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Review

Social Life Cycle Assessment in Municipal Solid Waste Management Systems with Contribution of Waste Pickers: Literature Review and Proposals for New Studies

Flávio Mattos * and João Luiz Calmon

Department of Environmental Engineering, Federal University of Espírito Santo, Vitória 29075-910, ES, Brazil
* Correspondence: flavio.mattos@ufes.br; Tel.: +55-27-4009-2648

Abstract: Since the publication of the Guidelines for Social Life Cycle Assessment (S-LCA) of Products by the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) in 2009, there has been an increase in publications and research using this tool to assess the positive or negative social impacts of products and services. This can be done by assessing all processes in the material supply chain, thereby identifying and quantifying the respective social impacts to inform decision makers. Because raw materials can come from different countries, some production processes may use recyclable or reusable materials handled by waste pickers in order to return them to the production chain. Since these waste pickers earn their living from collecting and selling these materials, the social impacts of the final product integrate the social evaluation results of the processes involving these materials. Thus, this article aims to survey the characteristics of current S-LCA models applied to Municipal Solid Waste Management Systems (MSWMS) that include waste pickers and their organizations, in order to identify research opportunities to expand the understanding and application of this tool. In this study, 33 articles were selected, using a systematic review methodology. Analyzing these articles has revealed possible paths to improve the choice of elements for S-LCA models applied to MSWMS that involve waste pickers or equivalents.

Keywords: life cycle assessment; municipal solid waste; waste pickers; recyclables

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1. Introduction

Social life cycle assessment (also known as Social LCA, S-LCA or SLCA) emerged from the need to evaluate social impacts within the LCA (life cycle assessment) methodology. According to the United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC) [1] (p. 33), the definition of S-LCA is:

> (. . .) "a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their potential positive and negative impacts along their life cycle encompassing extraction and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal".

S-LCA has been thriving in social studies of products and processes and, together with Environmental LCA and Economic LCA, can be used for sustainability assessments [2]. According to Reichert and Mendes [3], the same is true for LCA when used to design municipal solid waste management systems (MSWMS), initially assessing environmental aspects and conjugating them with social and economic properties. These MSWMS consider the generation, collection, recycling and treatment stages up to the environmentally correct final disposal [4] of waste and refuse.

Recycling is one of the possibilities for treating the generated waste [5,6]. As recycling favors the reuse of materials in place of virgin raw materials, it is an economical, environmentally important activity [7]. The social impacts of processes and products made with

these materials are now being scrutinized, because decision makers (company or public managers) need to understand how much a product or a certain process affects a particular group in society and to analyze, compare and/or choose the effect aligned with ensuring or improving social welfare [8].

The waste picker figure, connected with the collection and trading of these materials, emerges when analyzing new product manufacturing using recyclable or reusable materials in developing countries, like Brazil, Peru or Turkey [5–7]. Waste pickers are people who work alone or in groups [9]. In this context and based on the selected articles, Brazil was the only country with legal inclusion of waste pickers in MSWMS, supported by Brazilian Law no. 12,305 [10]. For this inclusion, pickers usually gather in organizations called waste picker organizations (WPOs), which are one of the links of the recycling chain in Brazil [9].

In Brazil, pickers perform functions such as collecting reusable and recyclable materials in public locations or from donating people or companies; receiving materials; sorting the different types of plastic, metal, etc. in piles; weighing; baling, which facilitates loading and transport; trading and dispatching the processed materials; and shipping the refuse [11]. However, unlike in formal collection systems, WPOs obtain their revenue based on sales of materials obtained by themselves [12], which serve to pay the pickers wages and other expenses of the WPO.

As S-LCA is not as mature as environmental LCA [13], a greater dissemination of S-LCA studies will provide greater knowledge of this tool, as well as greater communication about existing or potential impacts identified in the life cycle of a product, process or service [14], specifically ones that use recyclable materials. In addition, there are still many challenges in the use of S-LCA, for example variable selection and the use of indicators, impact categories and characterization systems [15]. This has resulted in a number of incipient papers in well-established databases in which this tool was used in social assessments of waste pickers in MSWMS.

S-LCA papers involving pickers or WPO are most frequently based on the UNEP-SETAC [1,16] methodology, e.g., Aparcana and Salhofer [5,17]; Foolmaun and Ramjeawon [8]; Menikpura et al. [18]; Yildiz-Geyhan et al. [19]; and Ibáñez-Forés et al. [6]. The development of LCA studies initially followed the LCA sequence (ISO 14040) [20] of four essential phases: goal and scope definition; inventory analysis; impact assessment; and interpretation. UNEP [21] introduced a fifth phase, communication, a differential item of S-LCA when compared to LCA.

However, cultural variations, ideologies, and degrees of development specific to each country can influence the social aspects related to MSW recycling, and consequently the S-LCA methods to be applied in studies [22]. This paves the way for an analysis of existing studies that include waste pickers in MSWMS and methodological characteristics in the use of the S-LCA, which will allow readers to verify the following items:

1. Major publications and authors in the research field that correlate S-LCA, recyclable waste management, and organized pickers or those in similar situations;
2. The main characteristics of the S-LCA methods used, analyzed within each S-LCA phase, for the review papers and S-LCA papers in the research field of Item 1;
3. Points for improvement and research gaps for S-LCA studies in the research field of Item 1.

2. Materials and Methods

2.1. S-LCA Structure and Nomenclature

The classification structure used in most of the selected articles—how the elements of the assessment system are interconnected—is shown in Figure 1. UNEP and SETAC were the precursors in fostering the development of a guide to orientate the execution of an S-LCA. In 2020, the 2009 guide was updated by UNEP [21], and it is divided into six stakeholder categories (workers, local community, society, consumers, value chain actors and children); six impact categories (human rights, working conditions, health and safety, cultural heritage, governance and socio-economic spillovers) and 40 subcategories, which

use inventory indicators [1,16,21,23]. These indicators are present in "The Methodological Sheets", published in UNEP-SETAC [16].

