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Incorporating social lifecycle assessment in circularity metrics to avoid the unintended consequences of circular economy

Anubhuti Bhatnagar [a], Kirsi Niinimäki [a]
a) Department of Design, Aalto University, Otakaari 12, Espoo, FI-02510

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Abstract: A sustainable transition towards a circular economy requires that businesses evaluate their environmental, economic, and social impact. Since there has been a limited effort for identifying the social impacts of businesses, social life cycle assessment (SLCA) was developed. In this paper, 44 peer-reviewed articles that reported the social consequences of a circular economy transition were identified and reviewed. The review shows that a circular transition may have negative consequences in waste recovery and recycling due to existing unfair labor practices in this sector or create social risks during material substitution, technology scale-up, or changes in the supply chains. However, uncertainty exists in the results because SLCA does not have a uniformly accepted methodology for data collection and analysis, which hinders the comparability of linear and circular economies. Researchers suggest that better stakeholder mapping, reviewing data collection techniques, and creating consensus-driven standard indicators will improve the social assessment of the circular economy.

Introduction

Only 7.2% of the material input in the global economy is recovered (Circle Economy, 2023). Hence, businesses are being encouraged to incorporate circular economy (CE) in their operational framework by changing the materials used in manufacturing, evaluating the impacts of the products across the life cycle, promoting end-of-life responsibility, and creating policies for CE transition.

Evaluating circularity requires tools that may track, monitor, and measure the degree to which the CE-promoting strategies succeed. The environmental life cycle assessment (ELCA) tool (ISO, 2006a, 2006b) is used to assess the environmental performance of a CE transition. Other tools are Material Flow Analysis (Foglia et al., 2021) and Input-Output Analysis (Shi et al., 2019). Based on these, the resource potential indicator, global resource indicator, and longevity indicator were developed to quantify resource recovery and recycling and measure the duration to which the material remained in the supply chain (Corona et al., 2019).

Despite the benefits, negative consequences of CE arise when governments or businesses are unaware of the less visible social impacts (Shaikh et al., 2020). A systematic evaluation of social impact across a product's life through the social life cycle assessment (SLCA) tool may reduce the negative impacts of a CE transition. SLCA was first discussed in 1996 as a complementary tool to ELCA, but at the time it only focused on the impact on human health (Arvidsson et al., 2015). This focus later expanded to include other indicators such as worker rights, protection of the indigenous population, and societal economic development. The first systematic guidelines for SLCA were developed by the United Nations Environment Program with the Society of Environmental Toxicology and Chemistry in 2009 (UNEP, 2009) and revised in 2020 (UNEP, 2020). Hereafter these will be referred to as the 'UNEP guidelines.' Another approach to measuring social impact was published in the Handbook for Product Social Impact Assessment (Goedkoop et al., 2020). This guideline is a consensus-based practical approach proposed by industrial stakeholders.

The present paper identifies the social risks of CE transitions in various industries, the role of SLCA in evaluating these risks, and makes recommendations to improve the assessment.

Methods

Two keyword searches shown below were performed using Web of Science ™ to identify papers related to SLCA and CE published between 2009 and December 2022:

a) "Social LCA" OR "social lifecycle assessment" OR "social life cycle assessment" (Topic) and English (Languages) and Article or Review Article (Document Types): 394 outputs
b) ("circular economy" OR recycle OR refurbish OR reuse OR recover OR circularity) AND "social impact" (Topic) and Article or Review Article (Document Types): 148 outputs

Excluding duplicates, the remaining 406 articles were sorted into 'review,' 'methodology development,' 'case study,' and 'methodology development with case study.' Further delving into the abstracts of the case studies showed that only 44 articles reported social impacts of a CE transition or CE-related concepts such as reduce, reuse, repair/ refurbish, recycle, and recover. A list of these articles is provided in the appendix.

