

Review

Social Consideration in Product Life Cycle for Product Social Sustainability

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Abstract: Social life cycle assessment (S-LCA) is an emerging and pivotal tool for sustainability evaluation of products throughout their life cycle. Understanding deeply published papers helps to modify methods and identify research gaps. The aim of this study is to discover the existing gap in the S-LCA of products and to find the weaknesses of the approach. The method of performing the review was a narrative review where published papers from 2006 to 2020 were included through the use of the Web of Science and Scopus databases. S-LCA is considered to be relevant to a majority of sectors and processes (agricultural, industrial, technology, energy, and tourism). However, there is not sufficient research on evaluation of S-LCA on cereal crops and livestock output. It is indicated that, in the present S-LCA studies, there has been a lack of attention paid to the society and value chain actors and final consumer stakeholders. The elements of sexual harassment and employment relationships are not considered in SLCA studies. Italy has the largest amount of cases of S-LCA studies. The major challenges of applying S-LCA (by using site specific data) is data collection, which is time-consuming. It is recommended to evaluate a comprehensive sustainability assessment by adding cost of social assessment to LCA since there has been a lack of attention on assessment of cost in S-LCA.

Keywords: social life cycle assessment; social sustainability; product life cycle; supply chain



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1. Introduction

Sustainability is explained in the Bruntland report as ensuring that society can meet individual present needs without compromising next generation needs [1]. The important outcome of the report covers the aspects of environmental safe guide, social equity, and economic viability as the three pillars of sustainability [1] (Figure 1). The major components of sustainable development are depicted in Figure 1, which emphasizes not just the environmental but also the economic and social factors. To achieve sustainable development, environmental, social, and economic sustainability are required [2]. The main scope of sustainable development is human wellbeing by considering the needs of the present and next generation [2]. According to LCA experts, sustainable development is defined as sustainability of economic, environmental, and social aspects for the current and next generation [2]. Valente et al. claimed that sustainability is not easy to define because the meaning of social sustainability is not clear [3].

Recently, sustainability assessment has attracted the attention of many researchers [4]. Different methodologies for evaluation of sustainability of products have been produced and developed. Social life cycle assessment (S-LCA) is identified as one of the three approaches (the other two are environmental life cycle assessment (E-LCA) and life cycle costing (LCC)) used for the evaluation of sustainable development of products, services, and organization [4] that have been noticed from researchers recently. S-LCA is a novel methodology in comparison with LCC and LCA [5]. S-LCA evaluates negative and positive social impacts of products and services alongside their life cycle [4]. The final intention

of performing S-LCA is to help decision makers find and choose the most appropriate alternative with favorable results [5]. S-LCA has been identified as a robust tool for sustainable development assessment [6]. S-LCA can produce social sustainable solutions and improve social performances of products [7] and greatly contributes to increasing the wellbeing of involved stakeholders [2]. Defining the meaning of human wellbeing is the first step in applying S-LCA [8]. Many terms can be used instead of human wellbeing, including living standard, life satisfaction, human development, and happiness. The major endeavor in conducting S-LCA is to select the suitable social impacts that indicate effects of an activity on communities in the matters of human wellbeing.

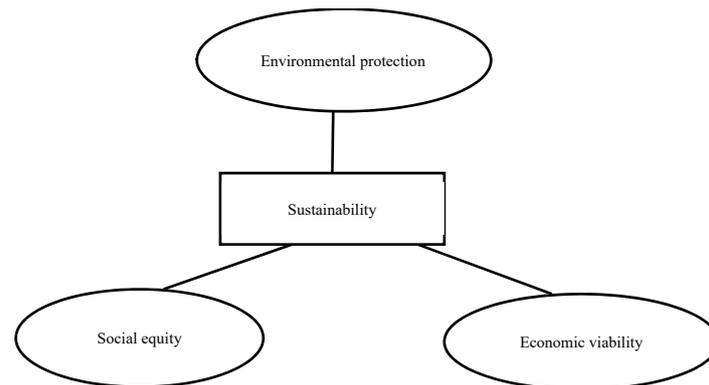


Figure 1. The elements for sustainability development.

The United Nations Environment Program (UNEP, 2009), in 2009, provided the first guideline for assessment of social impacts of products on involved stakeholders throughout their life cycle [2]. Involved stakeholders include workers, local communities, consumers, the society, and all valued chain actors [2]. Impact categories that are regarded in the UNEP 2009 are human rights, working conditions, cultural heritage, governance, and socioeconomic repercussion [2].

The framework of S-LCA guideline is consistent with ISO 14,040 and ISO 1444 in details [2]. Thus, it can be evaluated by following four steps, which are: 1) definition of goal and scope, 2) (social) life cycle inventory (LCI), 3) (social) life cycle impact assessment (S-LCIA), and 4) interpretation [4].

After the publication of the United Nations Environment Program (UNEP) guideline, the number of publications using the S-LCA method has increased [9]. In spite of rapid increase in the publication, the literature review on social sustainability assessment is scarce [5,8–12]. More research is required to address the complexity of S-LCA. Understanding deeply published papers help to modify the method and identify the research gap.

The goal of this study is to examine existing literature and identify gaps in S-LCA using a narrative review of publications from ISI Web of Science and Scopus published between 2006 and 2020. This study can provide answers to the following research questions: What are the elements of sustainability in life cycle management and how can we conduct them?

1. Which sectors are related to S-LCA evaluation?
2. Which countries have conducted S-LCA evaluation?
3. What is the research gap related to social life cycle studies?
4. What is the limitation of the S-LCA method?

This paper is structured as follow:

The first section provides an overview on the elements of sustainability in life cycle management including LCC, E-LCA, and S-LCA. Then, the evolution of each methodology is explained. The second part explains the methodology and the protocol of conducting the

review. Next, the literature review provides an overview and explains the different S-LCA studies. The countries (as case study of S-LCA) with the largest publication of S-LCA are also identified. Then, the limitation of S-LCA studies is explained. The conclusion section explains the findings of this review paper.

2. The Elements of Sustainability in Life Cycle Management

Sustainability is defined by integrating three elements, including economic, environmental, and social dimensions [13]. Beginning from the 1990s, it is indicated that it is essential to consider social, economic, and environmental dimensions in LCA for sustainability assessment of products [14]. Sustainable production and consumption can be achieved not only by environmental, but also by social modification of products [15]. For evaluation of sustainability of products, the life cycle sustainability assessment (LCSA) was established, which is an integration of three methodologies (LCSA = S-LCA + E-LCA + LCC) [16] for evaluation of sustainability development of products that refer to the three pillars of sustainability (UNEP, 2020).

