perspective using OLCA and Product Life Cycle Assessment (P-LCA) methodologies. The results show that recovering steel slag has lower impacts than landfilling it and OLCA and P-LCA can detect the efforts to recover slag similarly.. Yoshio and Haruo (2000) discussed about the social and environmental impact that packaging has. The management of packaging materials is a crucial sector with environmental impacts and resource consumption. Manzardo et al. (2016) assess the interest of these companies in using environmental management tools such as life-cycle assessment. However, challenges arise when applying this methodology at the organisational level, including the choice of functional unit, system boundaries, aggregation approaches, and assessment of environmental impacts. A pilot test on environmental impact assessment in the packaging sector was conducted by Rimano et al. (2021) in a plastic packaging industry production site. The OLCA test application helped detect environmental hotspots and led to improvement actions. The assessment approach was replicated in other facilities and used for corporate sustainability reporting activities.

Additionally, OLCA can be applied to services and institutions, for example, Lo-Iacono-Ferreira, Torregrosa-López, and Capuz-Rizo (2017) assess the suitability of OLCAs for higher education institutions (HEIs) and propose a mechanism to identify activities, processes, and material and energy flows specific to HEIs. In the healthcare sector, Cimprich and Young (2023) conducted a comprehensive OLCA on a 40-bed hospital in British Columbia. The study revealed hotspots in energy and water use, anaesthetic gas releases, and upstream production of materials and products, highlighting the sector's significant impact

on GHG emissions. Cities, as institutions, can also assess their environmental performance using OLCA. Cremer et al. (2020) propose a novel approach for city-scale environmental decision support, aiming to provide a holistic perspective to city's environmental performance beyond GHGs.

OLCA can also be applied to analyse social and socioeconomic aspects: Norris et al. (2019) presents this process for companies to assess their supply chain social footprint and identify potential positive impacts using SOLCA. D'Eusanio et al. (2020) propose a systematic approach to identify relevant social issues in a sector or company to be integrated within the SOLCA framework. These approaches enable companies to evaluate their social impacts and identify areas for improvement. In the realm of institutions, S-OLCA has been used to assess social impacts on social well-being in university life (Sining, Sharaai, and Wafa 2022). The study found that the department positively impacted students' well-being, but there were marginal issues such as discrimination, stress, and feedback mechanisms that needed improvement through timely and anonymous feedback. Additionally, OLCA can be applied to assess human beings themselves. Goermer, Lehmann, and Finkbeiner (2020) propose the concept of Life-LCA, which extends LCA to assess human beings as study objects. This concept has the potential to raise environmental awareness and measure specific environmental impacts. Measuring social performance in manufacturing settings presents challenges. García-Muiña et al. (2022) propose a SOLCA customized for an Italian ceramic tile manufacturer, using Industry 4.0 digital technologies to collect real-time primary and site-specific social data. Another article by the same authors (García-Muiña et al. 2021) focuses on environmental sustainability in manufacturing, emphasizing the importance of the integration of SOLCA and Industry 4.0 technologies to help fill this gap and monitor social performance. Industry 4.0 operating models in manufacturing could also lead to greener technologies and improved environmental sustainability (Cucchi et al. 2022). The organisational approach is an appropriate methodological option to obtain information on environmental performance that supports decision-making processes. Finally, Neef (2023) addresses the need for a method to combine past and future emissions modelling for Original Equipment Manufacturers (OEMs) to develop decarbonization strategies. The Decarbonization Index (DCI) is proposed as a key performance indicator that considers both past and future emissions, providing a basis for decarbonization planning. The DCI can be used by OEMs to monitor past emissions, model future emissions, and guide decarbonization efforts.

4.3 | Case Studies Results

OLCA has been employed in case studies to examine the environmental impact of specific sectors, they can be categorised in services, institutions, agrifood, and manufacturing.

In the services sector, OLCA has been used to investigate offices and related work fields, but also mobility and food sectors.

Cambaz, Taskin, and Ruzgar (2018) conducted an OLCA of a typical office revealing that electricity consumption, transportation, business travel, office consumables, and electronic devices were the main contributors to carbon dioxide emissions. Moreover, Cooney et al. (2021) focused on work-related activities and highlighted the importance of minimizing the environmental impact of research organisations. An OLCA of a research project showed that commuting, conference, training attendance, fieldwork, and meetings had the greatest impact. The recent shift to remote working practices due to the COVID-19 pandemic offers an opportunity for environmental relief.