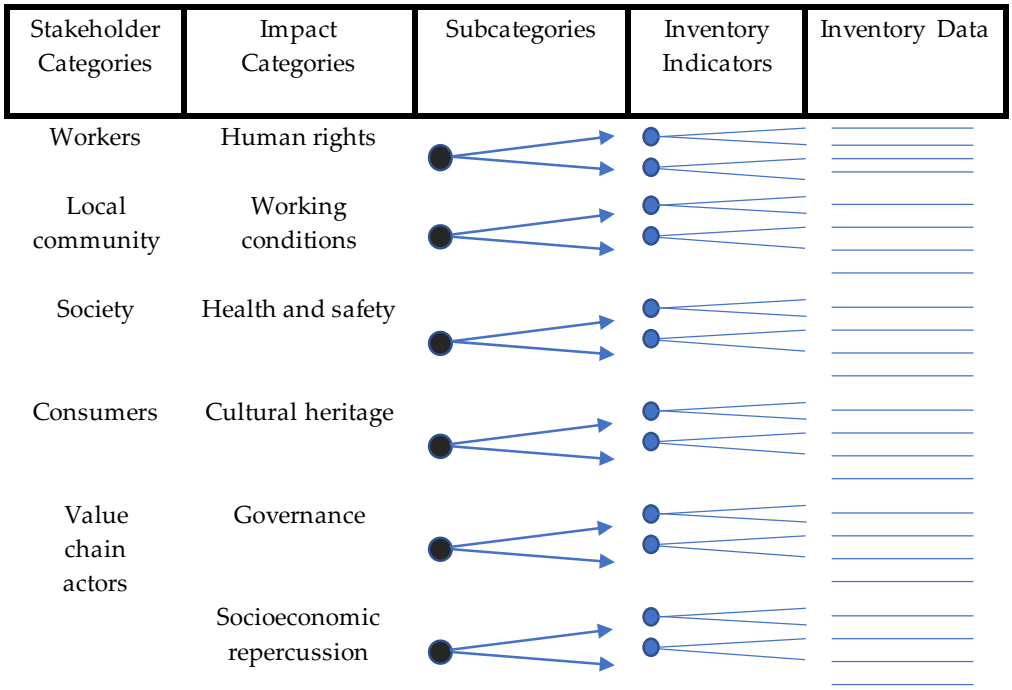

Figure 1. S-LCA classification structure used in the selected papers. **Source:** Adapted from UNEP [1].

In this classification structure, some definitions are necessary to understand its components and how they interrelate when the evaluation methodology is used:

- Impact categories are " . . . logical groupings of S-LCA results, related to social issues of interest to stakeholders and decision makers" [1] (p. 67). In short, these categories represent real or potential social impacts gathered during the assessment process;
- Subcategories can be perceived as subdivisions of the Stakeholder Categories. The Subcategories will synthesize or represent, in quantitative or qualitative form, the outcomes of the characterization system applied to the indicators. On the other hand, the contextualization below is also important to associate the S-LCA classification system with the impact categories.

  "Subcategories of an Impact Category seek to describe the overall meaning of the indicators used to represent this subcategory. This is done through a set of indicators used to represent this Category (e.g., Impact category: Working conditions, Subcategory: Social security and benefits, inventory indicators: percentage of employees covered by (1) health insurance, (2) retirement insurance, (3) paid maternity and paternity leaves, (4) legal contracts, etc.)" [1] (p. 68).

Depending on the stakeholder categories (workers, local community, society, consumers, value chain actors and children) there is a division into subcategories [21]. For example, the consumers stakeholder category is divided into the subcategories: health and safety, feedback mechanism, consumer privacy, transparency, and end of life responsibility.

- Indicators act as a bridge between inventory data, the subcategories and the impact categories and guide the data collection process [24]. The methodological sheets from UNEP-SETAC [16] provide recommendations for selecting indicators. Nevertheless, UNEP-SETAC [1] does not restrict the use of all categories and subcategories in S-LCA, nor the inclusion of new subcategories and indicators.

Regarding impact assessment models, there are two main alternatives, Type I and Type II. The first, or the reference scale approach, uses performance reference points (PRPs) or reference scales for the evaluation. Its inventory includes qualitative, semiquantitative, or quantitative data. Type II uses the impact path approach and has its inventory based on quantitative data. Figure 2 indicates the steps of Type I and Type II models, simplified.

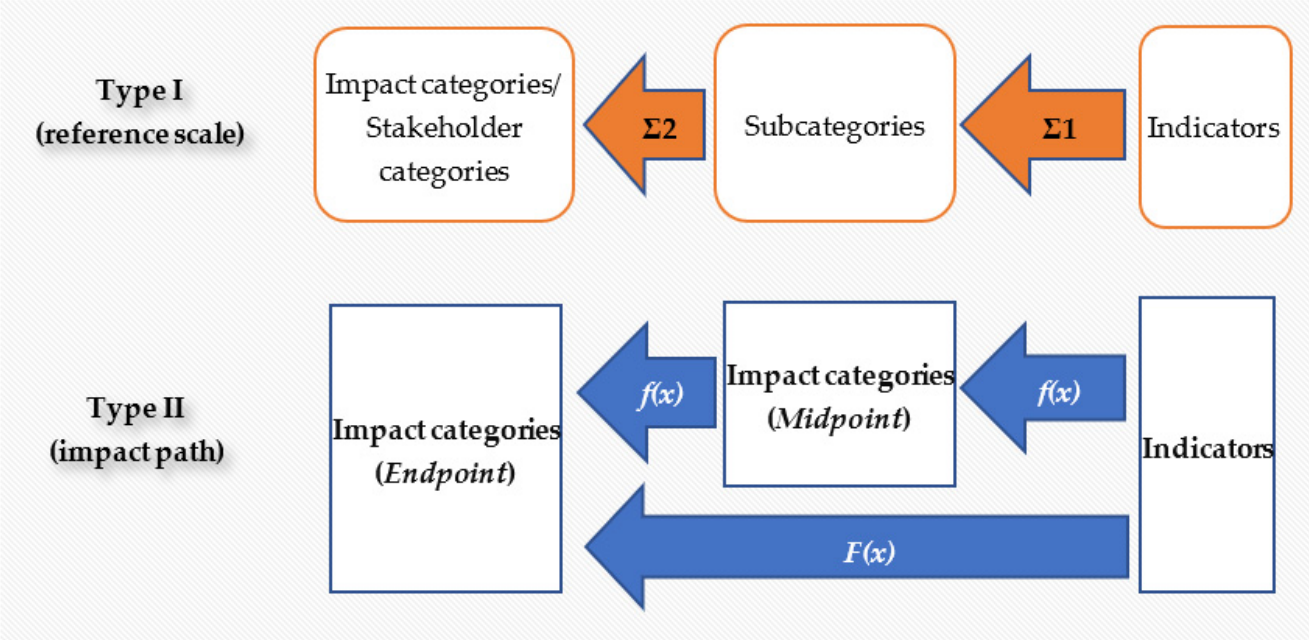

Figure 2. Type I and Type II impact assessment models. Source: Adapted from Wu, Yang, and Chen [25]. Note: Σ1 and Σ2 are characterization models that represent a relationship between the indicator or subcategory value and the value or code representing the impact on the categories; f(x) is a formula or mathematical model that brings the data or indicator value to the social impact value, relative to a midpoint or endpoint. The midpoint covers the characterization of the impact in the middle of the cause–effect chain and the endpoint does so in the area of protection (AoP), which translates to the final impact on human well-being [21].

Choosing Type I or II depends mainly on the purpose of the study:

1. Type I should be used if the goal is to describe the product's process with a focus on its social performance or social risk;
2. Type II should be used if the goal is to predict the social consequences (impacts) of the product's process, with emphasis on characterizing potential social impacts.