LCA is identified as a tool for evaluation of environmental impacts of products [17]. LCC is an evaluation of economic dimension throughout their life cycle [18]. The S-LCA was introduced to account for social impacts of products [19], and it is the most powerful tool for evaluation of sustainability of social impacts of products alongside their life cycle [20]. S-LCA has been developed in order to add the social sustainability aspect to the LCA approach [21].

2.1. Life Cycle Costing

LCC is an approach for collecting cost over the life cycle of products and processes [22]. It is identified as an economic approach that considers all cost over the lifespan of products [23] that include cost for construction, operation, maintenance, replacement, and utilities [24]. It also accounts for the cost for inflation, discount rate, and time value of money [24]. However, there is lack of framework for this methodology [25]. However, there is lack of framework for this methodology [25]. The forecasted LCC result produces useful information for decision makers to optimize a plan, buy products, arrange maintenance, and execute modification of the plan [18].

The LCC can be conducted by applying five steps [24] (Figure 2). The LCC approach is summarized in Figure 2. The first stage is to set goals for analysis. Setting defined objectives is a necessary component for running an LCC. The second step is to make a record of the overall cost and payback. The third stage is to create alternate scenarios and a base case. The fourth phase is to collect utility, construction, maintenance, and service costs for each choice. The fifth stage is to apply a life cycle cost analysis to each choice.

Figure 3 depicts the progression of the LCC application. It is clear that the first user of LCC was the military of the USA from 1970s to 1980s. After that, LCC was applied in different industrial sectors, including the oil sector (in 1980) and chemical industry, power industry, and railway industry [18]. In October 2005, the first guideline for LCC evaluation was established [24]. Three years later, the BS ISO 15686-5 (2008) provided a guideline for LCC that is standard and easily applicable. After nine years, the BS ISO 15686-5 (2008) guideline was revised, and a new guideline was produced, which is BS ISO 15686-5 (2017) (Figure 3). In 2010, [26] claimed that the reason of inefficient studies on LCC is a lack of standard approaches. LCC does not account for environmental and social costs of products [27]. Besides, there is a lack of agreement in the method [28–31].

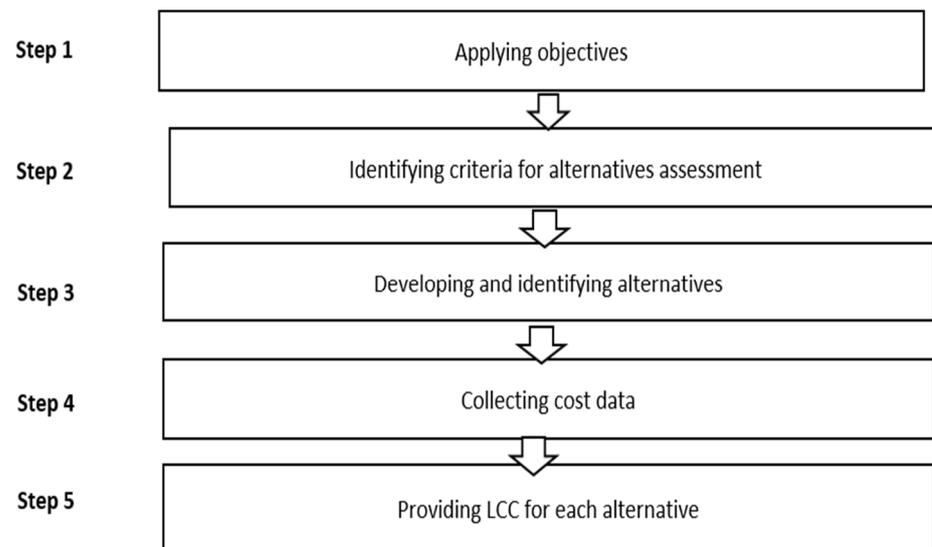


Figure 2. The steps for LCC method [24].

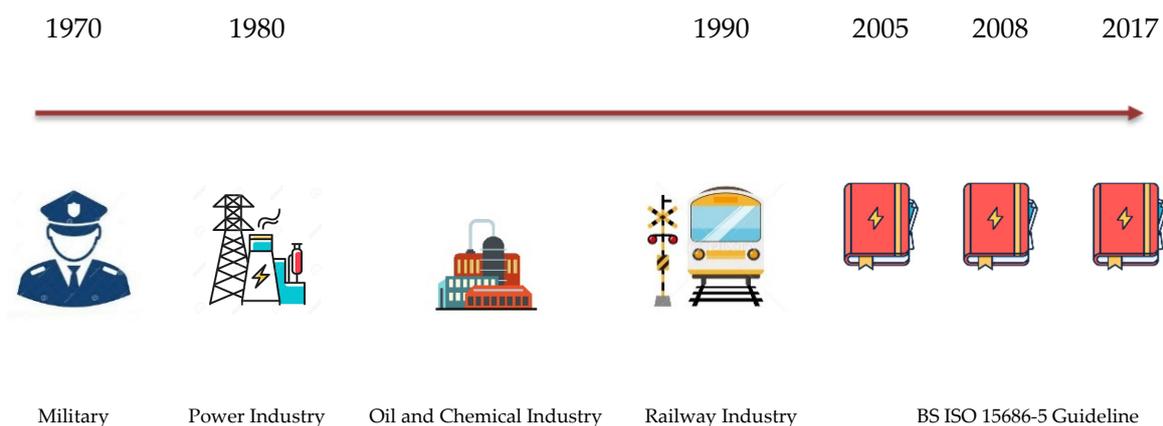


Figure 3. The evolution of LCC application.

2.2. Environmental Life Cycle Assessment (E-LCA)

The first Environmental LCA study was conducted in the 1960s, when environmental issues such as energy efficiency and resources scarcity, pollution, and waste control became of general concern. The first study that considered emission and waste was conducted in a Coca-Cola factory in 1969. During the period of 1970–1990, LCA was conducted without any framework. Rapid growth in the use LCA occurred in 1990s, gradually producing scientific guidelines. During this period, the number of guidelines had vastly increased [32–34]. From 1990 to 2000, the ISO (ISO 14040 and ISO 14043) had standardized and harmonized the LCA method. During this period, LCA was frequently used as a policy, and life cycle thinking was established. ISO 14040 and ISO 14043 were substituted with ISO 14040 and ISO 14044 in 2006. Both guidelines explain the elements of conducting E-LCA [2]. ISO 14040 [35] in 2006 provided a framework for LCA [36]. It explains the life cycle assessment (LCA) and life cycle inventory (LCI). ISO 14040 does not include details of the technique and methodology. ISO 14044 provided a guideline for LCA [36]. Different LCC methods and S-LCA approaches have been established and modified [37]. The differentiation of social, environmental, and economic (the three element of sustainability) dimensions of products throughout their life cycle has been performed during this period.

