



Factors contributing to the relevance and continuity of life cycle assessment networks

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Abstract

Purpose National LCA networks have been supporting the mainstreaming of LCA practice in around a hundred countries. The purpose of this paper is to discuss the factors which contribute to the continuity and relevance of LCA networks as LCA practice becomes more mainstream. This paper addresses the following research questions: what factors enabled the establishment of LCA networks and how is their relevance maintained? How do LCA networks maintain operational continuity? In-depth interviews with national LCA networks were conducted and thematically analyzed. The results analyze the factors contributing to the establishment of LCA networks, as well as offering a unique insight into the factors affecting their relevance over time and contributing to maintaining their operational continuity. While previously LCA networks focused mainly on raising awareness of life cycle approaches, now, they are moving towards providing a coordinated influence on policies and stakeholders. LCA is no longer only an academic method; it has become mainstreamed in business sectors. By offering diverse activities and networking possibilities, LCA networks remain attractive for their members who are willing to pay a membership fee, which secures their long-term viability. The driving force for starting LCA networks was individual experts with an interest in the topic. The formal establishment of the networks allowed greater budgetary resources and, thus, the ability to carry out a broader set of activities that are relevant for different groups of stakeholders. The role of LCA networks both as a learning platform as well as an influential interface between different organizations makes them relevant over time.

Keywords Cross-sectional collaboration · Networks · Societal impact · Multiple case study · LCA

1 Introduction

Life cycle assessment (LCA) is an internationally standardized analytical method to study the environmental impacts of products, services, and systems over their entire life cycle (Finnveden et al. 2009; ISO 14040, 14,044). In addition, other life cycle-based methods such as environmental life cycle costing (Swarr et al. 2011) and social life cycle assessment (UNEP 2020) are used to study social and economic impacts, in accordance with the life cycle sustainability assessment framework (Zamagni 2012; UNEP/SETAC Life Cycle Initiative 2011). Since the 1990s, not only have

academic interest and research activities in LCA increased rapidly (Finnveden et al. 2009), but an increasing societal demand has seen LCA activities become more widespread and mainstreamed (UNEP 2016). At the same time, the LCA methodologies have matured, becoming more sophisticated, and have been applied in a multitude of contexts (Guinée et al. 2011).

LCA has become an important component of policy and voluntary actions in many parts of the world (Guinée et al. 2011) and its significance in providing information on the sustainability performance of different strategic options has been noted (Peña et al. 2021). Furthermore, there is an increasing demand for LCA from national, pan-national, sectoral, and cross-cutting policies that address sustainable production and consumption and the circular economy (e.g., Di Maria et al. 2018; Säynäjoki et al. 2017). LCA has been promoted by the European Commission as the appropriate way of assessing the environmental impacts of products (European Commission 2003) and has been the basis for

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its Product Environmental Footprint (PEF) development (European Commission 2021; Finkbeiner 2014; Pedersen and Remmen 2022). Furthermore, LCA is to be explicitly integrated into European Union (EU) policy instruments, such as public procurement and sustainable finance targeting the construction sector (European Commission 2020). At the national level, several policies and actions have further institutionalized LCA and LCA-based methods, especially concerning environmental claims and marketing; for example, in 2021, the Danish Consumer Ombudsman has advised: “documentation for sustainability claims must be based on a life cycle analysis that shows that the company does not impair the ability of future generations to meet their needs” (Forbruggerombudsmanden 2021). The uptake of LCA in the private sector has also been on the rise, as companies increasingly adopt LCA for product or process development (Marconi and Favi 2020; McAloone and Pigosso 2017), communications (Molina-Murillo and Smith 2009), and strategic planning (Sevigné-Itoiz et al. 2021). Nygren and Antikainen (2010) found that companies rely mostly on existing LCA resources such as software and databases in conducting LCA and that the practical application of LCA is still more prevalent in pioneering enterprises. As studied by Testa et al. (2016), there is still a lack of awareness related to LCA, which hinders its further implementation in companies.

Together with the increasing demand and complexity of LCA, interest in collaboration among LCA professionals and the need for the formalization of LCA practices has increased. This has led to the establishment of LCA networks by academia, industry, and public institutions (Bjørn et al. 2013). LCA networks can be described as “issue-based networks,” i.e., coalitions of actors that aim to induce change by collective action (Dahan et al. 2006), where the network acts to reinforce its members’ collective benefit towards the issue at hand (Ritvala and Salmi 2010). The networks aim to share information and enhance the coordinated use of LCA among different stakeholders, with the final aim of improving the practice of environmental impact assessment of products and systems. In this article, the definition of an LCA network used is adapted from Bjørn et al. (2013): an independent, not-for-profit, centrally coordinated entity that supports a life cycle approach includes members from academia and industry as a minimum, which embodies some forms of communication that connects the members. In this paper, the term LCA networks also include entities that are referred to as LCA centers and LCA roundtables (Palander and Rex 2016).