An example for a Type I model: the worker's salary is an inventory datum, the fair wage (sufficient for worker's needs) is an indicator and the national minimum wage is a reference. The worker's salary may be above, equal to or less than the reference point, resulting in a coding that will represent a value for this indicator. Based on the indicator value and the characterization methodology, a value will be generated for the subcategory, and so on, up to the category to which the subcategory is linked. If the subcategory has more than one indicator and the category has more than one subcategory, it should be explained how this data will be combined to generate the value for the next element of the structure in the following sequence: indicator, subcategory, and category [1].

Conversely, Type II uses impact pathways (like environmental LCA), i.e., the value of a given indicator (for example, working hours), which, when inserted into a mathematical model (characterization), indicates how much human well-being (lifespan, for example) would be affected. Based on the example cited above, the increase in working hours on that product, under certain conditions, could cause a decrease in the worker's lifespan, which causes a decrease in human welfare [1].

Importantly, impact categories and subcategories can be independent of the type of impact assessment chosen (Type I or II) and are used to represent positive or negative social impacts, as well as relevant socioeconomic impacts of the product or process life cycle associated with the stakeholders selected for the study. However, Type I typically has a focus on impact subcategories and stakeholder groups, while Type II typically classifies stock indicators with impact categories at the midpoint and endpoint, like in environmental LCA [21].

2.2. Systematic Review Method

To identify the most relevant S-LCA studies on MSW management involving waste pickers to reinsert recyclable materials into the life cycle of products, a systematic survey of the literature was necessary. In order to be reproducible, this survey used a reproducible scientific method, using Bibliometrix [26] and Methodi Ordinatio tools [27].

Regarding the first phase, the keywords presented in Figure 3 were used in the Web of Science and Scopus databases. The time period was initially set at 10 years, then extended to 2009–2021 (February). This change was necessary in order to include the publication of UNEP-SETAC from 2009 [1]. The exported CSV files from the two databases were processed with the R Studio software [28] to remove the duplicate entries and merged into a single CSV file, usable in Microsoft Excel. Additionally, in a spreadsheet, the papers with an Ordinatio number greater than 10 were sorted in descending order. This value is obtained by the Methodi Ordinatio method formula and takes into account the journal impact factor, the year of publication and the number of citations of the paper [27]. The magnitude of this value can be understood as the scientific relevance of the article. The values generated for the articles ranged from 0 to 249, which generated a rank of the various articles.

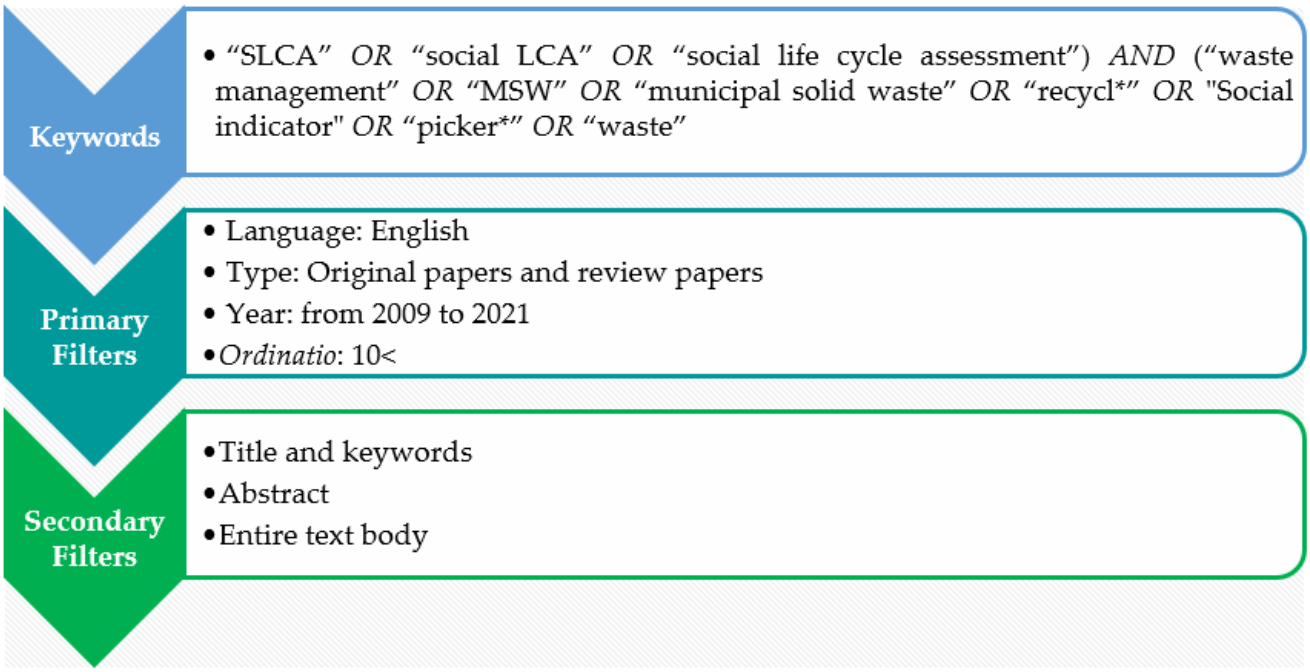

Figure 3. Steps for paper selection.

The papers were then manually filtered by (1) reading the title and keywords, (2) reading the abstract and (3) reading the entire text. After this selection, the initial 177 raw files from the Methodi Ordinatio were narrowed down to 33 relevant papers, including reviews. This activity removed papers misaligned with the scope of this review. The authors used other documents like papers, standards and grey literature to improve their studies, which were selected from the references of these 33 papers.

The selected papers were the object of a thorough bibliometric analysis, to verify the journals with the most papers published, publication year, first author and country predominance, among other aspects. Subsequently, a systemic analysis was performed to gather specific characteristics of the selected articles, which were allocated according to the S-LCA stage to achieve the goal of this study.

3. Results

The first part of the results takes into account the metadata of the articles, such as journal, authors, year of publication, country of the first author, etc. The second part deals with the actual text of the papers, extracting the necessary information to identify challenges for the improvement of S-LCA and the dissemination of this tool, especially regarding WPO in MSWMS. This information will be tabulated together with the authors of the articles.

3.1. Bibliometry Results

Of the 33 articles selected, 19 were studies and 14 were reviews. The top three journals with the most articles published were the International Journal of Life Cycle Assessment, Sustainability, and the Journal of Cleaner Production (Figure 4). The years of greatest publication were 2019 and 2018, followed by 2013, 2014 and 2020, with four papers each (Figure 5). In studies concerning waste pickers, WPO or similar alliances that can be considered as associations, nine S-LCAs based on UNEP-SETAC [1,16] were analyzed: Aparcana and Salhofer [5,17], Foolmaun and Ramjeawon [8], Menikpura et al. [18], Yildiz-Geyhan et al. [19], and Ibáñez-Forés et al. [6].