E-LCA are able to mitigate environmental impacts of products in their life cycle. It can be called cradle-to-grave as a tool for environmental sustainability evaluation of products,

process, and services [38]. E-LCA can be evaluated by following four steps, which are: (1) goal and scope definition: where the rationale for conducting LCA is outlined, as well as the scope of research, functional unit, and approach are detailed; (2) inventory analysis: where the system boundaries and processes are discussed; (3) impact assessment: this can be followed by weighing and normalization; (4) interpretation: at this stage, two earlier findings are combined to arrive at conclusions and suggestions (Figure 4) [36].

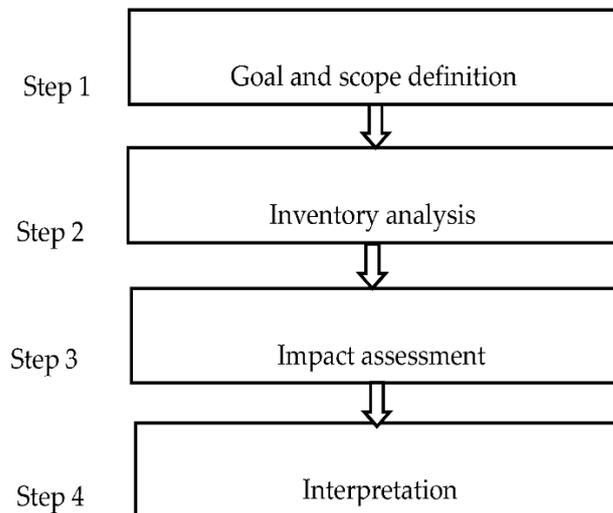


Figure 4. The steps of E-LCA, modified by [36].

In the E-LCA approach, the geographical dimension of products is considered. It evaluates environmental impact by considering whether production and consumption lead to environmental impacts. E-LCA requires producers to identify more cost-efficient products by integrating E-LCA with the LCC approach.

One of the most difficult challenges in conducting E-LCA is data availability. Obtaining inventory data is a difficult task. Besides that, placing all data together is also costly and time-consuming. The limitation of the E-LCA method is the quality of data [39].

2.3. Social Life Cycle Assessment (S-LCA)

The Evolution of S-LCA

In the 1900s, LCA experts discussed the consideration of a social aspect in the life cycle assessment approach [40]. O'Brien et al. (1995) [40] developed a comprehensive and novel approach called SE-LCA (social and environmental life cycle assessment) by combining S-LCA (social life cycle assessment) with E-LCA (environmental life cycle assessment) [40]. Gauthier et al. (2005) [41] introduced social indicators to evaluate social performance of products throughout their life cycle. In the following year, Dreyer et al. (2006) [42] provided a framework for social life cycle assessment, but the framework did not mention that the method can collect data for social LCA. Three year later, the United Nations Environment Program [2] in 2009 provided a guideline for social life cycle assessment [2], which was still an infant and under development. The guidelines determine negative and positive impact of social aspects of products through its supply chain [2]. The guidelines provide seven steps for S-LCA (Figure 5) [2]. In the social life cycle assessment guideline, social impacts on stakeholders throughout the life cycle of production and consumption are accounted for. Stakeholders are divided into five categories, including impact on workers, local communities, consumers, the society, and all value chain actors [2]; and six impact classes, which are human rights, health, working environment, cultural heritage, socio-economic response, and governance [2]. The selection of indicators completely depends on the goal and scope of the study [2]. A new version of S-LCA has been produced since then. In the new guideline [4], children have been added as a new stakeholder. Besides that,

new subcategories have been created, for example, sexual harassment and smallholders including farmers. In the new guideline, two impact assessment approaches are provided. For evaluation of social performances and social risk assessment, a reference scale method can be used. The impact pathway approach is introduced for assessment of potential social impact [4].

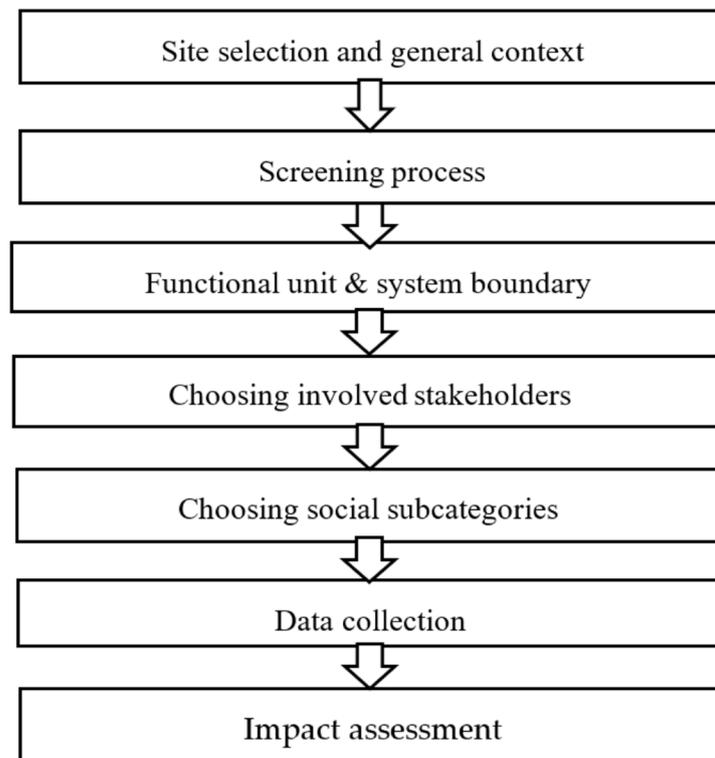


Figure 5. The Steps of S-LCA method according to the UNEP guideline.

The aspect of social impact assessment (SIA) is used in S-LCA, which serves as a forerunner for S-LCA. The main target of SIA is to check the social impacts of industrial activities, and it was introduced in the 1970s [43]. However, SIA does not consider a product's social consequences throughout its life cycle, but instead focuses on the influence of a single stage of a project or product on human wellbeing. The SIA of each step of a product's life cycle is incorporated in S-LCA [8].

The impact evaluation has to be quantified according to ISO (LCA 1997) [21]. A framework was designed by [42] for S-LCA, which was able to quantify assessment results. Unlike [21,42] is more of the opinion that generic data is more applicable and more reliable than site specific data. Hunkeler (2006) [44] is also of the same opinion with [21] in that generic data is more realistic; he also modeled S-LCA using socioeconomic data generated from national censuses and public databases that can provide researchers with a substantially larger sample size.

The objective of the study is to determine the quantification methods used for S-LCA because S-LCA methodology differs for a single product and for general products [8].

According to the UNEP's S-LCA guidelines, there are five standardized stakeholder categories in the manufacturing system in [2] adopted from [8].

To advance the analysis of S-LCA, some researchers such as Norris, Dreyer, Hunkeler, and Weidema provided four common outlines for quantification methodologies.

