Abstract

While academic literature related to sustainability assessment approaches in circular inter-firm networks continues to grow, little is known about the implementation and applicability of these approaches by industry practitioners across their supply chains. This chapter therefore compares the proposed approaches from the literature with those applied in practice according to four criteria: balance of sustainability dimensions; the intergenerational nature of sustainability; stakeholder involvement; and life-cycle thinking. Empirical data was collected through 43 semi-structured interviews with companies engaged in CE practices in Italy and the Netherlands. It was found that CE actors saw sustainable supply chains as a priority, even though about a third of the respondents did not conduct sustainability assessments across supply chains. The main reasons for this were the small size of companies or, for larger companies, the limited importance clients attributed to the sustainability impacts of products. The supply chain assessments conducted were mostly qualitative, in collaboration with firms' supply chain partners, or a life cycle assessment. It further emerged that, rather than relying on the assessment results, companies ascribed high importance to supply chain management tools and to a relationship based on trust with their supply chain partners.

Keywords: circular economy; sustainable supply chain; supply chain assessment; interviews; supplier network

10

Assessing sustainability across circular inter-firm networks

Insights from academia and practice

Anna M. Walker, Katelin Opferkuch, Erik Roos Lindgreen, Alberto Simboli, Walter J.V. Vermeulen, and Andrea Raggi

ORCID.org/0000-0001-7420-4864

ORCID.org/0000-0001-6820-1966

ORCID.org/0000-0002-7207-6261

ORCID.org/0000-0001-8753-3974

ORCID.org/0000-0002-5947-8688

ORCID.org/0000-0001-9748-3077

Introduction

Since companies using circular economy (CE) practices are usually embedded within regional or global networks of supply chains, it is essential to consider the comprehensive sustainability impact of these actors (Vegter, van Hillegersberg, & Olthaar, 2020). While the academic literature on sustainability assessment approaches for circular inter-firm networks (CIFN) has already been summarised by the authors (Walker, Vermeulen, Simboli, & Raggi, 2021c), research addressing the industry perspective on this topic is limited. Walker et al. (2021c) describe CIFNs as company networks which "consist of actors that are connected through open (intersectoral) and/or closed (intrasectoral) supply chains which are *de facto* circular" (p. 3).

This chapter aims to map out which sustainability assessment approaches are implemented by frontrunner companies from Italy and the Netherlands involved in CE practices. The 43 companies interviewed are assumed to be frontrunners, as they are members of national and international CE networks. Their insights can contribute to advancing the application of sustainability assessment across CIFNs, as CE practices mostly take place beyond company boundaries (Vegter et al., 2020). The second aim of this chapter is to benchmark the sustainability assessment approaches from academia and practice against sustainability assessment criteria identified from literature to further the development of sound assessment approaches.

The following section sets out the academic state of the art in sustainability assessment of CIFNs and then provides a brief literature review of the most pertinent criteria for analysing the efficacy of sustainability assessment approaches in CIFNs. The third section offers an overview of the methods employed, while the fourth section presents the empirical results. In the fifth section, the authors benchmark the identified approaches against criteria for sound sustainability assessment. The findings are discussed in section six and complemented with some recommendations for CE practitioners on how to conduct a meaningful sustainability assessment across supply chains.

Theoretical background

The state of the art in academia

Sustainability assessment approaches from industrial ecology (IE) and circular supply chain management (CSCM) are particularly well adapted to the realities of CIFNs (Walker et al., 2021c). IE provides mainly *ex-post* assessments focussing on the environmental dimension of sustainability, the most frequently applied approaches being life cycle thinking (LCT)-based methodologies. Meanwhile, the field of CSCM offers more *ex-ante* assessments, which sometimes cover all three sustainability dimensions traditionally addressed by companies: the social, environmental, and economic dimensions. Furthermore, CSCM literature mainly promotes the employment of mathematical programming for identifying the optimal constellation of a circular supply chain. However, these mathematical programming models are often based on singular indicators, which may obscure trade-offs and could be considered a reductionist approach (Gasparatos, El-Haram, & Horner, 2008). In line with other scholars, results from the literature review further revealed that assessment approaches for social sustainability should be further developed and integrated with assessment approaches for the environmental and economic dimensions (Roos Lindgreen, Salomone, & Reyes, 2020; Vegter et al., 2020; Walzberg et al., 2021). This discussion has been taken up by Walker et al. (2021b), documenting companies' understanding of the social dimension in the CE and its potential assessment, even across supply chains. Figure 10.1 presents the sustainability assessment framework for CIFNs developed based on the academic literature by Walker et al. (2021c). This framework is divided into two types of assessment approaches: first, evaluation approaches, with the goal of mapping sustainability impacts, and second, decision-supporting approaches, enabling informed decision-making based on the data observed.

[Insert 15032-5090–010-Figure-001 Here]

Figure 10.1 Sustainability assessment framework for CIFNs

Source: Based on Walker et al. (2021c, p. 15).