LCA networks have been the subject of limited academic inquiry (e.g., see Bjørn et al. 2013; Palander and Rex 2016; UNEP 2016). A decade ago, Bjørn et al. (2013) identified LCA networks globally and characterized them according to their size, funding, composition, and activity.

In addition, they provided an initial reflection about the impact of LCA networks on the development of the LCA methods and tools. Additionally, case studies of individual networks have been published reporting the establishment, aims, and activities of several LCA networks (see Sect. 2). These case studies explain the background to the establishment and functions of individual LCA networks and the activities they undertake (e.g., see Bauer et al. 2004; Cappellaro et al. 2008; Hauschild and Frydendal 2006; Hur 1999, 2003; Kulczycka et al. 2011; Moussiopoulos and Koroneos 1998; Felix 2016; Nakano et al. 2007; Nebel 2011; Sharma 2000). However, further experience in the operation of the LCA networks has been gained in the past decade and little research to date has explored the factors that contribute to their continuity and relevance over time. To the best of our knowledge, there are no in-depth qualitative studies that compare these factors across different networks. The aim of this paper is to investigate how LCA networks have been established, evolved, and what factors contribute to their continuity and relevance. It takes a multiple case study approach (Stewart 2012; Yin 2014) to answer the following research questions:

1. What factors enable the establishment of LCA networks and how is their relevance maintained?
2. How do LCA networks maintain operational continuity?

The paper is structured as follows. Section 2 reviews the literature on LCA networks and establishes the research gap. Section 3 presents the methodology, data, and analysis. Section 4 presents the empirical interview findings. In Sect. 5, we discuss the emergence and evolution of LCA networks in terms of activities, membership, financing, and their relevance over time. Section 6 offers practical recommendations and suggestions for future study.

2 Life cycle assessment networks

LCA networks exist at global, regional, and local levels with varying roles and functions. A six-criterion definition for an LCA network has been developed by Bjørn et al. (2013).

- Supports a life cycle approach and /or mentions LCA or life cycle thinking in mission/vision/goal and scope
- Includes, as a minimum, members from both the academia and industry (authorities, consultancies, NGOs, etc. are allowed, but not required)
- Is a non-profit that uses revenues to achieve its goals rather than to distribute them as profit or dividends
- Is based on some degree of central control and coordination
- Is an independent entity and not merely a subject-specific subchapter of a larger LCA network

- Embodies a communication platform to connect all the members (newsletter, website, etc.)

The definition has been adopted by UNEP (2016) with some alterations. According to UNEP (2016), an LCA network may consist of non-industry members only. Globally, Bjørn et al. (2013) found 29 networks fitting their definition and 100 networks that partially complied, with many forms and levels of activity. Most of the networks worked at a local or country level, and they were mostly found in Europe and the Americas (Bjørn et al. 2013), but several international networks were also identified (UNEP 2016). At the global level, the Life Cycle Initiative, hosted by UNEP, acts as a global umbrella for LCA networks (UNEP 2016), and the Forum for Sustainability through Life Cycle Innovations (FSLCI) is a community of organizations and individuals around LCA practice (Forum for Sustainability through Life Cycle Innovation n.d.).

The establishment of LCA networks is described in previously published individual case studies (Nebel 2011; Kulczycka et al. 2011; Cappellaro et al. 2008; Grant et al. 2001; Hur 1999). LCA networks have generally been established with the objective of promoting networking and knowledge sharing (e.g., Bauer et al. 2004; Cappellaro et al. 2008; Nebel 2011). For example, the Italian LCA network (*Rete Italiana*) was established as an informal network promoting knowledge sharing, mainstreaming LCA use, and encouraging new LCA projects (Cappellaro et al. 2008). Literature points to some factors that have contributed to the establishment of LCA networks: the initial organization conferences, workshops, or roundtables where LCA matters have been discussed (Nebel 2011; Grant et al. 2001; Cappellaro et al. 2008) and publicly funded projects with concrete LCA-development outcomes (Grant et al. 2001).