Norri et al. focused on health impact as an example, which developed an endpoint S-LCA approach to estimate a product's life cycle health effects [45]. According to the World Health Organization's European Office's 2002 Health Report, the health effect is believed to be determined by life expectancy. Norris' approach can be used to predict an

endpoint result value of the health impact by accumulating the health impact from both the economic contribution and the emissions caused by a product. This approach by Norris used generic data to make S-LCA easier to perform. The endpoint indicator for Norris' approach is life expectancy. Although there are lapses in Norris' methodology that need to be addressed, which are the link between economic development and life expectancy, it appears to be more complex than what Norris' model suggests, and second, S-LCA's effect on wellbeing is not the only indicator [8].

- Dreyer S-LCA methodology

The first set to complete the framework and concept of S-LCA was [42]. They tried to identify two important sections of S-LCA, which were either developed based on company perspective or societal perspective. Later, many scholars adopted the company perspective because it clarified problems that differentiate the S-LCA study with ELCA, instead of taking process units when not considering company perspective [19]. People are viewed as stakeholders in the S-LCA, which calculates the impacts of the company's business on human being. According to the ISO's 1997 request for LCA, [42] created a measurable effect evaluation process.

The important goal to be achieved by S-LCA studies is to improve human dignity and wellbeing, but due to differing local or national norms, the definitions of human dignity and wellbeing vary between countries and regions [46]. Risk assessment strategies were implemented by a multi-criteria indicator model, comparable to financial management in the credit score system, assessing a specific individual or an institution's credit score to determine the likelihood of financial distress. A new concept was created, which is company risk score (CR), to define the degree of risk or likelihood that a product will violate a stakeholder's human integrity and wellbeing.

Three measures make up a multi-criteria indicator evaluation. They are: (1) establishment of the impact category, (2) evaluating management effort in terms of human respect, and (3) wellbeing [11]. Child labor, freedom of association, and labor difficulties are only several of the social issues included in the impact category, unlike Norris' endpoint, where he pointed out only health impact as an impact category.

This approach focuses on a company's willingness and capacity to address a social problem. The modified CR, according to [42] methodology, is a midpoint proxy for comparison when the societal challenges are identical with others. Generally, the applicability and viability of both the collecting of inventory data and the characterization method are confirmed in this case study.

Both site specific and generic data can be applied to E-LCA, but in the case of S-LCA, site specific data is more suitable because it can provide more information from different companies in the same area. The method of [42] includes data from personal interview surveys, which can assess the research's reliability.

Dreyer and Hauschild, in 2010, suggested an S-LCA approach for evaluation that incorporates real-world social environments and regional cultures [42]. In S-LCA, the multi-criteria indicator model improves on the standard single-criteria model. Single-criterion indicators, also known as "direct indicators", often fall short of explaining the nuances of social issues [19]. This multi-criteria indicator model identifies particular managerial interventions or efforts to provide an aggregate explanation of each effect category with specific issues.

- Hunkeler S-LCA methodology

Hunkeler [44] realized that a relative value of the social impact assessment based on standardized data is more realistic than a number in absolute terms based on site-specific data. He took the unit process and explicitly calculated work hours using existing E-LCA data, which are considered as a link between the E-LCA data and the end social outcome indicators.

Hunkeler's S-LCA quantification method consists of five stages, which are:

Obtaining information on material handling and emissions during the course of a life cycle of the product;

Predicting the number of hours, a country's workers spend for extraction of raw materials, manufacturing, and emission management;

Predicting the number of hours worked in each nation during the life cycle of a product;

Determining a person's purchasing power in each country for an hour of labor;

Predicting each country's entire purchasing power based on their involvement in the life cycle of the product.

In Hunkeler's S-LCA, the employment hour is the labor unit associated with the manufacturing process. This S-LCA is also characterized by region, which is similar to Dreyer's S-LCA. Hunkeler's S-LCA method is entirely focused on generic data. The result is a valuable tool for decision makers to measure employees' public welfare over the course of a company's life cycle commodity, rather than an endpoint conclusion for social impacts [19]. This S-LCA quantifies the social impacts, Hunkeler's S-LCA complements Norris's methodology because they both use generic data to assess social impacts. Hunkeler's S-LCA provides a monetary value for social good, while Norris' S-LCA considers health effects.

- Weidema's S-LCA methodology

The new quantification method was initiated by [47], which is based on LCIA framework, where the protected areas are recognized, such as humans, biotic environment, and abiotic environment. The social effect of this S-LCA is based on human wellbeing, with human longevity as an indicator. Human life-years wasted during a product's life cycle are used to calculate social effect. As a final product of S-LCA, the quantification approach determines a human life-societal year's influence.

Damage categories were employed by [47] to develop a damage-oriented system. Quality adjusted life years (QALY) serve as an indicator of this S-LCA, which uses adjusted DALY (disability-adjusted life years) without a year's loss as a result of the damages. The DALY is the total number of years of life lost (YLL). As a result of the population's early death and the number of years lost as a result of disability, YLD are for those who are forced to live in unfavorable circumstances. The measure of how long it takes for a person to live (i.e., YLL and YLD) is accessible in the World Health Organization's database.

Weidema used generic data and not site-specific data. The social impacts as well as the impacted stakeholders are the subject of the impact pathway here [47]. The impact pathway is a complex framework that uses social impact categories to describe the connections between social problems (inventory indicator) and social damages (damage category). There are numerous paths or ties, ranging from forced work to autonomy and worry. The various stakeholders who will be harmed by the indicated damage categories, as well as the damage categories themselves, are both unknowns that are required for QALY estimation. The trick to estimating QALYs is to look at the impact pathway [19].

3. Materials and Methods

In this study the methodology that has been used for reviewing the S-LCA of products is a narrative review.

There are four steps included in a narrative review:

Conducting a search: The first step in performing a narrative review is searching on the Web of Science [48]. It is essential to find a variety of databases to make sure that the most relevant published papers have been identified [49].

Identifying a keyword: The second step is finding keywords related to the research. The keyword in this research that were used in the search engines included social sustainability, S-LCA, social life cycle assessment, and sustainable development method.

Reviewing articles: After a search is completed, all of the papers related to the research questions are reviewed. For a narrative review, it is not essential to include every article on the topic [49].

Writing results: The last step is to summarize all of the findings from the review research and integrate them appropriately.

ISI Web of Science and Scopus were chosen as databases for this paper because they contain efficient and appropriate data for reviewing papers and are also accessible through most institution subscriptions.

In this study, the search string comprised social life cycle assessment, social sustainability, social-LCA, SLCA, life cycle costing (LCC), and environmental life cycle assessment (E-LCA) in the title, abstract, and keywords of publications published before 2021. A total of 118 publications were used in this study.