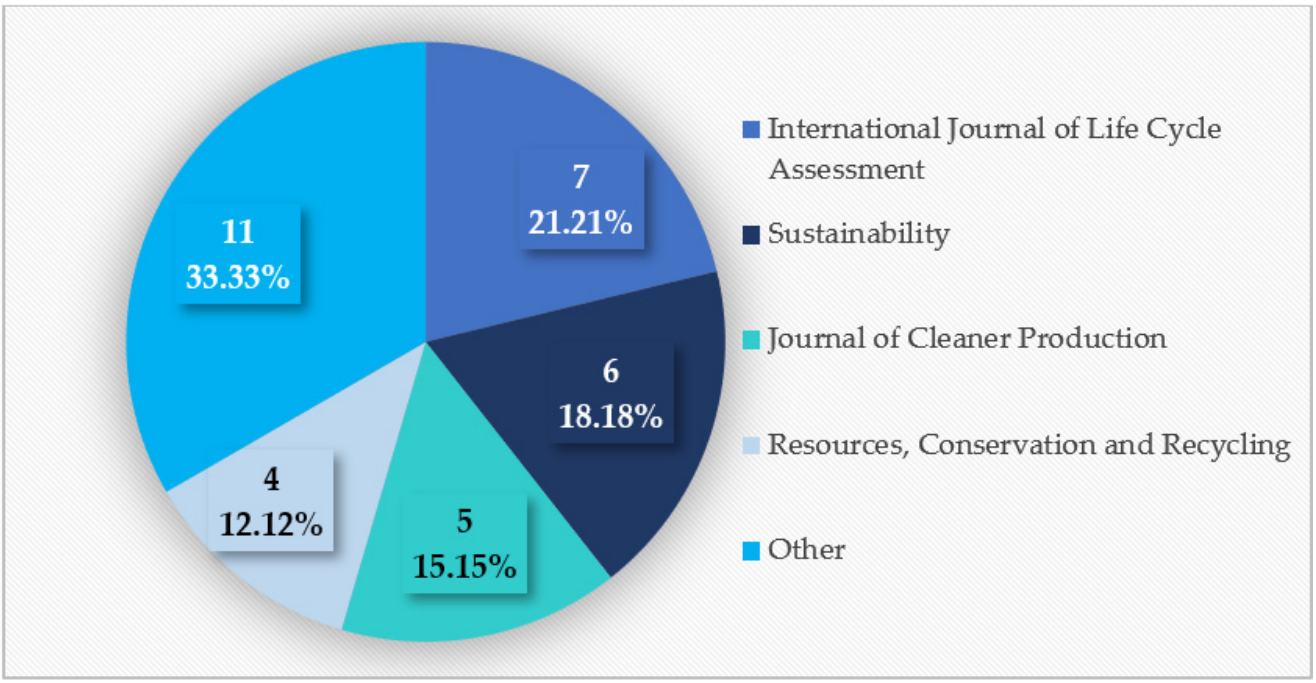

Figure 4. Publications by journal. Note: The category "Other" includes Clean Technologies and Environmental Policy, Corporate Social Responsibility and Environmental Management, Ecological Indicators, Sanitary and Environmental Engineering, International Journal of Environmental Science and Technology, Mitigation and Adaptation Strategies for Global Change, Waste and Biomass Valorization, Waste Management, and Waste Management and Research.

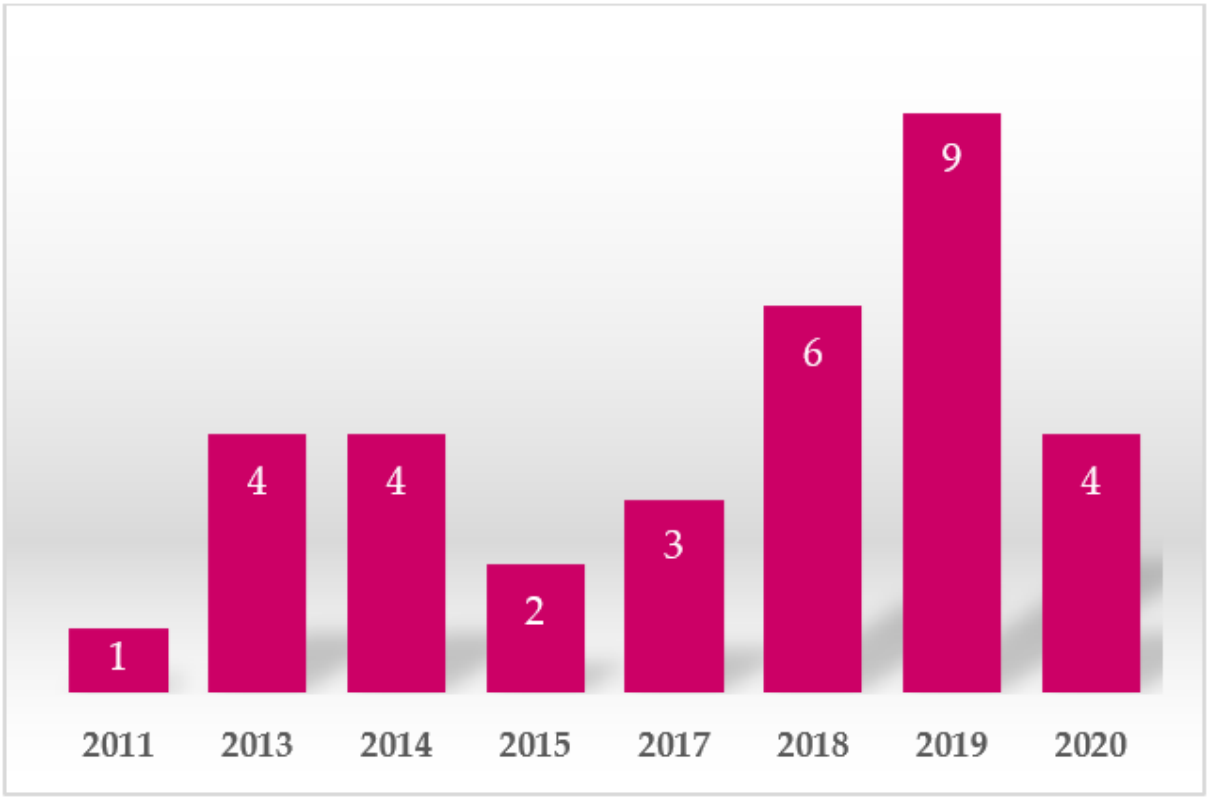

Figure 5. Number of papers throughout the time period of the analysis (2009–2021).

3.2. Systemic Analysis Results

The selected papers analyzed were divided into 19 application and methodology papers and 14 review papers. In the first group, the intrinsic characteristics of each study were verified and grouped according to the five S-LCA phases, according to UNEP [21]: goal and scope, inventory analysis, impact assessment, interpretation and results. As for the review papers, these S-LCA steps were also used to allocate the information, but in a different way: emphasis was given to the amount of repeated information on need for improvement, difficulty of consensus, and research challenges, among other things.