In the context of urban mobility, Cremer, Müller, and Finkbeiner (2022) discuss the potential impact of autonomous vehicles (AVs) on urban mobility and the environment using OLCA. The study found that while AVs could reduce Vienna's passenger capacity and increase motorized road traffic in some cases, shared AVs accompanied by a conventional car ban could alleviate traffic congestion and lower transport-related GHG emissions. However, the responsibility for emissions shifts to the public level, highlighting the importance of efficient mass transit, electrification of the mobility sector, and grid decarbonization in reducing transport emissions.

This study demonstrates the value of calculating the full organisational environmental footprint to identify and address environmental impacts in the gastronomy sector. Furthermore, Dantas, Amaral, and Soares (2022) combined circularity and OLCA to evaluate the environmental impact of a certified zero-waste vegan restaurant in Brazil. The study emphasizes the importance of avoiding meat and dairy, procuring agroecological food options, and implementing practices such as reuse, recycling, and composting to improve the overall circularity of the system. The production and procurement of goods were identified as the main impact drivers of environmental impact. The study combines life cycle and circularity assessments at the organisational scale, and the approach can be applied to other sectors and companies.

Other services analysed are energy-related services, as discussed by Marx, Forin, and Finkbeiner (2020). They highlight the interest of companies in reducing their environmental footprint and the challenges they face in identifying and mitigating their specific impacts. The OLCA method is proposed as a solution, but it poses challenges for service providing organisations. The study applies OLCA to a service-providing SME in the photovoltaic and wind energy business in the UK and identifies transport activities as the dominant environmental impact.

Waste management is a sector analysed by Camana et al. (2021) where they discuss the use of LCA and related tools to evaluate the environmental impacts of waste treatment scenarios in Italy. The selection of boundaries significantly affects LCA results, and the integration of different waste systems is crucial to avoid spatial or temporal shifts of environmental impacts. The article highlights the need for transparency and ease of reporting of studies to stakeholders and suggests using both OLCA and the life cycle sustainability approach for the overall waste management process to develop a standard method to address multifunctionalities and multiple sites.

Social performances of companies have also been conducted. Osorio-Tejada et al. (2022) apply the S-OCLA methodology to

analyse the social performance of companies involved in the supply chain of road transport companies in different contexts. The approach considers key components of the transport system and performs a multitier inventory analysis for 26 social impact subcategories. Stakeholders concurred that freight companies must focus on labour rights to improve their social performance, followed by human rights or socioeconomic repercussions depending on the context.

Valente and Rubach (2022) explore how SLCA and SOLCA can be used to shape the business model of early-stage companies that want to be socially sustainable. The study filters down a comprehensive list of indicators to focus on the most relevant for social entrepreneurship. The findings are evaluated through dialogues and workshops with a newly established centre for social entrepreneurship in Norway, the aim is to assess the social performance of products and the value proposition of companies.

The role of hospitals in reducing GHG emissions and mitigating climate impact is discussed by Keil (2023). The paper provides an assessment of a hospital in Germany using a cost-based approach and emission intensities. The study reveals that the hospital's main sources of emissions are direct emissions, electricity production, and upstream/downstream processes, with medical supplies production being the largest emitter among cost groups.

During the literature review of the agri-food sector, most papers were focused on water and beverage companies. Forin, Gossmann, et al. (2020) discuss the development of the organisational water footprint method to help companies understand the impact of their operations and supply chains on global water resources. The case study of Neoperl GmbH, a German company in the plumbing industry, shows that 96% of their total freshwater consumption is attributable to the supply chain, with metals being the major hotspot. The study suggests that sustainable purchase strategies and ecodesign options can be used to improve the company's supply chain water use. Moreover, Manzardo, Loss, Niero, et al. (2018) applied OLCA and product LCA to a multisite beverage company and found that different allocations of production of a specific beverage product among different sites could improve the product's environmental performance but worsen the overall organisational environmental performance. Therefore, both LCA and OLCA results should be used to plan environmental performance improvement, and production allocation strategies should be considered to avoid environmental burden shifting. D'Eusanio, Tragnone, and Petti (2022b) discuss the use of LCT methodologies to analyse the supply chain of wine, with a focus on implementing SOLCA in a wine-producing organisation in Central Italy. The study highlights the need to integrate the evaluation based on SA8000 with other data to capture additional working-related social themes in the assessment. Another study by D'Eusanio, Tragnone, and Petti (2022a) explores the methodology of SOLCA and its correlation with SLCA. The study implements SOLCA on an existing SLCA case study in the honey industry, examining the social performance of companies involved in the supply chain. The results show that while there are differences between the two methodologies, they become blurred when implemented.