Results and Discussions

Classification of case studies

Figure 1 shows the historical growth in the number of publications regarding SLCA and the cases which incorporate social assessment in a circularity framework. Over 70% of these have been published between 2018 and 2022. The industrial classification (based on the United Nations, 2008) of these studies shows (Figure 2) that waste collection, treatment, and material recovery have been the focus of most case studies.

Many case studies used the UNEP guidelines (UNEP, 2020) to evaluate social impacts on six key stakeholders— workers (W), local communities (LC), value chain actors (VCA), consumers (Co), children (Ch), and society (S). Figure 3 shows that workers are the most frequently evaluated stakeholders (33 cases), and researchers find health and safety to be important social issues because the recirculation of materials imbibes new risks for workers (Shi et al., 2019). However, in some cases, social impact has been assessed using methods like externality assessment (Blanc et al., 2019) or human-scale development (Clube & Tennant, 2022). The list of stakeholders and impact categories was also expanded to assess specific supply chains and is listed in Table A1.

Creating an inventory for SLCA is the most crucial step for the assessment for which the data was collected through primary, secondary, and mixed methods. Primary data collection involved structured or semi-structured interviews with stakeholders (Aparcana & Salhofer, 2013) or questionnaires for key members of the supply chain (Shaikh et al., 2020). Secondary data collection involved regional databases, technical reports, scientific publications, and statistical databases (Foglia et al., 2021; Yıldız-Geyhan et al., 2017). Expert interviews also helped identify the potential social impacts of technologies in the design or pilot phases (Opher et al., 2018). Mixed methods used a combination of primary and secondary collection techniques, such as a stakeholder survey, technical report, or regional database.

Status of social sustainability in the CE transition

Consequences of circular economy

Promoting circularity in supply chains may be a practical alternative to the resource-intensive methods of industrial production but the choice of a circular strategy may not always be clear. For instance, Suckling & Lee (2017) suggest that mobile phones can be either recycled at the end of first life (EoFL) or reused at EoFL followed by recycling. At EoFL, recycling prevents landfilling of hazardous waste, promotes material recovery, and removes the social and environmental burden of raw material extraction. But additional components have to be produced to replace the discarded product. Reuse at EoFL provides access to the technology to a second user and prolongs product life. However, phones are generally reused in countries with poor waste management systems that create health and environmental risks during the recycling phase (Umair et al., 2015). In this section, the consequences of several other CE transitions are discussed.

(a) Positive consequences

Nineteen of the cases reviewed had positive consequences, i.e., the benefits accrued for society and the environment, and the CE transition was economically viable. Several of these cases were concerned with using a closed-loop recycling technique to recover and reuse material from a single waste stream to create the same initial product. Recycling and reuse of waste materials have been found to improve working conditions and reduce exposure to toxins in plastic (Lukman et al., 2021), glass (Mansilla-Obando et al., 2022), and paper (Zerbino et al., 2023) production. Foolmaun & Ramjeeawon (2013) found that a combination of recycling (75%) and landfilling (25%) was socially and environmentally optimal. Public engagement regarding the management of plastic waste (particularly PET) further improved the waste collection rate and consequently improved the recycling rates (Bianchini & Rossi, 2021). In the textile sector, using waste sheep wool in Sweden reportedly halved the environmental impact of sweater production and reduced the social risks related to sourcing wool from outside the EU (Martin & Herlaar, 2021). In the construction sector, material substitution through the use of recycled concrete aggregates (Hossain et al., 2018), lime ash from the pulp industry for clinker (Simões et al., 2021), and bio-based alternatives (Barrio et al., 2021) reduced social impact on the recyclers, producers, and local communities. Regarding mixed waste streams such as municipal solid waste, Di Maria et al. (2020) reported that separating waste streams like bio-waste, paper, metals, and glass followed by material recovery reduced global warming potential, particulate matter emissions, resource depletion, acidification and eutrophication potential, and generated thousands of new jobs.