4. Results

4.1. The Sectors of S-LCA Studies

Table 1 indicates the sectors of the S-LCA studies. It shows that, to date, the social life cycle assessment has been evaluated in various sectors including the agricultural sector, such as [50–61] olive production [52], palm oil [53,54], sugarcane [55], pork production [56] cocoa production [57], honey [58], dairy farm [59], citrus production [60], and soybean [61]; the industrial sector, for example assessment of S-LCA on sugar industry [62], water [63,64], bioelectricity [65], energy [66], wood-based products [67], jewelry [68], waste management [69], computer software [70], laptop [71], bridges [72], technology [73], recycling [74], tourism [75], welding technology [76], (see Table 1). Walters and Mirkouei (2020) evaluated environmental and social LCA of the computer software industry to compare different scenarios to reduce time and CO₂ emission, and increase job satisfaction [70]. Besides that, Lehmann et al. (2013) evaluated the LCA of technology in developing countries [73]. It is not possible to evaluate the whole life cycle of technology because of a lack of data [73]. It is stated that there is a lack of research on the S-LCA of cereal crop production. In Thailand, only one study assessed the S-LCA of rice production [51].

S-LCA is also applicable for assessment of social negative and positive performances of process [74]. S-LCA is used in the tourism industry [75] as an approach for assessments of sustainability management (see Table 1). It is demonstrated that most S-LCA studies have been conducted in the agricultural sector. There has been little research into the S-LCA of cattle production. Only one study looked at the S-LCA of pork production.

Table 1. The product of S-LCA studies.

Author (Year)	Product	Country	Result
Hosseinijou et al. (2014)	Building	Iran	To compare different alternatives (cement and iron). To produce socially sustainable solution and improve social performances [7].
Nemarumane & Mbohwa (2015)	Sugarcane	South Africa	The social issue is regarded (health, safety, gender, equality, salary) [50].
Prasara (2019)	Sugarcane, rice, cassava	Thailand	Trash burning leads to air pollution that impacts local people life [51]. The production of rice leads to the lowest job opportunities versus other crops.
Lofrida et al. (2020)	Olive production	Italy	Comparison between traditional and organic farms investigated that organic farms have the highest socioeconomic performance. Increasing yield and mitigating pesticide cost leads to increased socioeconomic performance in olive production [52].
mohamad & Sharaai (2019)	Palm oil industry	Malaysia	Lack of job satisfaction and need to improve it. Communication between workers and employees should be increased [53].

Table 1. Cont.

Author (Year)	Product	Country	Result
Sawaengsak & Gheewala (2017)	Sugarcane industry	Thailand	Social and economic aspects of sugarcane production from farm to factory is evaluated. Social indicator identified such as labor use and working hours. Not any social impact as a result of deforestation on land right [55].
Zira et al. (2020)	Pork	Sweden	European pork production has the largest negative social risk versus Swedish pork production. Social risk indicator (SRI) and social hotspot indicator (SHI) identified as appropriate tools for evaluation of negative social impacts [56].
Sharaai, Zulkipli, Harun & Hui (2020)	Cocoa	Malaysia	To identify social dimensions that need to improve. Cocoa plantation provides job opportunities for nearby society and does not have any negative impact on health issue [57].
DEusanio et al. (2018)	Honey	Italy	Positive social impact of honey production is evaluated. Framework for assessment of social sustainability of honey production is established [58].
Chen & Holden (2017)	Dairy farm	Ireland	Positive and negative impact of daily farm production is investigated [59].
Iofrida et al. (2019)	Citrus	Italy	PRF impact for citrus production is evaluated. Musculoskeletal disorder has the highest contribution to negative social impact [60].
Kamali et al. (2017)	Soybean	Brazil	Modified and not modified soybean farms are chosen to compare environmental, economic, and social performances of soybean. It is not possible to conclude which soybean model is more sustainable since there are many factors that need to be considered. For social performance, working hours are considered [61].
Prasara (2018)	sugar	Thailand	Trash burning leads to negative social impact [62].
Tsalidis & Korevaar (2019)	Treatment of salt water	China India Congo	S-LCA is identified as a management tool To replace commodities with modified products. Use site specific analysis to discover social impacts. To increase social performances, reduce occupational accident [63].
Dunmade et al. (2016)	Water production	Nigeria	Identifying social hotspots needs urgent improvement. Assessing sustainability using social indicators. Facility needs to improve because of low social performance [64].
Martín-Gamboa—Gamboa et al. (2020)	Bioelectricity	Portugal	Investigation of novel S-LCA by adding conventional LCA. SLCIA: labor child, gender wage gap, health insurance [65].

Table 1. Cont.

Author (Year)	Product	Country	Result
Tsalidis (2020)	Energy transition	Netherland	Producing a new indicator while concentrating on people behavior [66].
Siebert et al. (2017)	Wood industry	Germany	Modifying novel social indexes to assess and monitor social performances, enables comparison of different alternatives, mitigates negative social impact, and accelerates positive social performance [67].
D-Eusanio (2019)	Jewelry	Italy	Supporting regional cultural heritage by introducing conventional products, improving educational actions of involved workers related to historical extraction of products [68].
Azimi et al. (2020)	Waste management	Afghanistan	The results showed poor social performance, lack of informal and formal communication between worker, child labor [69].
Walters & Mirkouei (2020)	Software	Canada	Comparing different scenarios to reduce time, CO ₂ emission, and increase job satisfactory [70].
Ekener (2013)	Laptop	Different countries	There was a problem associated with data collection in terms of quantity and quality. The social negative impact and hotspot of laptop is investigated. There is an essential need to produce a new systematic method for S-LCA in further research [71].
Navarro et al. (2018)	Bridge decks		S-LCA for verity of design alternatives are applied The best social performance has the lowest maintenance [72].
Lehmann et al. (2013)	Technology	Developing countries	It is not possible to evaluate whole life cycle of technology because of lack of data. Sustainability development can be obtained when technology is implemented correctly [73].
Aparcana & Salhofer (2013)	System of recycling	Peruvian	S-LCA is applicable for assessment of social negative and positive performances of process [74].
G Arcese et al. (2015)	Tourism industry	Italy	Produce new rhetorical framework for assessment of social impact of cultural heritage [75].
Chang et al. (2016)	Welding technology	Germany	Two welding methods (manual and automatic) are compared. The result investigated that manual approach leads to higher environmental impacts than automatic method [76]. In respect to the social impact, automatic welding contributes to lower risk compared to manual welding. However, welders in both of them receive efficient wages in Germany [76].
Foolmaun (2013)	Discarding of used PET bottle	Mauritius	A novel approach to analysis inventory data is established. Environmental impact of used bottle that is discarded is evaluated. It is suggested to combine E-LCA and S-LCA with cost incurred (CLC) [77]

Table 1. Cont.