Criteria for sound inter-firm sustainability assessment

Sustainability assessments are conducted to identify (potential) sustainability impacts of CIFNs. These impacts either bring society closer to (if positive) or further away (if negative) from achievement of the UN Sustainable Development Goals (SDGs) (United Nations, 2015). Several requirements for meaningful sustainability assessments in CIFNs can be identified from the literature for various stages of assessment. While scholars have provided insights into the selection process of assessment approaches (Gasparatos & Scolobig, 2012; Zijp et al., 2017), such as being aware of the underlying value system of each approach (Gasparatos, 2010; Sala, Farioli, & Zamagni, 2013), the ontology of the approaches (Sala, Ciuffo, & Nijkamp, 2015), or their feasibility in a certain context (Schöggl, Fritz, & Baumgartner, 2016), the authors would like to present those criteria most pertinent to CIFNs. Therefore, the four criteria presented by Muñoz-Torres et al. (2018) are applied here in a slightly adapted version, selected due to their frequent mentioning in supply chain literature and their aptness to CE practices. The four criteria are *balance of the different sustainability dimensions aligned with the SDGs, consideration of the intergenerational nature of sustainability, stakeholder involvement, and LCT.*

The first criterion entails the question whether the assessment approach can sufficiently *cover and integrate the sustainability dimensions*, aligned with the SDGs (Valenzuela-Venegas, Salgado, & Díaz-Alvarado, 2016), and whether trade-offs between them are made transparent (Haffar & Searcy, 2017; Morrison-Saunders & Pope, 2013).

The second criterion evaluates if the assessment approach can take the *intergenerational nature of sustainability* into consideration or, in other words, whether implications across time can be captured (Gasparatos & Scolobig, 2012; Sala et al., 2013).

The third (*stakeholder involvement*), mentioned by several authors (Kühnen & Hahn, 2018; Sala et al., 2015; Silva, Nuzum, & Schaltegger, 2019), can help develop trust and

empower stakeholders. This step is crucial for sustainability assessment, providing it with legitimacy and concurrently embedding it into its local context (Schöggl et al., 2016). The engagement of different types of stakeholders further allows for interdisciplinarity (across disciplines) or even transdisciplinarity (including practitioners), providing a more holistic perception of reality (Sala et al., 2015).

The fourth and final criterion is related to the circular nature of the inter-firm networks: *LCT*. As has been pointed out by several scholars (Peña et al., 2021; Sala et al., 2013), an assessment approach with a life-cycle perspective considers the sustainability impacts of a given product and the producing companies from the sourcing of material and production through to its final disposal or, in the case of circular networks, to the recovery of that product or its material/energy content (Vegter et al., 2020).

Methods

To compare the assessment approaches proposed by academia with those implemented by frontrunner companies engaged in CE practices, the sustainability assessment framework for CIFNs (Figure 10.1) is to be populated with approaches found in practice.

The empirical data was collected via semi-structured interviews from a subset of respondents who had participated in a survey on the connection between the CE and sustainability (Walker et al., 2021a). The 43 interview participants were mostly in upper management positions within micro-companies with less than 10 employees (49%), while the rest were from sustainability departments in small and medium companies (26%) and large companies with more than 250 employees (25%). All firms were operating either in Italy (n = 20) or the Netherlands (n = 23) and were members of a CE network. For more details on the interview methodology, please refer to Walker et al. (2021a).

Supply chain assessment in frontrunner companies engaged in CE practices

Over two-thirds of the interviewees acknowledged the importance of sustainability assessment in supply chains and confirmed that they performed some type of such an assessment. The main reason for this was that respondents could obtain a better oversight of the materials processed in their supply chains, use this knowledge to set internal performance targets, and strengthen their supplier relationships. Furthermore, the results of the assessment were also used for external communication at both a corporate and regional level. However, about a third of the interviewees did not conduct any sustainability assessments of their supply chains because they were either small companies with few supply chain partners, or larger companies, whose clients did not lend significant weight to sustainability criteria. Nevertheless, they still included information regarding their CE practices in their external communication.

Supply chain assessment approaches applied

In Figure 10.2, all the applied approaches are presented in their respective assessment category. Companies which conducted sustainability assessments mostly did so in a qualitative way, together with their supply chain partners, or opted for a method based on LCT. The qualitative approach usually implied client and/or supplier meetings to jointly evaluate product solutions. External consultants were sometimes involved in this process to help establish the sustainability impacts of products, mainly focussing on the environmental domain. Another type of evaluation consisted of visiting supplier sites or, where not possible, requiring suppliers to be members of ethical supplier networks. Whereas the aforementioned qualitative assessment practices were more common among smaller companies, large companies conducted regular supplier audits in line with their corporate purchasing policies. Concerning more intricate assessments, the most sophisticated methodology used was Life Cycle Assessment (LCA), either conducted by the

company itself or, more frequently, by external consultants. Related thereto, company supply chains also shared data on carbon emissions to determine their comprehensive carbon footprint, a process which was often initiated by clients. Given that no indices were mentioned by companies within the sample, the category “Indices” has been replaced by “Certification and labels required for suppliers” in Figure 10.2. Additionally, the category “Indicator frameworks” has been extended to specify “Indicator frameworks for suppliers”.