(b) Negative or mixed consequences

In 19 of the cases reviewed, the CE transition had negative social, environmental, or economic consequences. The closed-loop recycling of non-beverage high-density polyethylene bottles was found economically prohibitive due to the energy costs associated with material transformation despite the social benefits (Papo & Corona, 2022). Recycled aggregates reduce the impact on human health, the environment, and the costs of road construction, but have a higher economic and environmental burden during the use phase because the rougher texture of the roads increases fuel use and tire breakdown (Shi et al., 2019). The bio-based alternatives for food packaging were also economically unsustainable till greater production efficiency is ensured despite the reduced impact on climate change, pollutant emissions, and health risks for the cultivators (Blanc et al., 2019).

Other cases related to single waste streams showed that despite the environmental benefits, there were several negative impacts on stakeholders. For example, recovering phosphorous during agricultural activities in Japan reduced material import requirements, but adversely impacted gender equality since Japan showed higher workplace discrimination than other phosphorous producers like China and Morocco (Teah & Onuki, 2017). Organic waste from agriculture also showed potential to establish a new market for organic fertilizers, create new jobs, save working time, and reduce a crop's water use requirement, but these strategies require upskilling of the workers so that they can operate the technology and may expose LCs to harmful emissions from the use of organic fertilizers (Andrade et al., 2022). In another case, magnesium was recovered from the wastewater treatment plant in the Netherlands leading to increased self-reliance in Dutch society but leading to job loss for the primary magnesium producers working in Russia (Tsalidis & Korevaar, 2019). Regarding mixed waste stream, the benefits of treating MSW as a single waste stream for electricity production were dependent on the plant's location and were only competitive at a threshold waste generated and electricity substituted (Nubi et al., 2021).

Negative social consequences of waste recovery such as unregulated working hours, poor social security, discrimination, lack of adequate health benefits, and loss of unskilled jobs are also prevalent when informal workers are engaged in waste management (Umair et al., 2015). Regulatory intervention such as formalizing recyclers and safeguarding worker rights under government legislation has not shown enough benefits in low-income countries since formal recyclers were given short-term contracts that did not ensure social benefits or prevent discrimination (Aparcana & Salhofer, 2013). Replacing manual collection with urban collection centers led to significant environmental savings but also led to job losses for the disabled or low-skilled workers engaged in manual waste collection (Vinyes et al., 2013). It may be argued that manual waste collection promotes health risks due to exposure to toxic substances during waste collection and the compensation may not meet the economic requirements. Hence, Yıldız-Geyhan et al. (2017) showed that in a combined informal-formal scenario waste collectors' social security, health and safety may be legalized and safeguarded although the number of collectors employed was significantly less than in an informal sector.

Other consequences of a CE transition were related to regional-level transformation, such as finding a sufficient labor force to take over the skilled jobs created during the CE transition and limited consideration of inputs from citizens and civil society compared to companies and the municipal government Vanhuyse et al. (2022). Mohaddes Khorassani et al. (2019) reported that a refurbishing initiative undertaken by the local government to restore a heritage site created mixed impacts, with some environmental impacts related to the reconstruction and use phase and positive benefits for society.

Promoting social assessment of CE

Challenges of SLCA tool

Addressing the challenges of using the SLCA tool is necessary to evaluate the social sustainability of a CE transition. The challenges regarding the use of the SLCA tool that were identified in the cases reviewed in this paper are listed in this section.