Author (Year)	Product	Country	Result
Reveret et al. (2015)	Milk	Canada	The overall performance of milk production shows positive performance [78].
Garcia-Sanchez (2019)	Urban water system	Mexico	Health and environmental transportation phase has the largest environmental impacts because of energy consumption Good social performances. There is essential need to develop social performance to reduce health issue. It is recommended to evaluate comprehensive sustainability assessment by adding cost to environmental social assessment to LCA [79].
Yıldız-Geyhan et al. (2017)	Different recycling system	Turkey	S-LCA of different waste collection alternatives (formal, informal, integrated) are analyzed. Informal collection scenario has the lowest score in all impacts [80].
Agyekum et al. (2017)	Bicycle	China	Comparison of environmental impact of different bicycle frames shows that bamboo bicycle is environmentally friendly [81]. Social impact of bamboo bicycle shows good performance [81]. Assessment of social impact in a small scale has limitation on data collection [81].
Manik et al. (2013)	Biodiesel	Indonesia	Conducting comprehensive assessment is impossible in many cases of study. There is an essential need to modify S-LCA at different levels of decision making [82].
Fortie et al. (2019)	Energy justice	Italy	S-LCA indexes for energy justice are investigated Applying new technology and low carbon use are recommended [83].
Pelletier (2018)	Egg	Canada	New social dimensions for social sustainability of egg production and other agro food products is indicated [84].
Singh & Gupta (2018)	Steel industry	India	Producing new S-LCA indicators. There was lack of data (site specific), inefficient knowledge of stakeholders [85].
Osorio-Tejada et al. (2020)	Freight transport system	Malaysia	Social performance indicator (SPI) is evaluated in impact assessment step by multilevel valuation method. Worker and human rights were the most important categories. Social impact method provides important knowledge about priorities that need to be regarded to improve social aspects [86].
Arcese et al. (2017)	Wine	Italy	New conceptual framework and indicator for assessment of S-LCA in wine industry is established and modified S-LCA in agro-food section [87].
Werker et al. (2019)	Hydrogen production	Austria	Adding policy management can improve social performance Lack of communication for trade leads to risk of social performances [88].

Table 1. Cont.

Author (Year)	Product	Country	Result
Lobsiger et al. (2018)	Energy	Swaziland	Producing a new comprehensive method to compare different steps of supply chains of energy [89].
Souza et al. (2018)	Ethanol production	Brazil	To produce a helpful and novel approach to advocate for decision makers in order to sustain sugarcane production socially [90].
Haaster et al. (2016)	Novel technology	Different countries	Producing a new framework to assess social impact of new technology on human wellbeing [91].

4.2. Countries of S-LCA Studies

Countries with case studies of S-LCA were Iran, Italy, Malaysia, Germany, China, Portugal, Afghanistan, Swedish, Nigeria, Netherland, Swaziland, Brazil, Ghana, Ireland, Indonesia, Mauritius, Thailand, Brazil, South Africa, Canada, India, Mexico, Peru, and Turkey. With eleven S-LCA studies published, Italy has the most S-LCA usage. (Figure 6). Italy undertook S-LCA research in the agricultural, tourism, wine, jewelry, and honey producing industries. Malaysia and Brazil are the second largest cases of S-LCA study after Italy, with five publications in palm oil production, freight transport system, cocoa production, and ethanol production. The application of S-LCA as a decision-making tool in developing and in third-world countries are increasing (Table 1).

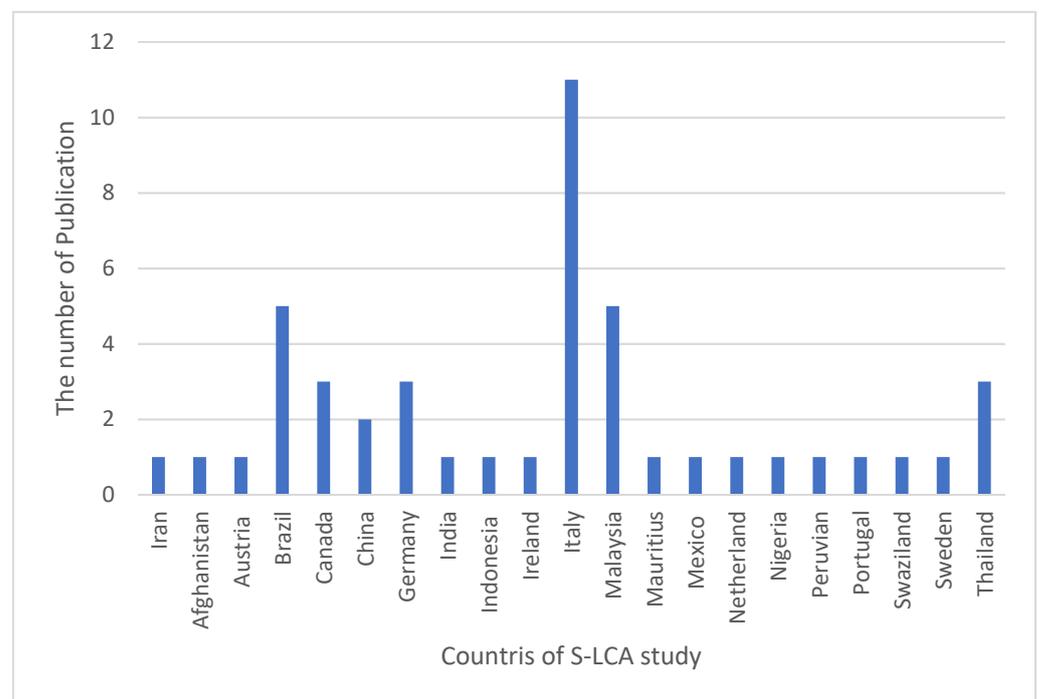


Figure 6. The S-LCA case study countries.

4.3. Overview of S-LCA Research

Table 2 lists the techniques utilized in S-LCA studies. It can be seen that most LCA scholars integrated S-LCA with environmental aspects by conducting an E-LCA method that is called social environmental life cycle assessment (ES-LCA) [61,65,70,76–78,80,81]. Combining two methods can produce comprehensive and useful information about social and environmental impacts of products' life cycle that contribute to sustainable assessment

of products. Applying ES-LCA can increase social performances and reduce environmental negative impacts. Moreover, different alternatives and scenarios can be compared to identify the most environmentally friendly and best social performance scenarios (Table 2).

Table 2. The literature on using S-LCA and S-LCA integrated with another method.