3.2.1. Application and Methodology Papers

Goals and Scope

Of the papers that apply S-LCA to MSW management, 19 focus specifically on S-LCA or sustainability (both with 42%) or on S-LCA with environmental LCA (16%). This indicates that S-LCA is most frequently an element of sustainability analyses of products and processes, rather than used in isolated social studies.

As to the object of analysis, recyclable MSW is the most chosen (53%), indicating concerns that go beyond environmental issues, and also converging on social issues regarding material recycling processes. The study by Menikpura et al. [18] confirms this by verifying that recycling 24% of the waste compensates environmentally, economically, and socially for the rest of the materials landfilled.

Regarding location, the city/neighborhood level is the most widely used (in 58% of studies) while the country level is second (37%). For example, Yildiz-Geyhan et al. [7] describe the study site as a neighborhood with a cosmopolitan structure that represents the profile of the whole country. However, more information can be given about its population, income, and other features, to reference their characteristics and thereby promote understanding and utilization of the information by other studies.

The facilities of the MSWMS most addressed in the studies are collection/recycling/treatment/final disposal (42% of the studies), followed by collection/recycling (32%). This

shows the importance of collection and recycling, especially in developing countries, as these papers address informal collection and recycling of materials as a mean of subsistence for the pickers [5–7,17,29]. Regarding the addressed facilities, the system boundaries can be considered as grave-to-grave: after the disposal of the used product and recycling or final disposal. This definition is an indication that the material was collected either from litter or through source-separated collection and will be used in recycling and the refuse will be sent to final disposal [25].

Among the case studies, 13 articles, the most-used functional unit (FU) was 1 ton of waste in four articles, and, in other four, the FU was not cited or used. There are cases in which the FU still cannot be used as a representation of the process, as in the environmental LCA, even though it is a representative form of the process. This can be a consequence of the inventory data being of the qualitative type [29]. Another possibility is that the way the FU is formulated does not allow comparisons with other research, given that its conception is particular to the case under study, e.g., total waste collected by collectors in a particular city.

The information gathered from the selected articles reveals that the main stakeholders are the workers, followed by the local community and society. As for the impact categories, in this order they were working conditions, health and safety of workers, and the community (which would be equivalent to public safety). The subcategories by order of use frequency are worker health and safety, equal opportunity/discrimination, social benefits/welfare, and safe conditions (regarding public safety)—the only subcategory not referring to workers. In terms of indicators, because the worker is the most-studied category, this implies the predominance of the use of indicators related to workers, namely, worker's salary, number of work accidents, and weekly working hours. The number of jobs created is a frequent indicator that can be linked to the local community category as well. A summary of the stakeholders and subcategories used in the articles that conducted case studies is presented in Table 1, as well as the United Nations Sustainable Development Goals that are directly or indirectly linked to these subcategories.

Inventory Analysis

Regarding the type of data, 79% of the papers use specific data (primary or secondary), which shows the effort to collect these data on site (neighborhood, city, or company) or the lack of data for the conducted S-LCA studies [18]. This is in line with the review and research papers, through interviews and field visits [5–7,17,29].

The indicators for which inventory data were collected are linked to those proposed by UNEP-SETAC [1,16], which were used by 42% of the articles. Nevertheless, 32% used "mixed" data that included indicators in addition to those proposed by UNEP-SETAC. This, together with the number of publications since 2009 verified in the review articles [15], demonstrates the importance of the UNEP-SETAC guide and methodology sheets [1,16] for S-LCA studies, which were revised in 2020 [21].

Articles with case studies or methodological studies, especially those involving pickers, had their data obtained through interviews, which qualifies them as primary sources. Secondary data, from other studies or collected by other individuals or researchers [21] (UNEP, 2020), were used when the primary data were not available or were taken from other processes, such as environmental LCA, and employing other indicators beyond the UNEP-SETAC [1] list.

The data from analyzed papers did not mention structured quality assessment, such as the use of an adapted pedigree matrix or equivalent. Such assessment was already used in environmental LCA and is now advocated in S-LCA in UNEP [21].

Table 1. Articles with case studies, with the categories of stakeholders and the subcategories used.

Authors of Papers with Case Studies	Stakeholder Categories	Subcategories	United Nations Sustainable Development Goals
Aparcana and Salhofer [17] Azimi, Tooth and Hashimoto [30] Di Maria et al. [31] Foolmaun and Ramjeeawon [8] Harijani et al. [32] Ibáñez-Forés et al. [6] Umair; Bjorklund and Petersen [29] Yildiz-Geyhann, Altun-Ciftcioglu and Kadirgan [19] Yildiz-Geyhan et al. [7] Zhou et al. [33]	Workers	1 Child labor 2 Discrimination 3 Possibility of being unionized/unionized agreement 4 Hours of work 5 Fair wage 6 Health and safety 7 Employment contract and social benefits 8 Physical working conditions 9 Psychological working conditions	Poverty eradication (5, 12, 16) Health and wellness (6, 8, 9, 14, 16) Gender equality (2, 5, 9, 10) Clean water and sanitation (15, 16) Decent work and economic growth (1, 2, 4, 5, 6, 7, 8, 9, 12, 17) Infrastructure innovation (17) Reduction of inequalities (5, 10, 12, 16, 17) Sustainable cities and communities (15, 20)
	Local Community	10 Education 11 Community participation 12 Local employment 13 Society engagement 14 Social acceptability	
	Society	15 Public commitments to sustainability issues 16 Contribution to economic development 17 Technological developments 18 Governance	
	Consumers	19 Feedback mechanisms 20 End-of-life responsibility	

Note: Numbers in parenthesis indicate the direct or indirect link of the subcategory to the United Nations Sustainable Development Goals.

Impact Assessment

Aggregation was performed predominantly (32%) with numerical models (e.g., formulas), followed closely (26%) by means of coding through scales or tables. This is largely a consequence of using qualitative data, obtained from interviews and observations, which are transformed into semiquantitative data [6,29], which is substantiated by the dominance of Type I characterization (47%) instead of Type II models (11%). This fact shows that cause–effect relations and impact pathways, used in Environmental LCA, are still uncommon in S-LCA.

The relative importance of a social impact category or subcategory can be solved by applying different weights. However, weighting is infrequent, used only in 4 papers out of 19, and in S-LCA itself was only used in two articles, and only two articles used the AHP tool to perform it. For example, Aleisa and Al-Jarallah [22] used AHP to allow a cross-evaluation of tangible and intangible measures of different social indicators when assessing social impacts through S-LCA.

In studies that include pickers and/or WPO, there are equalities regarding the type of data collection and characterization, i.e., with the use of primary data (interviews) and the Type I characterization method. This is because the characterization models are mostly developed by the authors themselves, which restricts the use of specific programs and databases. For instance, Social Hotspot Database (SHDB) and the Product Social Impact Life Cycle Assessment Database (PSILCA) were created to obtain the social impacts of products and processes, although some limitations can be attributed to the use of generic data [14].