(a) Utility: Several small and medium companies that operate with local suppliers can ensure open communication regarding social risks and do not find utility in performing a formal social assessment (Walker et al., 2021).
(b) Validity: SLCA practitioners report that establishing the validity of data collected is challenging in informal sectors where stakeholders are uncomfortable in responding honestly either due to fear of losing their jobs (Shaikh et al., 2020) or receiving poor social responsibility ratings (Barrio et al., 2021). Further, regional databases do not adequately assess the social impacts of specific supply chains (Teah & Onuki, 2017).
(c) Comparability: Several SLCA sub-categories have multiple interpretations making a comparison challenging. For instance, the creation of jobs is considered a 'positive impact' when considering a regional CE-transition (Vanhuyse et al., 2022) but for regional waste collection program, the CE-transition that led to most jobs was harmful to the environment (Vinyes et al., 2013). SLCA results are incomparable when a circular supply chain is significantly different from a linear supply chain due to changes in the number of stakeholders or organizations involved (Tsalidis, 2022).
(d) Completeness: More than one study reported that the provided sub-categories and stakeholder categories in the UNEP Guidelines were insufficient for the assessment (See section 3.2). SLCA also cannot capture the product's "use phase" despite its significance in extending the product's lifetime through options like repairing or reusing (Suarez-Visbal et al., 2022). In addition, it is still not clear how to assess the potential social impact of materials with multiple life cycles in terms of impact attribution across the various life cycles (Papo & Corona, 2022).

Recommendations for improving SLCA

Based on the consequences of CE and the challenges of using SLCA, several recommendations have been made to better incorporate social sustainability in the CE transition and promote the use of SLCA tools.

1) Stakeholder engagement: A step-by-step approach for defining the boundaries and moving through stakeholder identification, mapping, and monitoring, using stakeholders and experts may narrow the scope of the SLCA (Vanhuyse et al., 2022) and help identify what generates additional social value in a product-specific context.
2) Standardizing indicators: Standard indicators should be created based on the global consensus of socially relevant themes such as the Sustainable Development Goals (Herrera Almanza & Corona, 2020) or through collaboration with businesses regarding context-specific requirements (Walker et al., 2021).
3) Reliability: The quality of the stakeholder responses should be checked using a scoring system, which calculates average scores from individual stakeholders by

corroborating the response with available reports (Zerbino et al., 2023). In general, the global databases for secondary data collection (like PSILCA or EcoInvent) need to be expanded continuously with more localized case studies.

4) Improving comparability: It is recommended to create normalization and weighting factors to categorize the social impacts of the organizations. Kühnen & Hahn (2019) suggest that developing an expertise-based consensus on these factors may promote the use of SLCA.

Conclusions
There has been a steady increase in the publications evaluating social impacts of circular transition in industries. In this review paper, 43% of the cases studied reported that these transitions are socially, economically, and environmentally sustainable. However, an equal number of cases reported negative impacts on one of the dimensions of sustainability. Especially during material recovery and reuse many stakeholders face health and safety risks or job losses. There are also environmental impacts due to energy used in restoring the recovered material's quality for reuse. Further, data collection for SLCA and impact assessment remain challenging. Hence, many researchers recommend the use of a scoring system to assess the quality of stakeholder responses when primary data is used, expand the global databases to include more site-specific cases and develop weighting factors for comparing linear and circular economies in terms of their social impacts.