The existing literature about LCA networks tends to describe, in addition to the objectives, the activities of LCA networks. Bjørn et al. (2013) found that the types of activities carried out by the LCA networks are most commonly knowledge sharing and communication, LCA application through case studies, life cycle inventory/data collection, and development of life cycle impact assessment. These kinds of activities are also described in the country-specific case studies (see Bauer et al. 2004; Cappellaro et al. 2008; Grant et al. 2001; Hauschild and Frydendal 2006; Hur 1999; Hur 2003; Kulczycka et al. 2011; Moussiopoulos and Koroneos 1998; Felix 2016; Nebel 2011; Stadtherr et al. 2006). Furthermore, according to Bjørn et al. (2013), networks typically used websites and conferences as dissemination and communication fora, with a third of networks having online courses, seminars, and newsletters. Activities related to LCA software, standards, or regulations were taking place in half of the surveyed networks. Networks seldomly undertook activities related to life cycle management, costing, and sustainability assessment or input/output LCA. In only very

few networks did activities focus on hybrid LCA or social LCA. While most common networks are working on LCA overall, others may have a more narrow focus on life cycle inventory data or datasets in countries where LCA practice has been well established (Palander and Rex 2016; Bjørn et al. 2013). One of the conclusions made by UNEP (2016) is that countries having active networks based on a legal entity are more likely to maintain a national LCA database.

The structure, size, and activities of LCA networks vary considerably (Bjørn et al. 2013). In a survey of 25 networks, Bjørn et al. (2013) inferred that the LCA networks are typically made up of academia (present in almost all networks), and consultancies/companies of different sizes (more than half). Larger networks also had members from other institutions (Environmental Protection Agencies 12%, standardization organizations 20%, or environmental NGOs 28%). Slightly over half of the networks also had small and medium enterprise (SME) members. Even though the need for a broader cross-sector collaboration, also including businesses, policymakers, and NGOs, has been recognized (Bjørn et al. 2013), there continue to be fewer networks where government agencies and NGOs are involved (Palander and Rex 2016).

LCA networks have been mentioned in scientific literature also as isolated and sporadic efforts, even though not all of these mentions are in line with the definition of an LCA network given above. In addition, some networks have been described as informal arrangements in the published studies but have since then been formalized and attained a legal status. For example, the Italian LCA network (see Cappellaro et al. 2008) was originally set up as an informal network promoting knowledge sharing, mainstreaming LCA use, and encouraging new LCA projects. Also, a very informal LCA collaboration network around three Brazilian universities was studied by Zanghelini et al. (2016) to get an insight about how the studied themes and cooperation around LCA have evolved by these actors. In some cases, the mentions of LCA networks in literature have related to a certain group of LCA actors having a joint, concrete target, such as the development of a national life cycle database in Peru (Vázquez-Rowe et al. 2019). De Souza and Barbastefano (2011) focused on a global “collaboration network based on co-authorship relations,” in which the network is essentially unstructured and unmanaged, but with an identifiable social interaction between them, covering 37% of the LCA authors globally.

The impact of LCA networks has been difficult to determine and measure. In general, as the networks have been regarded as information and cooperation platforms, or as bases for scientific development (Bjørn et al. 2013; Bauer et al. 2004), the relationship between these platforms and their concrete impacts (e.g., new policies, investments, or operational changes) is difficult to isolate. Bjørn et al. (2013) have discussed measuring the impact of networks by

comparing their development to the scientific production within the region. However, this is far from an adequate measure of detecting practical changes into the operational environment. Palander and Rex (2016) have discussed the impacts of LCA networks at a general level by studying how the networks are able to impact the functions of a technological innovation system, such as knowledge development and diffusion, entrepreneurial experimentation, resource mobilization, market formation, legitimation, influence on the direction of search, and development of social capital. For each of these functions, Palander and Rex (2016) have distinguished unique actions by the different networks, demonstrating measurable impact. From a practical perspective, it may be different to distinguish impacts from reaching the networks' goals and listing their relevant actions.

3 Methods

To explore the factors contributing to relevance and continuity across several LCA networks, we undertook a multiple case study (Stewart 2012; Yin 2014). According to Stewart (2012), a multiple case study (or multi-case study) is an investigation of a particular phenomenon at several different sites; in the case of this paper, different LCA networks. With a multi-case study research design, it is possible to investigate patterns across organizational boundaries and to compare instances of the phenomenon, and thereby explore and characterize contributing factors (Stewart 2012).