No.	Method	No. of Study	Author
1	S-LCA	28	Zira et al. (2020), Pelletier (2018), Muhammad & Sharaai (2015, 2019), Prasara (2018), Prasara (2019), G Arcese et al. (2015), Tsalidis & Korevaar (2019), D-Eusanio (2019), Werker et al. (2019), Dunmade et al. (2016), Sharaai, et al. (2020), Tsalidis (2020), Haaster et al. (2016), Arcese et al. (2017), Chen & Holden (2017), Ekener (2013), Lehmann et al. (2013), Sawaengsak & Gheewala (2017), Manik et al. (2013), Nemarumane & Mbohwa (2015), Singh & Gupta (2018), Osorio-Tejada et al. (2020), Chang et al. (2016), Garcia-Sanchez (2019), Fortie et al. (2019), Aparcana & Salhofer (2013), Navarro et al. (2018), Arcese (2013)
2	S-LCA + LCC	1	Lofrida et al. (2020)
3	S-LCA + ELCA	8	Walters & Mirkouei (2020), Agyekum et al. (2017), Foolmaun (2013), Yildiz-Geyhan et al. (2017), Reveret et al. (2015), Kamali et al. (2017), Martin-Gamboa et al. (2020), Chang et al. (2016)
4	S-LCA + Material Flow Analysis	1	Shirazi (2014)
5	SLCA + ELCA + LCC	1	Traverso et al. (2012)

Only limited studies have conducted comprehensive sustainability assessment by integrating social, economic, and environmental dimensions [92]. The Life Cycle Sustainability Dashboard (LSCD) was established, which is a combination of LCA, S-LCA, and E-LCA methods [93]. Literature on using the combination of S-LCA and LCC is still scarce. Most of them use one of the methods individually. Most recently, only one study in Italy has combined the S-LCA with the LCC approach in olive production to evaluate social and economic elements of different frame performances in terms of sustainability [52]. There has never been a study that integrated the S-LCA, ELCA, and LCC methods. Only one study used S-LCA in conjunction with material flow analysis.

5. Discussion

5.1. Social Life Cycle Studies of Products

S-LCA facilitates decision makers to choose an alternative with the most preferable social performances [7]. Assessment of S-LCA at a small scale can contribute to higher certainty than at the large scale [62]. S-LCA can identify social hotspots of products during their life cycle [62]. Determining social hotspots helps stakeholders to reduce social negative impacts by taking urgent action to modify social aspects [2].

The major challenges in applying S-LCA are a lack of agreement in using social indicators, limitation of data availability, and inefficient methodology. There is a lack of agreement in applying social impact assessment in the S-LCA approach [62]. The new version of the guideline [4] provides two impact assessment methods. Type 1 is the reference scale method, which emphasizes social performances and social risks. Type 2 is the impact pathway method, which focuses on characterizing a pathway.

Unlike environmental impact indexes, most of the social impact indexes in the guideline are not easy to quantify [82] because it is difficult to know accurate social indexes and which impact categories need to be included in the assessment.

Some scholars use the UNEP (2009) guideline supplementary impacts categories [73]. Others authors use questionnaires or survey to collect social impact data [83].

Some of the researchers produced new indicators to assess social performance [55,67,83–86]. Most recently, Osorio-Tejada et al. (2020) established a social perfor-

mance indicator (SPI) in an impact assessment step by multilevel valuation method. Social impact method provides important knowledge about priorities that need to be considered for improvement of social aspects [86].

Tsalidis produced a new indicator by concentrating on people behavior in the Netherlands in the energy transition sector [66]. Other authors established a new framework for how assessment of negative and positive social impacts [87–91] produced a helpful and a novel approach to advocate to decision makers in order to make sugarcane production in Brazil socially sustainable. Another author [87] investigated a new conceptual framework and indicator for assessment of S-LCA in the wine industry and modified S-LCA in the agro-food sector.

5.2. Stakeholders Involved in the SLCA Research and Subcategories Selected

The stakeholders included in S-LCA studies are listed in the table below (Table 3). As can be seen, limited research has placed an emphasis on all five concerned stakeholders (worker, local community, consumer, value chain actors, and society) [56,66,70,85,89,94]. In S-LCA, the majority of authors considered employees and local community stakeholders in related subcategories [50,51,64,65,68,69,81,88]. The majority of the focus has been on worker stakeholders. Consumer and value chain actor stakeholders, conversely, receive scant attention in social life cycle assessments. In one study, Zira et al. (2020) included animals as stakeholders.

Table 3. The involved stakeholders in S-LCA studies.

Author (Year)	Worker	Local Community	Consumer	Society	Value Chain Actors
Hosseiniyou et al.(2014)	*	*		*	
Lofrida et al.(2020)	*				*
Mohamad & Sharaai (2019)	*	*			
Prasara (2018)	*	*		*	*
Prasara(2019)	*	*			*
Siebert et al. (2017)	*	*		*	
Walters &Mirkouei (2020)	*	*	*	*	*
G Arcese et al. (2015)	*	*	*	*	*
Tsalidis & Korevaar (2019)	*	*	*		*
D-Eusanio (2019)		*			
Martin-Gamboa et al. (2020)	*	*		*	
Azimi et al. (2020)	*	*	*		
Zira et al. (2020)	*	*	*	*	*
Werker et al. (2019)	*				
Dunmade et al. (2016)	*	*			
Muhammad & Sharaai (2019)	*	*			
Tsalidis (2020)	*	*	*	*	*
Lobsiger et al. (2018)	*	*	*	*	*
Haaster et al. (2016)	*			*	
Souza et al. (2018)	*				
Arcese et al. (2017)	*	*	*	*	
Agyekum et al. (2017)	*	*			
Chen& Holden (2017)	*	*		*	*
DEusanio et al. (2018)	*	*	*	*	*
Iofrida et al. (2019)	*				
Foolmaun (2013)	*	*		*	
Lehmann et al. (2013)	*	*	*		
Sawaengsak & Gheewala (2017)	*				*
Kamali et al. (2017)	*				

Table 3. Cont.

Author (Year)	Worker	Local Community	Consumer	Society	Value Chain Actors
Manik et al. (2013)	*	*			*
Nemarumane& Mbohwa (2015)	*	*			
Pelletier (2018)	*	*		*	
Reveret et al. (2015)	*				
Osorio-Tejada et al. (2020)	*	*		*	*
Singh &Gupta (2018)	*	*	*	*	*
Garcia-Sanchez (2019)	*				
Fortie et al. (2019)	*	*	*	*	
Aparcana &Salhofer (2013)	*				
Navarro et al. (2018)	*	*	*	*	
Arcese (2013)	*	*	*		

Chang et al. (2016) added an ergonomic dimension on S-LCA since there was a lack of attention on musculoskeletal disorder aspects, which led to an increase in the cost, and reduced productivity and attendance of workers [95]. Furthermore, Chang et al. introduced new benchmarks for the S-LCA such as force, backache, repetition, and duration [95].

Martín-Gamboa (2020) investigated a novel S-LCA by adding conventional LCA [65].