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Figures and Tables

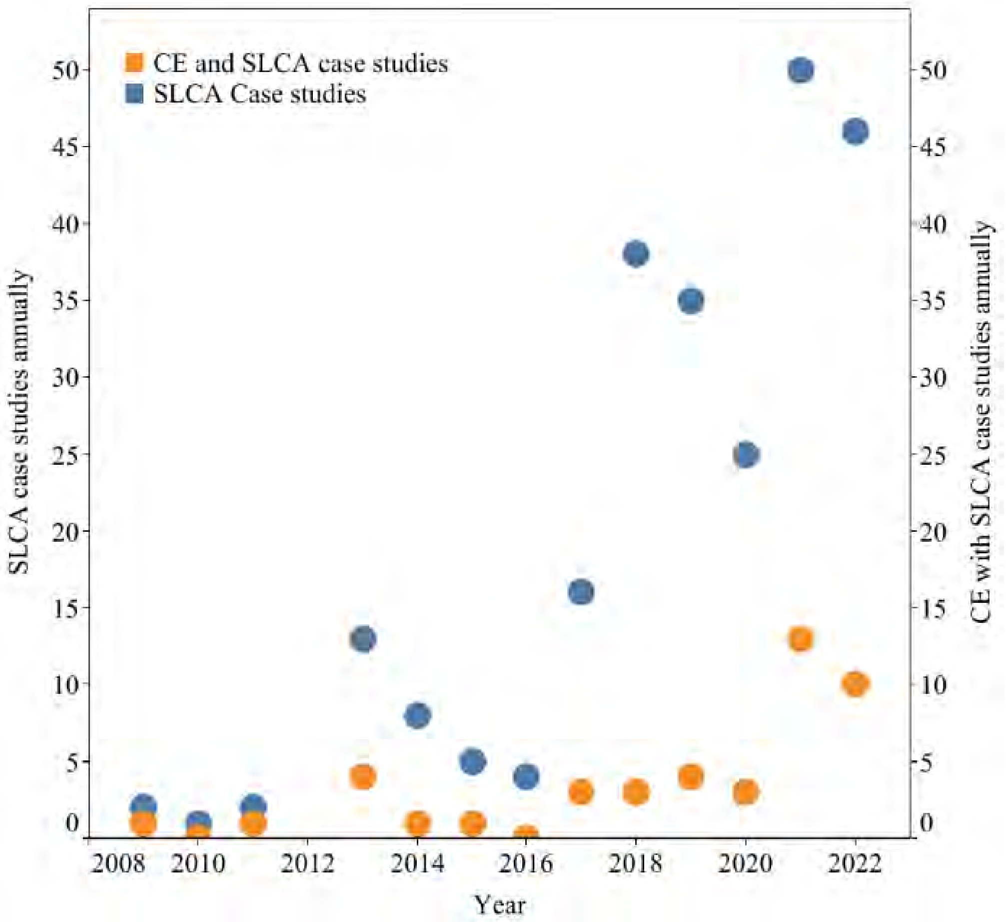

Figure 1. Historical growth rate of publications on SLCA and social impacts of CE.