Furthermore, there were several cases where companies monitored their CE practices, such as the number of items of used equipment handed down to other companies, the amount of demolition material used to make bricks, or the amount of used cooking oil utilised as input to produce lubricants or detergents. Yet, the sustainability impact of these CE practices was not necessarily calculated.

[Insert 15032-5090–010-Figure-002 Here]

Figure 10.2 Use of supply chain sustainability assessment approaches by sampled companies

Source: Own elaboration.

Reliance on supplier criteria (ex-ante assessment)

While in the past the most important indicator for choosing a supplier has been the cost factor, the criteria have now widened considerably. Around three-quarters of the companies have determined both formal and/or informal criteria for their supplier selection. Within larger companies, these criteria were often defined explicitly in a socially responsible purchasing policy or circular sourcing strategy. Though these were frequently developed internally, external consultants were sometimes also involved in the process. The supplier criteria usually took the form of either certifications and labels, or sustainability indicators. For companies with a formal supplier selection process, a group which accounted for about half of the respondents and consisted mainly of large companies, most of the suppliers also needed to sign a code of conduct, subscribing to the principles of the procurement policy of the issuing companies. In the case of

large companies, these criteria were often requirements for suppliers participating in official tenders. Additionally, these larger companies were in a better position to impose supplier criteria because of their power in the supply chain. However, if subject to green public procurement laws (mainly in Italy), these companies had limited leeway in setting minimum criteria due to the stipulation of keeping the tendering process as accessible as possible. To procure sustainably, some of the companies chose to add optional indicators on strategic aspects of sustainability as bonus points, instead of making them a minimum requirement.

Regarding the first group of official requirements, about a quarter of the companies asked for specific data on sustainability aspects, necessitating suppliers to assess data on energy used, the means and distances of transportation, as well as CO_2 emissions. The indicators were mainly developed based on the aforementioned sourcing strategy and were sometimes also derived from international and industry standards.

The latter are part of the second group of official requirements, namely certifications and labels [e.g. ISO 14001, SA8000, Forest Stewardship Council (FSC) or Energy Star]. In contrast, small companies prioritised standards certifying organic agriculture and ethical treatment of workers, rather than management system standards.

Besides companies employing formal selection criteria, several, in most cases small companies, also had prominent informal criteria which they perceived to be indispensable for a fruitful collaboration. Namely, suppliers needed to have company values and a vision on sustainability and circularity which aligned with their own. Related thereto, several companies also mentioned the importance of keeping the supply chain within a “reasonable” radius to valorise their local territory. If the materials or ingredients for their products were not available in geographical proximity, they relied on suppliers’ membership in networks of ethical suppliers for sustainability assurance.

Continued collaboration with suppliers (ex-post)

Deemed just as relevant as the supplier criteria was continued collaboration with suppliers, underlined by about two-thirds of the companies. Ongoing collaboration was seen, on the one hand, as a driver for CE, while, on the other hand, some companies also saw the novel CE paradigm as a catalyst for more collaboration. Especially in the case of smaller companies, collaboration with suppliers was often based on long-term relationships with partners that pursued similar values, establishing trust. For larger companies with more formal supplier protocols ensuring competitiveness, this kind of relationship was less frequent; but taking a stance on circularity still had a positive impact on supply chain collaboration. In addition to collaborating with key suppliers, these companies also conducted educational workshops on sustainability and CE with their suppliers. On this collaborative basis, it was possible to evaluate the production process for a joint product, either by means of an official assessment or by deliberating the different production options as a first step. Some companies mentioned that the level of collaboration with their suppliers has also increased due to the supply chain sustainability assessment, because it required them to actively reach out to their suppliers and to find out how their supply chain was organised. While, in some cases, incumbent companies came together to develop new product solutions and services, often facilitated by smaller, more agile companies, others did not necessarily want to change the product. Instead, they wanted to better understand their suppliers' actions and the impacts on the product. At the end, collaboration did not only happen within supply chains, but also across industries and supply chains, for example in industry working groups such as the CE100, the Factor10 of the World Business Council for Sustainable Development, or industry consortia, and the aforementioned ethical supplier networks.

Depending on the type of collaboration, Figure 10.2 shows that the meetings with suppliers and clients were regular, *ad-hoc*, and, in some cases, facilitated by consultancies or a coordination team, mainly as part of cross-industry initiatives. These external parties were often also essential to initiate collaboration by, for example, finding suitable buyers for by-products of companies, while ensuring the financial competitiveness of these transactions. Besides the

economic aspects, geographical proximity was also seen as a driver of collaboration both within and across sectors.