Regarding the methodologies found in the articles, the characterization models used aggregated the data in subcategories most frequently (74%). This shows that the classification into indicators, subcategories and impact categories is applied mostly to subcategories,

using tables and scales. These can be evaluated to obtain the social impact or impact indicator hotspot and then represented in the impact category [8,34].

Results Communication

The results of case studies are usually communicated through an analysis of the values obtained via the characterization methodology applied. The existence or not of social impacts can be shown with a binary value (0 or 1), colors, or in other ways, further detailed in Section 4.3, a characteristic of the Type I characterization model used in most studies addressed. This means the author has to describe an analysis of this result aiming at the understanding of the reader to whom the study is intended.

3.2.2. Review Papers

Fourteen review studies were analyzed, and one paper by Ibáñez-Forés et al. [6], besides an S-LCA, also contained a review. Of these 14, 11 of them identified S-LCA improvements intended to make the use of this tool easier and more precise (Table 2). Thus, the most relevant aspects raised in this analysis were whether general or specific data should be prioritized for the study and difficulty in selecting indicators and system boundaries. These aspects will serve as a reference for the analysis of case studies and methodological papers used in S-LCA studies in MSWMS with waste pickers. This helps to identify the development points for S-LCA used in the research field covered here.

Table 2. Aspects of interest for improving S-LCA raised in the review studies.

Authors **Aspects of S-LCA in Need of Improvement, Difficulty in Consensus and/or Research Challenges**	**Bonilla-Alicea e Fu [15]**	**Wu, Yang and Chen [25]**	**Chhipi-Shrestha, Hewage and Sadiq [23]**	**Dubois-Iorgulescu et al. [35]**	**Di Cesare et al. [36]**	**Petti, Serreli and Di Cesare [37]**	**Venkatesh [2]**	**Wulf et al. [38]**	**Huarachi et al. [39]**	**Subramanian, Chan and Yung [40]**	**Zhou et al. [41]**	**Total**
Data availability/Collection criteria	×	×					×			×		4
Use of general or specific data	×	×	×				×	×		×		6
System limits under study	×		×	×		×	×					5
Definition/use of functional unit (FU)	×					×					×	3
Definition of protection area (PA)	×		×							×		3
Selection of stakeholder categories/selection of impact categories	×	×	×									3
Selection of indicators	×	×			×		×	×		×		6
Use of qualitative, quantitative and semiquantitative data			×						×		×	3
Use and/or form of weighting, normalization and characterization	×		×							×	×	4

Table 2 summarizes the main challenges of S-LCA studies, as analyzed by Bonilla-Alicea and Fu [15], and presents a synthesis of enhancements aiming to bring maturity and greater use to this tool. Among them are choosing which social impacts to consider and their quantification; selection, normalization, aggregation and weighting of indicators; definition of the FU and whether it should be used; minimum criteria to be met in data collection; allocation of social impacts by categories; definition of "social well-being" to be used in the analysis and affected by the impacts; selection of a normalized method for

S-LCA; system boundaries; selection of general or specific data; scoring scales to inform the results achieved (scoring method); and which stakeholders are relevant to the study.

Other aspects not highlighted in the review papers, but important for the alignment of this research are that: the use of semiquantitative indicators by several papers emphasizes the effort of the authors to express the indicators as quantitative variables [36]; the positive impacts are still at an early stage in the S-LCA; the indicators related to safety and health and implications for employees are the most used [38]; there is a shortage of techniques to integrate positive and negative social impacts [40]; any new S-LCA method should be validated by a case study, with the topics of interest being linked to bioeconomy and bio-based products [39]; and that there are few articles on MSWMS in South America, notably those of Aparcana and Salhofer [5] in Peru and Reichert and Mendes [3] in Brazil [6].

It is noteworthy that UNEP, at the end of 2020 [21], published an update of the 2009 guide, entitled Guidelines for Social Life Cycle Assessment of Products and Organizations 2020, which includes better explanations of mentioned aspects that are under development or that raise questions among S-LCA practitioners. However, the results of this guide will only appear after 2020, and are probably not captured in the selected bibliometric articles. Nevertheless, the challenges raised here can still be considered, as they can be used for new developments and updates in other guides, standards and articles to be published on S-LCA, especially in the line of research addressed.

4. Discussion

As the articles have already been analyzed using the steps of an S-LCA study, according to UNEP-SETAC [1] and SETAC [21] this form will also be employed for the discussion to correlate the issues discussed in the analyzed articles. These aim at S-LCA improvement in the addressed research field and identify gaps and challenges for future research. Figure 6 shows the items identified as of interest for the correlation proposed above, for each of the S-LCA steps.

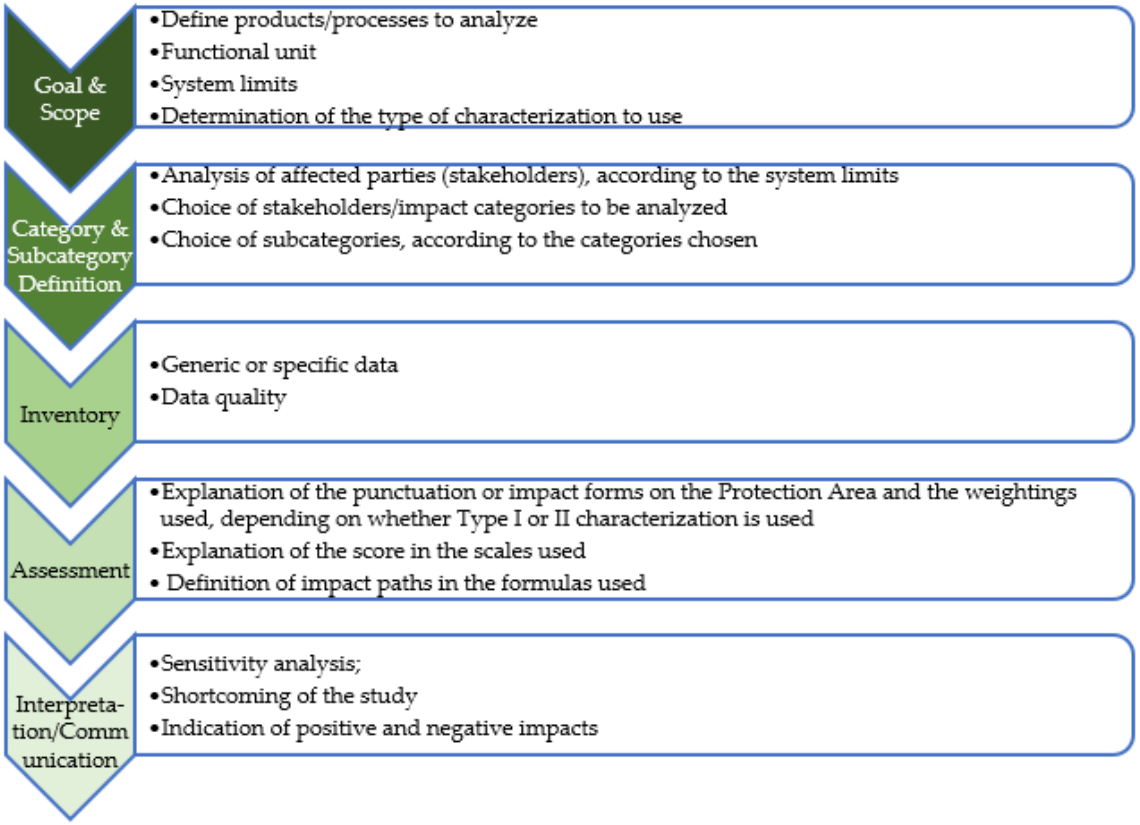

Figure 6. Summary of the S-LCA guidelines most used by the analyzed articles.