3.1 Sample selection

In this multiple case study, a desktop study was followed by in-depth interviews with the coordinators, other staff, or members of eight national LCA networks. First, the websites of 36 LCA networks listed by the International Life Cycle Initiative (Life Cycle Initiative n.d.) were screened to identify active networks in the EU, North America, and Asia. The screening showed that some of the networks included in previous analyses (see Bjørn et al. 2013; UNEP 2016) were currently inactive, judging by the last date of the website update, news, or activities on their websites. For example, the review indicated that the LCA Center of Denmark and the Polish Center for Life Cycle Assessment are inactive. Information on the websites regarding the date of establishment, goals, organizations, membership, and financing was gathered. The web-based desktop study identified the basic information for selecting a representative sample of networks to interview, including those with different member groups, as well as with different financing arrangements.

LCA networks selected for the interviews had recent activity and were having a multi-activity focus (i.e., not only focus

on conference organization) and a focus on LCA only (e.g., not environmental assessment in general). Some functioning networks, such as the Swiss Discussion Forum on Life Cycle Assessment focusing solely on conference organization, or the Turkish network active in areas beyond LCA, were not selected for interviews. In addition, an inquiry for information on existing LCA networks was made on the PRÉ LCA discussion list (4.3.2021). A total of 12 LCA networks were contacted, with eight participating in an interview. The interviewed networks fitting under the definition of Bjørn et al. (2013) or UNEP (2016) were the American Center for LCA, Australian Life Cycle Assessment Society, Industrial Chair for Life Cycle Sustainability Assessment (ELSA-PACT), Life Cycle Society of New Zealand, Hungarian LCA Center, Rete Italiana, and Swedish Life Cycle Center. Also, one network with industry members only, Score-LCA, was interviewed.

3.2 Data and analysis

Semi-structured interviews (Gillham 2005) were conducted (18.3–8.4.2021) by two interviewers with each LCA network coordinator or board members. The interview topics covered the following: (a) history of the network; (b) organization and secretariat; (c) membership; (d) financing; (e) current activities of the network; (f) societal role of the network; (g) achievements; (h) challenges, and (i) future plans. For a full list of interview questions, see the Appendix. The interviews were carried out in a virtual environment, recorded, and transcribed verbatim. Computer-aided thematic analysis (Yin 2014) was applied to the transcripts using the Atlas.ti software online tool. The coding, categorization, and interpretation were performed by the main author, in collaboration with the other interviewer, to enhance the validity of the findings (Puusa and Juuti 2020). A cross-case analysis of the data was undertaken to explore the factors that contribute to the continuation and relevance of LCA networks over time. The results have been anonymized for reporting.

4 Results

The following sections report the results of the interviews: (1) establishment of the LCA networks; (2) aims and activities of the LCA networks; (3) factors affecting network relevance over time; and (4) factors contributing to maintaining operational continuity of the LCA networks.

4.1 Establishment of LCA networks

This section describes why and how LCA networks were established and the motivations for establishment. Factors

which played a role in formalizing the networks, such as financing and mobilizer efforts, are also presented. The networks interviewed for this paper were established during the 2000s or 2010s, except for one which dates to the 1990s. All networks have existed continuously since their foundation either as the same entity or under a different name.

A common denominator for a network establishment was the need for LCA practitioners and researchers to meet, communicate, share, develop methodological knowledge, and collaborate on projects. As it was pointed out by one interviewer (Interviewee A) that at the time, LCA was unknown, and therefore having a “a visible face for life cycle assessment” was useful.

Several networks started through organizing LCA conferences, and their coordination has continued as activities have evolved and broadened. Many LCA networks were initiated as activities of individuals or groups of individuals with a common interest in increasing the collaboration between LCA practitioners and/or researchers. Several interviewees discussed that in the beginning, the networks were operating informally and on a voluntary basis as a forum where LCA could be discussed and advanced. Network coordinators mentioned that in the beginning, collaboration entailed organizing annual meetings or conferences to discuss LCA matters followed by network formalization as the participants saw the need for it. Two of the interviewed networks were born out of other existing networks that felt that there was a need for a structure with an LCA focus.

In some of the networks, the formalization was made possible by a commitment to public funding. Also, when a volunteer-based activity became a formal association, members started paying a fee. This formed a budget enabling the development of new activities. Responsibilities were shared, and activities, such as research or working groups, were initiated.

4.2 Aims and activities of LCA networks

LCA networks aim to create a “community of practice” for LCA, where researchers and companies and other stakeholders cooperate and bridge expertise to expand and spread life cycle thinking and the use of LCA. In this regard, an LCA network enhances a culture of life cycle thinking as part of sustainability activities. All the interviewees emphasized the role of the networks in promoting information sharing and cooperation. Additionally, typical aims described in the interviews were as follows: showcasing the LCA activities of members, following new developments, as well as discussing LCA practice-related challenges.