Barriers to implementing supply chain sustainability assessment

The respondents mentioned several reasons why their assessment did not go further in detail and scope, which are summarised in Figure 10.2 in the top left. The main issue was that information on the supply chain was often simply missing, given it would have to be collected from the lower tiers. This was particularly relevant for companies working with secondary materials and products, given these materials had already gone through at least one life cycle or were complex products such as electronics. In other cases, the suppliers did not directly want to share information for competitive reasons, though this was less frequently mentioned. Where companies were themselves suppliers for larger companies, they also did not necessarily have the leverage to ask their downstream partners for further information. This is closely related to the second main barrier, namely the limited leverage over the decision-making and behaviour of upstream and downstream partners, as well as that of consumers. Several respondents mentioned that their clients were often informed about the sustainability impacts of certain product and material choices. Yet, the decision on whether to opt for the potentially more (expensive) sustainable option or not lay beyond the interviewees' sphere of influence. There were several instances where clients did not demand a sustainability assessment, especially when informed that it might increase costs. Another barrier, faced mainly by large companies with diverse product portfolios, was the high number and diversity of supply chains, so the assessments were kept to the most important partnerships and impact categories such as global warming.

Benchmarking approaches from academia and practice

Based on the four criteria of sound sustainability assessment, approaches from academia and practice are compared in the following subsections. An overview of the comparison is provided in Table 10.1.

Balancing sustainability dimensions aligned with SDGs

Both academics[1] and practitioners use LCT methodologies, but the assessment is mainly put into operational practice for the environmental dimension of sustainability. While LCA covers a wide range of environmental impacts, the integration of these impacts with social and socio-economic factors is still limited across supply chains. Regarding mass balance and input–output analyses, the social dimension is not covered in the literature and in practice. In contrast, the identified indicator frameworks are more inclusive and contain a more holistic set of indicators. Yet, it was found that both in practice and in the literature, social indicators are often limited to job creation, sometimes focussing on people disadvantaged in the labour market. Indices found in the literature encompass either an environmental or a social dimension but do not necessarily address the balance among them. In the newly created category of certifications and labels for suppliers, it was noted that companies require both environmental and social certifications when selecting suppliers. The other evaluation approaches such as scenario analysis and stakeholder consultation can also be considered holistic in terms of sustainability assessment for both academia and practice, whereas the environmental cost–benefit analysis is focussed only on the environmental and economic factors. With regards to decision-supporting approaches, none of the interviewed companies applied mathematical programming, heuristics, multi-criteria decision-making and simulation approaches. In the academic literature, there are instances of mathematical programming models covering all sustainability dimensions, but they often consider only a limited number of indicators per dimension. Also, costs are the most common indicator to be optimised, while the social (mostly job creation) and environmental indicators

(mostly greenhouse gas emissions) are generally modelled as constraints, rather than simultaneous optimisation goals. Regarding multi-criteria decision-making models proposed by academia, they can indeed include all sustainability dimensions, depending on the underlying indicators chosen in the evaluation step. Similarly, simulation can also model the effects on all sustainability dimensions, if the cause-and-effect relations are known. At the end, concerning analytical models, the Political, Economic, Sociological, Technological, Legal and Environmental (PESTLE/LESTS) analysis, stakeholder/expert consultation, as well as backcasting usually include the sustainability dimensions considered to be important by the decision-makers, both in practice and academia. However, it has been found that the companies within this sample rarely asked external parties (e.g. consultancies) for social assessments.

Table 10.1 Benchmarking literature and practice according to criteria for sound sustainability assessment

	Sustainability criteria / Assessment approach categories	**Balance of sustainability dimensions**		**Addressing intergenerational nature of sustainability**		**Stakeholder involvement**		**Life-cycle thinking**	
		Literature[a]	**Practice[b]**	**Literature[a]**	**Practice[b]**	**Literature[a]**	**Practice[b]**	**Literature[a]**	**Practice[b]**
Evaluation	LCT methodologies	Possible	Not implemented	By default	Implemented	Possible	Implemented	By default	Implemented
	Mass balance and input–	Not possible	Not implemented	Possible	Not implemented	Possible	Implemented	Possible	Not implemented

	output analyses								
	Indicator frameworks (for suppliers)	Possible	Implemented	Possible	Not implemented	By default	Implemented	Possible	Implemented
	Indices/Certifications and labels for suppliers	Possible	Implemented	Not possible/ found	Implemented	Possible	Implemented	Not possible	Not implemented
	Other evaluation methods	Possible	Implemented*	Possible	Not implemented	Possible	Implemented	Possible	Implemented
Decision-support	Mathematical programming and heuristics	Possible	N/A	Not possible/ found	N/A	Possible	N/A	Possible	N/A
	Multi-criteria decision-making methods	Possible	N/A	Possible	N/A	By default	N/A	Possible	N/A
	Simulation	Possible	N/A	Possible	N/A	Possible	N/A	Possible	N/A

	Analytical models	Possible	Implemented*	Possible	Not implemented	Possible	Implemented	Possible	Implemented

[a] For details, refer to Walker et al. (2021c).