4.1. Goal and Scope Phase

The functional unit (FU) is used to quantify the functions identified in the product and is a definition of a performance measure for the product under analysis (e.g., m^3 of material when analyzing the production of concrete). The FU is simpler to understand and use in environmental LCA. However, in S-LCA, data and information are frequently particularities or characteristics of the processes and/or companies that hold the process or product under study, which has no way to be aggregated in FUs throughout the life cycle of an S-LCA study [42]. Such facts, among others, lead to citing of the FU but not relating it to the process or product under analysis [19]. The most-used FU in the research field of this article was one metric ton of recyclable waste or refuse. Despite the controversy in the use of FUs, such a unit is necessary for a compatibility between S-LCA, environmental LCA and economic LCA, particularly in sustainability assessments.

As for scope, the boundaries of the system under study were:

- *Grave-to-grave* [25]—when the process for obtaining recyclable products happens after the use of the product and before final disposal in landfills or incineration.
- *Grave-to-cradle*—when the material is collected by pickers or another process, like source-separated collection, and is sent to a recycling company to be returned to the production chain as raw material.

The system components and its boundaries should be clearly presented, allowing the readers to identify the parts of the product/process life cycle that are being assessed and the respective impacts. This also enables its compatibility with environmental LCA, although the boundary of S-LCA can be considered broader [15]. In support of environmental LCA, the phase in which the system is analyzed should be explicit, e.g., the construction, operation, maintenance or demobilization phase. However, data collection leads the S-LCA to be used, according to the articles reviewed, in the manufacturing phase of a product or system/process operation. Five of nine review papers indicated that the system boundaries are research challenges, because they can obscure comparison between studies.

In the articles with case studies, Type I characterizations were chosen more often than Type II characterizations. This tended to be influenced by the type of data that was collected—qualitative or semi-quantitative—which generates a tendency to choose methods that use reference scales, for example to score indicators that are based on these types of inventory data.

4.2. Definition of Categories and Subcategories

The choice of *stakeholders* will be based on the context of the study, according to the possible situations that can generate social impact arising from the production of a given product or process. This results in a prediction of the categories that will possibly be impacted [43]. The stakeholder categories most used in the articles were workers, local community and society. Workers is the stakeholder group most studied by researchers not only in MSWM systems, but also in other LCA studies [6,36,44], where the number of jobs generated, hours of work and worker's wages or earnings indicators are analyzed. Regarding the local community and society, they receive direct influence from MSWM systems.

The selected impact categories are also in the direct area of influence of services and economic opportunities brought about by the MSWM system. Human Rights, Working Conditions and Socio-Economic Repercussion are the impact categories most frequently used, which are included in case studies from Aparcana and Salhofer [17], Ibáñez-Forés et al. [6], and Yildiz-Geyhan et al. [7]. Three review papers address the choice of stakeholders or impact categories.

As for the choice of subcategories, there is no consensus among S-LCA studies in the field of research of this paper (Table S2) regarding the categories that should be prioritized and the non-standardization of these by the guidelines or methodological sheets [45]. However, the use of the subcategories proposed by UNEP-SETAC [1,16] is more frequent.

4.3. Inventory (Data)

The wide selection of indicators includes those related to universal rights, based on the authors' perception of what should be evaluated, and focused on the consequences of operation along the service or product life cycle [44]. The analysis reveals that the authors have a great influence on the definition of the indicators, whose choices may result from their experience, may be characteristic of a certain sector or may have relevance in a certain geographical area. Nevertheless, this causes differences in approaches and heterogeneous lists, thus certain studies may lose meaning when analyzed in a different context [36].

The 2013 methodological sheet [16] has information on data sources—primary or secondary—for the indicators. Primary data are gathered through interviews or field research, while secondary data comes from reports and research, among other things, at the regional or national level [6]. From this difference, the researcher may be driven to use more specific data as it would bring more accurate information when compared to more generic data [1,46,47]. However, the time and cost of obtaining these data could make their use unfeasible. Choosing between general and specific data is one of the most cited points for improvement and research challenges in review papers.

Another important issue is that, unlike in the environmental LCA, where the cause-and-effect chains are already relatively clear, there is already a mathematical correlation that shows that a certain amount of a given indicator causes a particular environmental impact; in S-LCA, the choice of appropriate indicators becomes difficult due to the difficulty in correlating cause-and-effect chains in production activities, therefore in potential social effects. Additionally, the non-standardization of a set of indicators and/or the lack of data causes a wide variety of indicators to be used in the literature [48,49]. This and other factors led to the selection of case study articles in the bibliometric analysis that used primary data based on questionnaires or interviews, specifically studies performed on MSWM systems with waste pickers.

Regarding data quality, a pedigree matrix adapted from environmental LCA was published in an update of the S-LCA methodological guide [21]. Prior to 2020, the PSIA [50] already recommended a table for data qualification, which enabled authors and researchers to choose a type of data (primary or secondary) depending on the beneficiary (person or institution) of the study. However, the studies analyzed here did not contemplate any kind of data qualification.

Finally, it is noteworthy that the review papers pointed out the *selection of indicators* as one of the main aspects with the greatest potential for improvement, to expand the knowledge and use of this tool.

4.4. Assessment

Depending on the impact assessment model chosen (Type I or Type II), a characterization method will be necessary to perform the S-LCA. The most commonly used methods in the articles obtained in bibliometric analysis are listed in Table 3. The studies on recyclable MSW and waste pickers predominantly use the Type I model.

These characterization methods are used to give a meaning to the indicators, allowing interpretation of the collected data on potential or real social impact in protection areas (AoP), which are linked to social welfare. For a better understanding of these methods in S-LCA, UNEP (2020) contains a detailed explanation of Type I and II characterization.

Of the selected case study articles, data collection through interviews and questionnaires ends up impacting the characterization systems, because the indicator data codification used to materialize the results relies on qualitative or semi-quantitative data. This is a reason for the Type I characterization being preferred in evaluated studies.

Regarding weighting for stakeholders or impact categories, the case study papers did not consider using different weights. This gives the same importance to all real or possible social impacts, which raises the question of which one is more damaging or should be addressed first. When discussing weighting on each pillar of sustainability, Aleisa and Al-Jara [22] assigned 25% to the social and economic LCA results and 50% to the environmental

LCA. However, in the social aspects, geographical, cultural and political conditions can bring variations in social impacts and indicate the possibility of using different weights for impact categories or subcategories.