In the food service sector, a case study can be found in the study by Jungbluth, Keller, and König (2016), it investigated the environmental impacts of food consumption in canteens and identified ways to reduce these impacts. They found that food purchases had significantly higher environmental impacts compared to canteen operations, with meat and dairy products identified as key areas for improvement. Based on their findings, the SV Group implemented the "ONE TWO WE" program, leading to a reduction in GHG emissions in participating canteens.

In the manufacturing sector, the paper by de Camargo et al. (2019) presents a case study of a Brazilian cosmetics manufacturer implementing OLCA to quantify and manage environmental impacts throughout their global supply chains and individual products. The study demonstrates that OLCA allows for methodological choices and implementation challenges encountered by the company, including a broad product portfolio. A hybrid approach is used for data collection, with major impacts detected during the use phase and in the supply chain. The study confirms the applicability of the OLCA model and identifies gaps and opportunities for future implementation and LCA-based management. As in the manufacturing sector, Manzardo, Loss, Jingzheng, et al. (2018) employed OLCA to monitor the environmental impacts of a special purpose entity building a tourist village in Italy. The study demonstrated the applicability of OLCA in the construction sector and introduced the activity portfolio concept, control, and influence approach to identify environmental hotspots and areas for improvement.

In the context of institutions, multiple case studies on HEIs have been conducted. Erauskin-Tolosa et al. (2021) discuss the use of SOLCA to estimate the social footprint of the University of the Basque Country (UPV/EHU) and its potential contribution to Sustainable Development Goals (SDGs). The study found that labour activity at UPV/EHU had the greatest social impact, followed by processes related to transport, energy, materials, and waste management. SOLCA was recognised as a valuable tool for HEIs. Similarly, Bueno et al. (2021) calculated the University of the Basque Country's (UPV/EHU) environmental and social footprint in 2016 collecting input and output data flows. The environmental and social impacts of the academic activity were modelled using various methods, identifying hotspots such as transport and the life cycle of computers. The social footprint also revealed traces of child labour and illiteracy. Alternative scenarios and improvement actions were explored to reduce the environmental and social impacts of UPV/EHU's activity. Bueno et al. (2022) conducted both OLCA and SOLCA for the University of the Basque Country UPV/EHU in 2016, they provide detailed information on the UPV/EHU, and the boundaries considered, as well as the compilation and quantification of the life cycle inventory (LCI). The data presented may be used as a reference for future calculations of the environmental and social footprint of HEIs. Alternative scenarios were explored to check pathways to reduce the social and environmental impacts of the academic activity of the UPV/EHU. In the analysis of cities, (Cremer et al. 2021) assessed the feasibility of city-OLCA with real data from Vienna. The discusses the environmental pressures caused by cities and the use of OLCA as a framework for city-scale environmental decision support. The city-OLCA approach extended beyond public service provision and GHG emissions, revealing that current accounting practices may underestimate the city's GHG emissions by up to a factor of 3.

The UNEP/SETAC report titled "LCA of Organizations," analysed by Martínez-Blanco, Forin, and Finkbeiner (2018), showcases the results of a road-testing initiative conducted by 12 organisations across various sectors and regions. Serving as a complement to the "Guidance on Organisational Life Cycle Assessment," this report offers guidance to practitioners and inspires method developers. Through comprehensive OLCA studies, these organisations validated the practical application potential of the OLCA method, indicating minimal immediate updates required to the OLCA Guidance. However, the road testing also identified key priority actions for enhancing OLCA application, including addressing methodological challenges specific to certain organisation types, overcoming road testing difficulties, and leveraging the organisational perspective in related LCA fields. Additionally, Forin, Martínez-Blanco, and Finkbeiner (2019) discuss similar findings from an anonymous survey, emphasizing the prioritization and achievement of analytical goals over managerial and societal goals in OLCA studies. Challenges were encountered in categorising organisational activities, data collection, quality assessment, and interpretation. The survey underscores the usefulness of OLCA Guidance but highlights the need for additional resources and guidance to facilitate OLCA case studies. The OLCAs conducted by the 12 organisations, representing various sectors, revealed significant environmental hotspots, and provided valuable insights for mitigating environmental footprints. These analyses informed sustainable practices within their respective industries and regions. Collectively, these findings underscore the importance and potential of OLCA in promoting environmental sustainability across diverse organisational landscapes.

4.4 | Limitations

As organisations navigate the complex landscape of sustainability, OLCA emerges as a strategic tool that extends beyond traditional environmental impact assessments. Its comprehensive approach not only provides a comprehensive understanding of the environmental consequences associated with a diverse product range but also empowers organisations to make strategic decisions aligned with sustainability goals. In the context of a rapidly evolving business environment, OLCA serves as a valuable ally in the pursuit of environmentally responsible and resilient organisational practices.