[b] Based on interviews with companies.

* Social dimension mostly left out.

Addressing the intergenerational nature of sustainability

With regards to intertemporal aspects, the LCT methodologies are well suited, because they consider the long-term impacts of resource use and depletion beyond generations (Sala et al., 2013). However, besides those respondents who conducted a full LCA, several companies only examined single-impact categories, such as the carbon footprint, providing a limited picture of the long-term impacts. In the category of the mass balance and input–output analyses, the temporal scope of such analyses can extend over long time periods, especially when covering large regions. Yet, the monitoring of materials as described by the interviewees and in literature does not explicitly take a long-term perspective. Regarding the indicator frameworks in the literature, they do not necessarily specify the importance of long-term availability of resources, though indicators related to the R-hierarchy (Reike, Vermeulen, & Witjes, 2018), for example, do point in this direction. In practice, companies have started to consider introducing indicators related to the CE, such as recyclability of products or amount of recycled content, into their purchasing requirements, but in most cases have not yet done so. When it comes to indices proposed in the literature, scholars do not include any long-term indices. In contrast, some of the certifications and labels for suppliers contain inter-temporal aspects, such as the FSC and the organic agriculture label, which stand for sustainable and regenerative forestry and agricultural

practices. Regarding the other evaluation methods, several can depict different timeframes, in particular, scenario analysis. For the decision-supporting approaches, temporal aspects can be included in mathematical programming models, also combined with heuristics. However, these models are usually not optimised for time spans across generations and often are modelled with infinite stocks of resources. Concerning the multi-criteria decision-making models, they have the option to include indicators based on the R-hierarchy, yet the indicators' importance depends on their weighting. Similarly, a simulation can model any time span required if the dynamics within the system are known. Yet, fast-changing CIFNs usually have time horizons of less than one generation. In contrast, analytical models such as backcasting are well suited to address the intergenerational aspects of sustainability, depending on the timeframe set. Regarding the other methods such as stakeholder consultation and the PESTLE/LESTS analysis, these might, both in theory and practice, focus more on short-term impacts, as they are meant to find solutions for current situations, and the needs of future stakeholders are not necessarily considered (Wannags & Gold, 2020; Wu & Pagell, 2011).

Stakeholder involvement

In literature, stakeholder involvement has been considered to a rather limited degree for LCT methodologies, besides data collection from suppliers (Sala et al., 2013). In particular, the social LCA addresses various stakeholder categories beyond suppliers, though their consultation does mostly not go beyond data collection. Whereas the interview respondents report LCA information throughout supply chains, the actual assessments are usually done by external consultancies. Involvement is also limited for mass balance and input–output analyses as described by scholars. Yet, when considering the monitoring of material flows in practice, there is considerable communication between supply chain partners, but not necessarily beyond this stakeholder category. Regarding indicator frameworks, stakeholder involvement is seen as being critical for the validation and selection of indicators. In practice, the indicator frameworks for

suppliers are often developed based on clients' needs, legal requirements imposed by public stakeholders, or indicators communicating corporate information to civil society stakeholders. Similar considerations are also true for the required standards and labels. In addition to this, labels are sometimes promoted to sell products within industry networks. When looking at the indices proposed by scholars, it becomes evident that stakeholder involvement is limited, except for indices which also include the social dimension. As already anticipated previously, stakeholder involvement is often used as a first step to identify relevant indicators. Stakeholder involvement can further be used to inform scenario analysis, as well as cost–benefit calculations. In practice, consultation of stakeholders is essential to both set strategic priorities and legitimise CE practices. This is often carried out in the form of a (materiality) survey or stakeholder meetings. Scenario analysis has also been informed by potential partners of a regional industrial symbiosis project for evaluating its feasibility. Moving on to the decision-supporting approaches, mathematical programming models and heuristics have traditionally not been considered participative. However, both Stindt, Sahamie, Nuss, and Tuma (2016) and Voinov et al. (2016) report that initial involvement of (non-academic) stakeholders before the actual modelling is fundamental for the applicability of the models. Furthermore, a considerable number of authors propose the stakeholder involvement when applying multi-criteria decision-making methods, though expert involvement is slightly more common. Simulation approaches could also be informed by stakeholder involvement, though this is not necessarily the case in literature. At the end, analytical models in literature involve stakeholders to help with decision-making and to inform the PESTLE/LESTS analysis. In practice, stakeholder consultation for decision-making is frequent, primarily limited to supply chain partners and consultancies through meetings and workshops. With regards to clients, companies often provide them with sustainability evaluation results, while leaving the final decision up to them.