Table 3. Types of characterization methods used in the analyzed papers.

Methods	Definitions
Performance Reference Point Method (PRP) *Type I Model*	Explanation: This method assesses the relative position of a subcategory or indicator in relation to an international benchmark (e.g., recommendations of the International Labor Organization—ILO). From this comparison, the valuation outputted for the subcategory can, for example, indicate whether or not it complies with the used benchmark. Example: Aparcana and Salhofer [5] and Foolmaun and Ramjeeawon [8] have valued the indicators with YES/NO or 1/0, to show compliance or non-compliance with the established benchmark.
Impact Path Method * *Type II Model*	Explanation: This method uses impact paths as characterization models. Such paths can be seen in this example: excess work time can place higher levels of stress on the employee, which can cause depression (midpoint impact), which in turn will cause loss of psychological well-being (endpoint impact). Example: Norris's [51] work makes a connection between the improved health of a nation (considered a human health aspect), through increased lifespan, to increased economic growth (e.g., increased gross domestic product).
Checklist Method *Type I Model*	Explanation: This method uses a checklist for assessing the impact, by checking for presence or absence of a factor causing the impact (e.g., child labor). This is done at the indicator level, consequently affecting the subcategories. If this category influences the impact category, then it receives a certain color. Depending on how many subcategories are linked to the impact category and have been marked with the presence of the impact, this category receives different colors. Example: Franze and Ciroth [52] have used a color scale (green–yellow–red, where red indicates the "worst" situation) to represent whether the established benchmark was met or not, i.e., more or fewer social impacts within the impact categories analyzed.
Scoring Method *Type I Model*	Explanation: This method uses a scoring scale (with numbers, percentages, etc.) to code the social impacts, which can be positive or negative. Example: When assessing the social impacts of producing a notebook, Ciroth and Franze [53] used an impact scale from 1 to 6, with 1 being positive and 6 very negative.
Environmental Life Cycle Inventory Database Method *Type II Model*	Explanation: Use of the LCA database to estimate social impacts. Restricted to health impacts that are modeled and used in the environmental LCA inventory, thus not following the impact categories defined in UNEP-SETAC [1] or UNEP [21].

Source: Adapted from Wu and Su [24]. * Note: Although the Type II model exemplified differs from the findings in the analyzed articles, the examples portray widely cited studies in S-LCA research.

4.5. Results Interpretation and Communication

In the interpretation phase, correlations are established between the impacts found and the objectives and scope defined in the study, allowing researchers to reach conclusions and make recommendations that will be directed to stakeholders or decision makers [54]. All assumptions adopted should be clear, as well as the limitations imposed during the inventory survey or characterization model [1]. In the case study papers, S-LCA was used to verify the social impact occasionally associated with environmental economic LCA, in order to show the sustainability aspects of products and processes.

Results communication is important, and the case study articles had different ways to communicate their results. Yildiz-Geyhan et al. [7] and Ibáñez-Forés et al. [6] represented the results using graphs. In the second paper, the authors used web graphs that correlated

the impact categories with a percentage (0–100%) that referenced how favorable that category would be for the stakeholders involved. Aparcana and Salhofer [5] conditioned the results according to the subcategory score, according to whether or not the indicators met what was evaluated (Table 3). For example, if the working hours were too high for more than 50% of the inquired, they would receive a "0" score, which would cause the indicator to receive a "0" in its evaluation. This would allow a comparison between scenarios, the most favorable (score "1") being the one with the least negative impact.

In Foolmaun and Ramjeeawon [8], the result is the sum of scores obtained in the subcategories of stakeholders assessed. Conversely, Aleisa and Al-Jarallah [22] analyzed the S-LCA result only, based on a score relative to each scenario analyzed. However, this scoring form derived from AHP methodology, with questionnaires made for a group of people involved in the systems under study. In both cases, the highest value in the sum of scores determines which scenario has the most socially appropriate process.

As said, in the specific research field of this paper, the authors ended up using the Type I impact assessment model more frequently to conduct their studies and assess social impacts. Because the result presentation was almost unique for each paper, it is difficult to compare papers with different characterization models within Type I.

5. Conclusions

Few studies use S-LCA to assess the social impacts of MSW recycling with intervention from waste pickers in WPOs or similar organizations. This may be caused by a lack of primary or specific data availability, demanding more time and resources for studies, and secondary or generic data may not represent specific cultural and political issues in the countries where the study is conducted. Primary data are most frequently used, despite the difficulties, translating into high obtention time and costs, while secondary data are necessary when specific data are unavailable, or to complement them. Therefore, use of one or the other depends on the intrinsic characteristics and difficulties of the study and for whom the study is intended. The S-LCA data inventory is incipient compared to the environmental LCA databases, particularly for developing countries where the MSWM systems typically include pickers and WPO, missing in those databases. Moreover, the study of generic data that would indicate social impacts with the same level of representativeness as generic data could bring down the costs of S-LCA.

Regarding impact assessment models, the most used was Type I. Unlike in Environmental LCA, where the cause-and-effect chains are relatively clear—meaning that it is already known that a certain amount of a given indicator causes a particular environmental impact—in S-LCA, these cause-and-effect chains are not yet fully developed, explaining the reduced use of Type II characterization. Developing Type II models would facilitate the comparing S-LCA studies, especially for the form of communication and possible availability of quality data used.

As for indicators, most authors used the ones proposed by UNEP-SETAC [1,16], but also other sources in some cases. Their choice depends on the specificities of the study, like scope, data availability and the characterization model used. Therefore, the source of indicators is still individual, which makes it a major challenge, not only in S-LCA studies, but also in studies in this field of research.

The workers are the most analyzed in the stakeholder category when social impacts of a products/processes are assessed. Other stakeholders, such as the local community, society and consumers, were also evaluated more frequently than the others, indicating a stronger relationship between the MSWM systems and these particular stakeholders.

Different social impact assessment methodologies have been used to analyze processes related to MSWM systems or parts of them, but the methodologies for recycling systems are limited and dependent on primary data. The impact categories and stakeholders related to the social problems of waste pickers have been identified. Issues such as FUs and system boundaries, although cited, still need to be more clearly correlated with the

S-LCA system characterization, especially in studies involving pickers, to allow comparison between studies.

Issues such as sensitivity analysis of some processes or scenarios; the results of internal or external changes that impact the activities of the organizations; relative weights for the categories evaluated; and the quality of data used in the studies were not identified in the analyzed papers, therefore are paths for future research.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/su15021717/s1, Figure S1: Number of original and review papers in each year of the selected time period, Figure S2: Number of: (a) S-LCA studies by country; (b) papers by country of the main author, Table S1: Bibliometric analysis of Social Life Cycle Assessment phases [55–58], Table S2: Bibliometric analysis of the phases of the S-LCA case study papers.

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