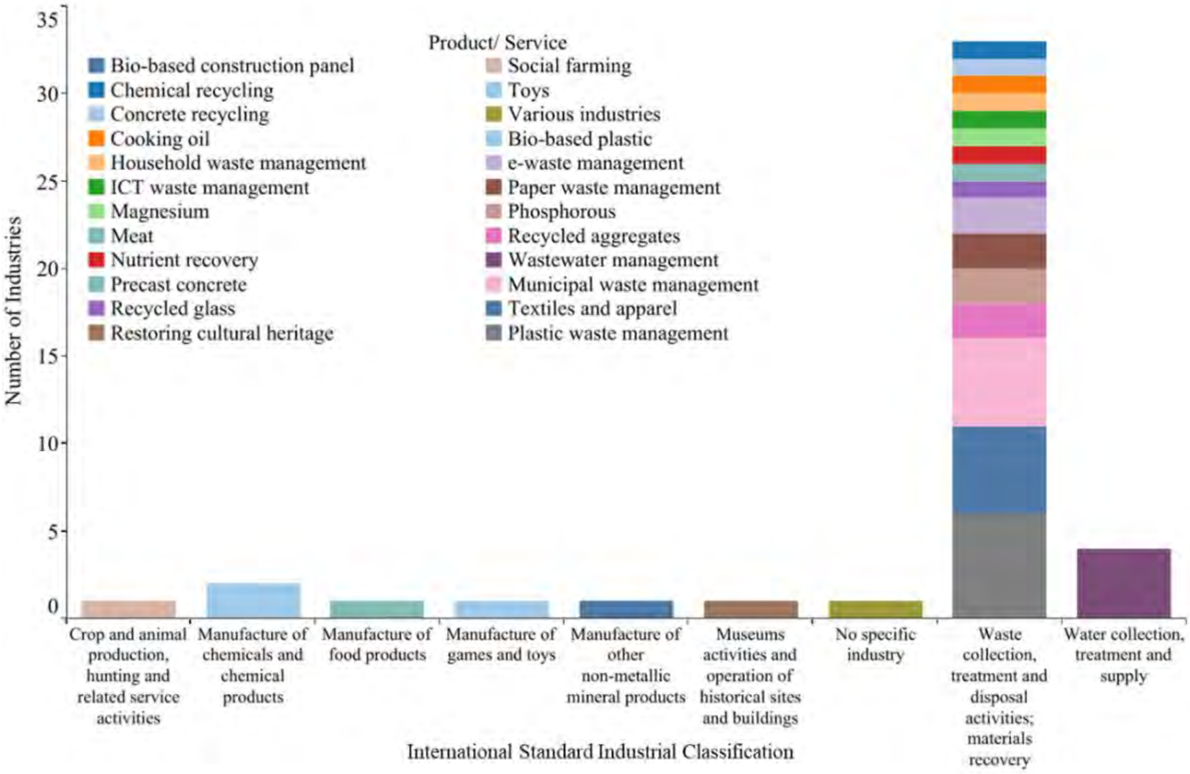

Figure 2. Distribution of case studies as per the industrial classification.

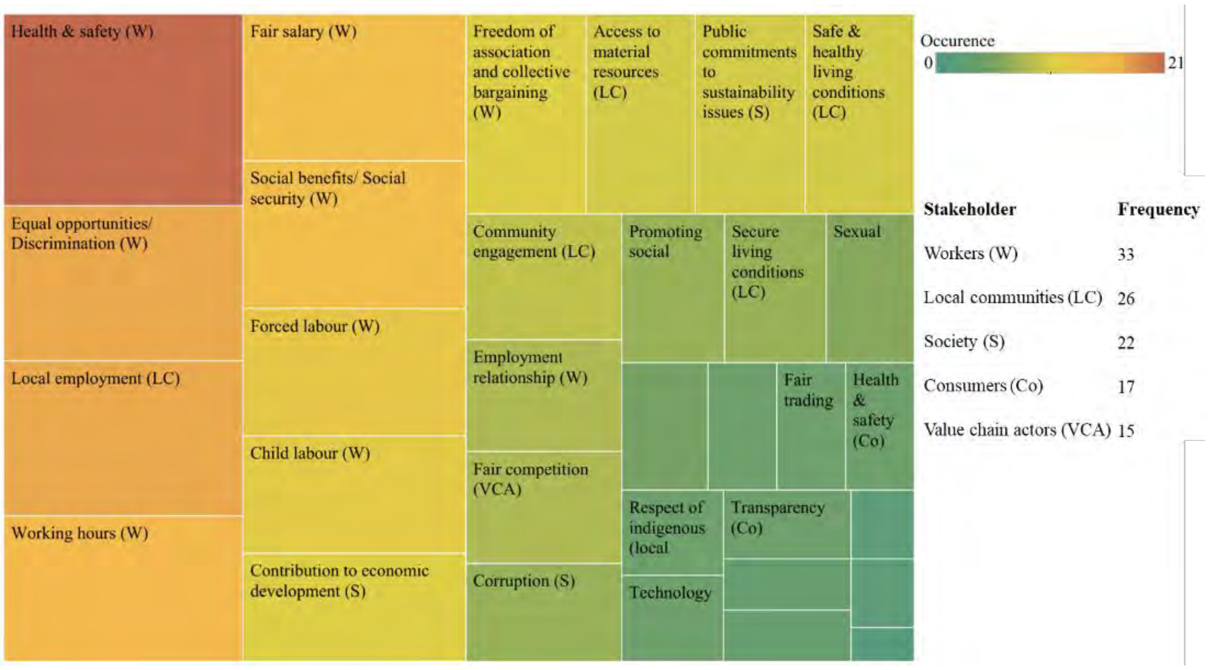

Figure 3. Stakeholder and sub-category distribution in case studies reviewed.