Life-cycle thinking

As the name already anticipates, LCT methodologies are rooted in LCT. Nevertheless, it needs to be underlined that, in practice, LCAs do not always cover the whole life cycle of a product. Likewise, a mass balance or input–output-based method can be used to depict a whole life cycle or just a part of it. In practice, it was found that the monitoring of material flows does often not include the whole life cycle of materials but just the respective next tiers of the supply chain. Regarding indicator frameworks and indices in the literature, neither of these is necessarily LCT-oriented, as some are based on direct impacts, particularly the social ones. Yet, a number of LCT-based indicators are included. The same is true for companies using the indicator frameworks and certification and labels intended for suppliers. As regards the other evaluation methodologies, scenario analysis is often combined with LCT methodologies in the literature and thus is well suited for the integration of LCT; something which is also done in practice. The same is true for stakeholder or expert interviews, though whether LCT is included or not depends on the content of the discussion. In the environmental cost–benefit analysis, it is also possible to cover the whole life cycle of a product. Similarly, the respondents underlined that, through their CE practices and collaboration with their partners, they have taken an LCT approach to organising and assessing their supply chain network. When looking at the decision-supporting approaches, LCT-based indicators are frequently included in the mathematical programming models. In contrast, multi-criteria decision-making methods do not necessarily employ LCT-based indicators, though they would be able to integrate them. The same is true for system dynamics, which can model whole life cycles of products within a system. Concluding with the analytical models, they are not based on LCT per se, if this is not explicitly required – for example through expert or stakeholder consultation, or backcasting. Yet, in practice, it was found that companies engaged in CE practices attribute a high degree of importance to the inclusion of the whole product life cycle, making LCT essential in decision-making.

Discussion and conclusion

When comparing the approaches proposed in the literature with the ones actually applied by frontrunner companies engaged in CE practices, it is noticeable that most of the approaches used were qualitative. There is however one important exception which are the LCT methodologies, such as LCA and the carbon footprint. These two approaches were principally established in larger companies and smaller specialised firms. Otherwise, the approaches primarily consisted of indicator frameworks for supplier selection and other methodologies such as stakeholder consultation, scenario analysis, or cost–benefit calculation. Furthermore, while some companies monitored their material flows across supply chains, they did not do so in a comprehensive material flow analysis but rather collected data on the volume of material flows between two tiers only. Another interesting observation was that most of the approaches used in practice were evaluation approaches, while quantitative decision-supporting approaches were absent. The main decision-supporting approach applied was expert consultation, namely through consultancies. This finding is in contrast with the literature, where the most frequently proposed approach was mathematical programming, often in connection with LCT-based indicators or heuristics. Furthermore, the combination of indicator frameworks and multi-criteria decision-making models also prevalent in the literature was not employed in practice. The low application of more quantitative decision-supporting approaches might partly be explained by the high share of micro-companies in the sample. The only similarity between the findings from literature and practice was that both proposed employing LCT-based methodologies, though mainly for larger companies. Schöggl et al. (2020) have arrived at a similar finding in their review of CE research. Swarr et al. (2015) also pointed out increased collaboration with suppliers and customers and cross-functional integration within companies as benefits of LCT approaches for SMEs. When Galindro et al. (2020) asked practitioners why they conducted LCAs, companies reported that they mostly responded to clients' requests. The lack of these requests was seen as one of the main barriers to assessment by the interviewees in this study.

Regarding the fulfilment of the criteria for sound sustainability assessment, it was generally found that LCT methodologies strongly favoured the environmental dimension.

Another notable result from literature and practice was that the requirement of addressing the intergenerational nature of sustainability was least fulfilled. It further emerged that stakeholder engagement was already a best practice for most of the interviewed companies, while, in the literature on LCT methodologies as well as mass balance and input–output analyses, this was documented only sporadically. Concerning LCT, this criterion was also broadly applied in practice by the respondents, though sometimes practitioners did not involve the whole life cycle but only the next tiers of the supply chain.

A third main finding of the comparison is that the answers to the question of what approaches were suitable for assessing sustainability across CIFNs were provided on different levels. While literature offered plenty of assessment approaches, thus providing methodological support, practitioners underlined the importance of relationships when initiating CE practices and assessing them. It thus became clear that rather than relying on quantitative assessment results for decision-making, high importance was attributed to frequent exchange of best practices, trust, and supply chain management tools such as supplier selection criteria, codes of conduct, audits, and certifications and product labels. As already anticipated by Qian, Seuring, and Wagner (2020) and Brown, Bocken, and Balkenende (2019), collaboration based on trust was seen as a critical starting point both for initiating CE practices and evaluating them jointly. It was also found that the connection between collaboration and assessment was reciprocal; the more collaboration there was, the more likely an assessment would be conducted. Simultaneously, the need for assessing a joint product led to more collaboration. Scholars have also noted that collaboration had positive effects on performance, especially when sharing knowledge along the supply chain (Qian et al., 2020). This was put into practice by several interviewees, who conducted workshops for and with suppliers to share information on sustainability aspects and CE practices. Frontrunner companies engaged in CE practices with short supply chains also mentioned that the geographical proximity to their suppliers was an essential driver for their collaboration.