One study [56] introduced a social risk indicator (SRI) and social hotspot indicator (SHI), which are identified as appropriate tools for evaluation of negative social impacts. Lack of communication for trade leads to risk of social performance [88]. A study conducted by [67] modified novel social indexes to assess and monitor social performances of wood-based products in Germany, which enable researchers to compare different alternatives, mitigate negative social impact, and accelerate social performance [67].

S-LCA can be more useful when making a comparison of social performance of a variety of products. S-LCA is considered a management tool to allocate resources [96]. Moreover, the advantages of applying S-LCA are its abilities to mitigate negative impacts and improve social conditions of involved stakeholders [97].

5.3. Limitation of Social Life Cycle Assessment (S-LCA)

Applying S-LCA is difficult due to the limitation of data availability and challenges in identifying social indexes [97]. Data collection is a big challenge for practitioners. Jørgensen asserted that more accurate results can be obtained by using generic data [21]. However, Dreyer (2006) [42] claimed that site-specific data can produce more accurate results compared with generic data. The quality of site-specific data relies on an auditing method. For generic data, location, section, and size should be considered [21]. Hunkeler used generic data to model S-LCA of products in factories [44]. Generic data is applicable at larger scales compared with site-specific data [8]. Generic data usually takes advantage of statistical data or an input and output database, and sometimes it can be available in reports of companies that is difficult to access. Site-specific data can be obtained using interviews and surveys [11].

Data collection is the most time-consuming step when conducting the S-LCA approach. However, a small number of databases have been established to evaluate social impact of products along their life cycle (such as social hotspot databases (SHDB) [98] and product social impact life cycle assessment (PSILCA) [89]). According to UNEP guideline, social hotspot databases (SHDB) are identified as an important source for evaluation of social impact that can determine social vulnerability for more than 99 indexes [10]. SHDB is an adequate database for assessment of social performances that are not applicable at the regional scale [99]. The PSILCA database provides data for more than 150 countries. All of the mentioned databases cannot be used at the local and regional scale. Besides that, a high fee is required to gain access to all of these databases [9].

The S-LCA approach enables researchers to account for the sustainability of the social aspect of products during their life cycle. A comprehensive LCA approach needs to be produced in order to evaluate the sustainability of economic, social, and economic aspects altogether. Assessment of comprehensive social sustainability (all social performances and indicators) is difficult due to the lack of data availability since many data are needed to conduct a comprehensive social sustainability evaluation. Aggregating data in the S-LCA approach (UNEP, 2009) is difficult since aggregation of qualitative data is not easy and applicable.

Issues in social life cycle impact assessment also need attention, especially with regard to several methods from different research, as [89] revealed that there is great variation in application of social life cycle impact assessment methods. As many of the researchers have different ways for their own proposal for S-LCIA methods, there needs to be real scientific justifications.

Lobsiger-Kägi [89] identified different limitations for the development of social life cycle impact assessment methods, including the difficulties to measure sustainability in the social dimension. There is yet to be a standard consensus across the world for a social life cycle impact assessment method, and there is a need for standard methods for impact assessment [53,95].

Hundreds of social issues have been identified in the methodological sheets of the UNEP guideline. However, there is no complete set of social issues for the purpose of conducting S-LCIA. Only several issues among hundreds can be related to the products or processes being studied [73].

With regard to cut-off criteria, there is no single say among the S-LCIA community when it comes to identifying the socially important process system boundary and weighting system. This is a big challenge that needs to be addressed such that the impact assessment methods can be accepted scientifically [100].

A majority of the studies of S-LCIA have not included the “use” phase of a product for which there is need for assessment [89].

Four problems need to be addressed by practitioners of S-LCA, which are:

- The definition of human wellbeing;
- The selection of social indicators for S-LCA;
- The preference of site-specific or generic data;
- The methods for quantifying social impacts.

6. Conclusions

The social life cycle (S-LCA) approach is an assessment of social impacts of products with focus on the life cycle activities that impact stakeholders’ lives [101]. S-LCA can identify the social hotspot of products during its life cycle. Determining the social hotspot helps stakeholders to reduce social negative impacts by taking urgent action to modify social aspects.

This paper provides useful information about published papers on S-LCA for different sectors. It provides important knowledge for researchers to deeply understand the evaluation of social sustainability of products using the S-LCA method. It also helps scholars to understand the existing gaps in the published papers. This study summarizes S-LCA papers from 2006 to 2020 in terms of their applications and results. It has been investigated that a novel method can be produced by integrating social LCA with a life cycle cost approach to cover economic and social dimensions.

6.1. Main Findings

This study reveals that the S-LCA approach is applicable in most sectors and processes to assess the social sustainability of products. Most of the published papers have conducted S-LCA on the agricultural sector, while no paper has handled a comprehensive sustainable assessment. Although it is applicable in most sectors, data collection in order to conduct S-LCA is difficult and time-consuming. Moreover, one of the challenges of conducting S-LCA

is finding appropriate impact categories that contribute to human wellbeing. Understanding the definition of human wellbeing is a major issue in S-LCA study.

The majority of the S-LCA research has been conducted in agricultural industries. However, there has been ineffective research on the S-LCA of grain crops and livestock production.

Only several papers considered backache and ergonomic aspects (physical disease of workers). Most attention has been paid to the health and safety of worker stakeholders, and there is a lack of attention on society and value chain actors stakeholders. Furthermore, sexual harassment has not been considered in the existence-LCA research.

6.2. Limitations of the Study and Future Research Directions

The findings from this study highlight that the major challenges in applying S-LCA is the lack of agreement in using social indicators, limitation of data availability, and the lack of agreement on impact assessment methodology. More research is needed to standardize methodology, modify indicators, and develop impact assessment approach.

There has been little research into the S-LCA of cereal crop production. It is critical to assess the S-LCA of cereal crops in order to sustain cereal crop output by improving social performance and human wellbeing.

Existing S-LCA studies do not assess sexual harassment and employment relationship characteristics (on worker stakeholders).

The majority of the focus has been on the social performance of workers and local community stakeholders. Few studies considered society and consumer stakeholders.

There is no comprehensive assessment of product sustainability that incorporates S-LCA, ELCA, and LCC. In future studies, it is suggested that a new method be developed that combines all of these elements of sustainability.

Conducting comprehensive social sustainability (all social performances and indicators) evaluation of products is difficult due to the lack of data availability since many data are required to conduct a comprehensive social sustainability evaluation.

In order to produce a more comprehensive sustainable assessment, it is recommended to consider the cost dimension on social LCA. Integrating the S-LCA with the LCC approach can increase the socioeconomic performance of products and enable the evaluation of social and economic sustainability of the products.

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Abbreviations

LCA	life cycle assessment
S-LCA	social life cycle assessment
LCC	life cycle costing
SLCC	social life cycle costing
E-LCA	environmental life cycle assessment
LCSD	life cycle sustainability dashboard
ES-LCA	environmental and social life cycle assessment

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