However, some limitations can be recognised, from the analysis of the literature.

A primary challenge with OLCA is the difficulty in directly comparing results. According to ISO/TS 14072, results from OLCA cannot be directly compared between different organisations. This limitation arises because, unlike product LCA, where a functional unit allows for direct comparison, OLCA deals with entire organisations that have unique and varied purposes. Consequently, comparing two distinct entities becomes problematic, as their activities and goals are not aligned in a manner that allows direct comparison.

Another critical challenge is setting system boundaries for the OLCA. This involves several complex decisions. It is crucial to identify and account for all relevant activities within the organisation to ensure a comprehensive assessment. Deciding whether to include indirect downstream activities can significantly impact the assessment's scope and results. The inclusion of activities is often constrained by the availability of reliable data, making it essential to balance comprehensiveness with practical data constraints. For organisations in the service sector, defining relevant activities can be particularly challenging due to the intangible nature of many services.

Effective data collection is fundamental to OLCA but poses several challenges. A thorough understanding of the data required for the assessment is necessary, which involves identifying all pertinent data points. Collecting primary data from various organisational sites requires significant coordination and resource allocation. In cases where primary data is unavailable, organisations must rely on secondary data, which can vary in quality and relevance.

Assessing the quality of collected data is another critical step, fraught with difficulties, as it requires to develop criteria for assessing data quality, which can be subjective and vary widely between organisations. The absence of a standardised method for evaluating data quality further complicates this process, leading to potential inconsistencies and biases in the assessment.

Finally, organisations may lack familiarity with ISO standards, making it difficult to accurately interpret and apply OLCA results. Proofing the consistency of the results is essential to ensure reflection of the actual organisation's environmental impact. Making the results understandable to a non-expert audience, including stakeholders and the public.

5 | Conclusion

The authors view OLCA as a crucial initiative to inspire companies to adopt the LCA perspective for their products or services. This methodology serves as a potent tool, not only fortifying strategic management within an organisation but also providing insights into both the nuances of products and the familiar terrain of organisational activities.

OLCA emerges as a tool with global applicability, for organisations of all sizes and sectors, stressing the role that it can have for SMEs. The ongoing initial steps in OLCA implementation have already highlighted notable improvements in environmental performance. Organisations with prior experience in environmental tools can leverage OLCA as a foundation for comprehensive integration, encouraging them to continuously improve about their environmental impact. Tailored recommendations for small, medium, and large organisations offer pragmatic avenues for progression.

Incorporating OLCA within MSME operations, especially those involved in complex value chains, allows for a more actionable application of LCT. This methodology serves not only to enhance transparency but also empowers these enterprises to compile and publish detailed sustainability reports. Such proactive reporting enables MSMEs to implement corrective measures effectively during the design and production phases, as well as in their supply chain decisions, facilitating the creation of innovative, sustainable, and intelligent business models. These models significantly reduce

environmental footprints and promote greener, more self-aware operations with quantifiable outcomes. The study contributes to the field by demonstrating how OLCA can directly benefit MSMEs by making environmental monitoring more accessible and providing a platform for clear communication through sustainability reports. These capabilities help avoid greenwashing and burden shifting at organisational level, thanks to the reliance on robust, scientific data, and support the implementation of circular strategies and sustainable business models. By articulating these benefits and showcasing successful implementations, the work aims to inspire other MSMEs to adopt OLCA. The integration of this methodology not only enhances consumer awareness and meets market demands for sustainable products but also ensures that adopting sustainable practices is both economically viable and operationally feasible. Thus, the findings highlight the transformative potential of OLCA in enabling MSMEs to engage in sustainable practices.

Furthermore, the adoption of a multicriteria assessment approach beyond carbon footprint at the organisational level has been instrumental in enhancing sustainability practices. Leveraging science-based assessment methodologies has facilitated the establishment of reduction targets on hotspots pertinent to the organisation, ensuring a targeted approach towards environmental improvement. Moreover, the quantitative assessment provided serves as a robust foundation for future sustainability reporting efforts, enabling transparent communication of environmental impact results relevant to the sector.

A crucial area highlighted by existing research is the lack of case studies, which needs to be addressed to provide empirical evidence of OLCA's benefits and challenges. This gap in case studies calls for future research to provide a solid and comprehensive base, encouraging other researchers to explore this area further. Such studies could also promote OLCA's influence on product innovation and design for sustainability, ultimately contributing to the development of sustainable and economically viable products. This future research will be pivotal in ensuring that OLCA contributes effectively to organisational and environmental sustainability goals.

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Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

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