Besides these informal ties between supply chain actors, almost half of the interviewees had additionally established formal supplier selection criteria, either in the form of sustainability performance indicators, often based on LCA data, or certifications and product labels. The importance of balancing formal supplier criteria with trust when managing the corporate social responsibility (CSR) performance was also underlined by Hyder, Chowdhury, and Sundström (2017).

The authors would like to bring this chapter to a close with the recommendations for practitioners presented in Table 10.2, based on best practices from the interviews and literature.

Table 10.2 Recommendations for developing and applying assessment procedures

Development steps	**Recommendation**
1. Identifying partners	• When reaching out to companies within your supply chain, be clear and vocal about the overall vision you are pursuing as a company. • When contemplating about whom to include in the assessment, aim to involve actors across the whole value chain of a product, including those recovering the materials at the end of life.
2. Building trust	• When planning to do a supply chain sustainability assessment, ensure that the partnership with the supply chain actors is sufficiently strong for sharing information and inform them why you are doing the assessment.
3. Conceptualising the assessment	• When conceptualising the supply chain assessment, ensure that all three sustainability dimensions are sufficiently covered to make trade-offs transparent.

	• When selecting indicators, ensure the fulfilment of the criteria for sound sustainability assessment for CIFNs, either through the indicators themselves or the way they are chosen (e.g. the criteria of stakeholder involvement can be covered by including stakeholders in setting the priorities of the assessment or a corporate strategy). • When setting supplier selection criteria, award the inclusion of LCT-based indicators and other sustainability indicators in line with your CSR strategy with higher scores, if you do not want to be too restrictive for suppliers.
4. Continuous learning	• Join an industry initiative or retailer network related to CE or sustainable sourcing to stay up to date regarding innovative best practices in your sector.

Source: Own elaboration.

Acknowledgements

This research constitutes part of the research project CRESTING (Circular Economy: Sustainability implications and guiding progress), funded by the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement number 765198.

Note

References

Brown, P., Bocken, N., & Balkenende, R. (2019). Why do companies pursue collaborative circular oriented innovation? *Sustainability*, *11*, 635.

Galindro, B. M., Welling, S., Bey, N., Olsen, S. I., Soares, S. R., & Ryding, S. O. (2020). Making use of life cycle assessment and environmental product declarations: A survey with practitioners. *Journal of Industrial Ecology*, *24*, 965–975.

Gasparatos, A. (2010). Embedded value systems in sustainability assessment tools and their implications. *Journal of Environmental Management*, *91*, 1613–1622.

Gasparatos, A., El-Haram, M., & Horner, M. (2008). A critical review of reductionist approaches for assessing the progress towards sustainability. *Environmental Impact Assessment Review*, *28*, 286–311.

Gasparatos, A., & Scolobig, A. (2012). Choosing the most appropriate sustainability assessment tool. *Ecological Economics*, *80*, 1–7.

Haffar, M., & Searcy, C. (2017). Classification of trade-offs encountered in the practice of corporate sustainability. *Journal of Business Ethics*, *140*, 495–522.

Hyder, A. S., Chowdhury, E. H., & Sundström, A. (2017). Balancing control and trust to manage CSR compliance in supply chains. *International Journal of Supply Chain Management*, *6*, 1–14.

Kühnen, M., & Hahn, R. (2018). Systemic social performance measurement: Systematic literature review and explanations on the academic status quo from a product life-cycle perspective. *Journal of Cleaner Production*, *205*, 690–705.

Morrison-Saunders, A., & Pope, J. (2013). Conceptualising and managing trade-offs in sustainability assessment. *Environmental Impact Assessment Review*, *38*, 54–63.

Muñoz-Torres, M. J., Fernández-Izquierdo, M. Á., Rivera-Lirio, J. M., Ferrero-Ferrero, I., Escrig-Olmedo, E., Gisbert-Navarro, J. V., & Marullo, M. C. (2018). An assessment tool to integrate sustainability principles into the global supply chain. *Sustainability*, *10*, 535.

Peña, C., Civit, B., Gallego-Schmid, A., Druckman, A., Pires, A. C., Weidema, B., & Motta, W. (2021). Using life cycle assessment to achieve a circular economy. *International Journal of Life Cycle Assessment*, *26*, 215–220.

Qian, C., Seuring, S., & Wagner, R. (2020). Reviewing interfirm relationship quality from a supply chain management perspective. *Management Review Quarterly*, *71*, 625–650.

Reike, D., Vermeulen, W. J. V., & Witjes, S. (2018). The circular economy: New or refurbished as CE 3.0? – Exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. *Resources, Conservation and Recycling*, *135*, 246–264.

Roos Lindgreen, E., Salomone, R., & Reyes, T. (2020). A critical review of academic approaches, methods and tools to assess circular economy at the micro level. *Sustainability*, *12*, 4973.

Sala, S., Ciuffo, B., & Nijkamp, P. (2015). A systemic framework for sustainability assessment. *Ecological Economics*, *119*, 314–325.

Sala, S., Farioli, F., & Zamagni, A. (2013). Progress in sustainability science: Lessons learnt from current methodologies for sustainability assessment: Part 1. *International Journal of Life Cycle Assessment*, *18*, 1653–1672.

Schöggl, J. P., Fritz, M. M. C., & Baumgartner, R. J. (2016). Toward supply chain-wide sustainability assessment: A conceptual framework and an aggregation method to assess supply chain performance. *Journal of Cleaner Production*, *131*, 822–835.

Schöggl, J. P., Stumpf, L., & Baumgartner, R. J. (2020). The narrative of sustainability and circular economy – a longitudinal review of two decades of research. *Resources, Conservation and Recycling*, *163*, 105073.

Silva, S., Nuzum, A. K., & Schaltegger, S. (2019). Stakeholder expectations on sustainability performance measurement and assessment: A systematic literature review. *Journal of Cleaner Production*, *217*, 204–215.

Stindt, D., Sahamie, R., Nuss, C., & Tuma, A. (2016). How transdisciplinarity can help to improve operations research on sustainable supply chains – a transdisciplinary modeling framework. *Journal of Business Logistics*, *37*, 113–131.

Swarr, T. E., Asselin, A. C., Milà i Canals, L., Datta, A., Fisher, A., Flanagan, W., & Rasteiro, M. G. (2015). Building organizational capability for life cycle management. In G. Sonnemann & M. Margni (Eds.), *Life cycle management, LCA compendium* (pp. 239–256). Dordrecht: Springer.

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development [WWW Document]: Sustainable development knowledge platform*. Retrieved January 12, 2012, from https://sustainabledevelopment.un.org/post2015/transformingourworld

Valenzuela-Venegas, G., Salgado, J. C., & Díaz-Alvarado, F. A. (2016). Sustainability indicators for the assessment of eco-industrial parks: Classification and criteria for selection. *Journal of Cleaner Production*, *133*, 99–116.

Vegter, D., van Hillegersberg, J., & Olthaar, M. (2020). Supply chains in circular business models: Processes and performance objectives. *Resources, Conservation and Recycling*, *162*, 105046.

Voinov, A., Kolagani, N., McCall, M. K., Glynn, P. D., Kragt, M. E., Ostermann, F. O., & Ramu, P. (2016). Modelling with stakeholders – next generation. *Environmental Modelling & Software*, *77*, 196–220.

Walker, A. M., Opferkuch, K., Roos Lindgreen, E., Raggi, A., Simboli, A., Vermeulen, W. J. V., Caeiro, S., & Salomone, R. (2021a). What is the relation between circular economy and sustainability? Answers from frontrunner companies engaged with circular economy practices. *Circular Economy and Sustainability*. doi:10.1007/s43615-021-00064-7

Walker, A. M., Opferkuch, K., Roos Lindgreen, E., Simboli, A., Vermeulen, W. J. V., & Raggi, A. (2021b). Assessing the social sustainability of circular economy practices: Industry perspectives from Italy and the Netherlands. *Sustainable Production and Consumption*, *27*, 831–844.

Walker, A. M., Vermeulen, W. J. V., Simboli, A., & Raggi, A. (2021c). Sustainability assessment in circular inter-firm networks: An integrated framework of industrial ecology and circular supply chain management approaches. *Journal of Cleaner Production*, *286*, 125457.

Walzberg, J., Lonca, G., Hanes, R. J., Eberle, A. L., Carpenter, A., & Heath, G. A. (2021). Do we need a new sustainability assessment method for the circular economy? A critical literature review. *Frontiers in Sustainability*, *1*, 620047.

Wannags, L. L., & Gold, S. (2020). Assessing tensions in corporate sustainability transition: From a review of the literature towards an actor-oriented management approach. *Journal of Cleaner Production*, *264*, 121662.

Wu, Z., & Pagell, M. (2011). Balancing priorities: Decision-making in sustainable supply chain management. *Journal of Operations Management*, *29*, 577–590.

Zijp, M. C., Waaijers-van der Loop, S. L., Heijungs, R., Broeren, M. L. M., Peeters, R., Van Nieuwenhuijzen, A., & Posthuma, L. (2017). Method selection for sustainability assessments: The case of recovery of resources from waste water. *Journal of Environmental Management*, *197*, 221–230.

[1] The findings from the literature are taken from Walker et al. (2021c), where further information can be found on specific articles.