Interviewees described that the value of the network is in linking researchers, companies, and service providers, to discuss LCA practice, data needs, modeling, and other

methodological issues. Value was seen in being able to exchange on common questions within a neutral platform. Several interviewees mentioned the need to actively manage the “neutrality” of the discussion forum through a code of practice or ground rules.

The networks’ activities were seen to enhance LCA expertise through e.g., training of industry, certification, and promoting that expertise by placing a directory of LCA experts online. All the interviewed networks organized conferences, typically annually. They also organized workshops and seminars. For many of the networks, the work is organized around thematic working groups on topics such as policy, education, best practice, the application of LCA in specific industrial sectors, LCA methodology, social LCA, data, methods, software, biodiversity, land use, and PEF. These activities aim at discussing methodological issues and challenges, among others. Maintaining a product category rule repository, carrying out work on environmental product declarations, having domestic data system and tool development have all been carried out under the scope of LCA networks.

Educating students was indicated as an important aim for several networks; one network organizes courses in different university departments including law students and another network offers university students the opportunity to practice the use of LCA software. Activities targeted to students, such as webinars, seminars, summer schools, and software training, are organized by some networks, and students are invited to participate in annual conferences. Others have promoted teaching LCA in different academic institutions. One network offers an award for young scientists, thereby encouraging young researchers to enter the LCA field.

In addition, networks act as an entity that pushes LCA into policies through participating in public consultations, raising the needs of LCA-related guidelines, contributing to international initiatives such as the PEF, or participating in the ISO committees. The networks allow the dissemination of information from international conferences to members.

Table 1 summarizes the activities of the interviewed LCA networks.

The emphasis of the activities varies somewhat depending on the membership type. For example, those networks that are organized around academia tend to focus on scientific research and case studies, while those which focus on industry members tend to concentrate on practice-oriented LCA studies for the partners. Some of the networks have, e.g., published LCA-related books or other publications either as individual efforts or as projects of international collaboration among networks. In summary, the focus of activities is on knowledge sharing and creating, and broadening, an epistemic community around LCA, even if the outputs of the various network types may differ.

Table 1 Current activities of interviewed LCA networks

	Event	Working group	Methodology development	Database	Scientific publications	Other publications	Policy input	Joint projects	Newsletter	Education	Certification
#1	x	x	x	x		x	x	x	x	x	x
#2	x		x	x	x			x	x	x	
#3	x	x	x	x		x	x	x	x	x	x
#4	x		x		x	x	x		x	x	
#5	x	x	x		x	x	x	x	x		
#6	x	x			x	x	x	x	x	x	x
#7	x	x	x	x		x	x	x	x	x	
#8	x	x	x		x	x	x	x	x	x	

4.3 Factors affecting network relevance over time

LCA networks need to respond to evolving stakeholder demands, thus justifying the relevance of their activities. In general, a growing interest in LCA has been noted by the LCA networks, but the exact needs and trends are context specific. The extent and source of demand are linked to industry agendas and the maturity of LCA practice in the respective countries. Hence, the limited sample of interviewed networks does not give a definitive answer.

Many interviewees have noted an accelerated and high industrial demand for LCA. In some contexts, it can be interpreted that the demand for LCA is not (anymore) driven only by the LCA networks; however, in other contexts, the network continues to be the driving force in creating the demand for LCA. With the need to carry out LCAs, the demand for qualified practitioners is growing, and thus, engagement of LCA end users was seen to be valuable. Some interviewees pointed out that the professionalization of LCA practice through a network membership or a certification is giving credibility to the practitioners and their work. Staying relevant means that the LCA network offers a structure from which network members can benefit, for example, through activities that respond to their needs such as research and joint meetings. The formalized activities allow for keeping contact with others in the field and support practitioners' work.

Some networks have identified that LCA awareness and competence of government agencies have increased. They have seen them as potentially relevant participants in networks' activities and also see that policy-making can involve the LCA network increasingly in their activities. The formalized structure of the network ensures an accessible partner for government agencies regarding LCA-related policy initiatives, such as ecolabels, PEF, and new legislation. The interviews showed that LCA experts have been increasingly active in influencing policymakers to consider the role of LCA in policy and regulation, starting to establish partnerships with the government in the scope of the LCA network. The following quotes highlight the relevance of government collaboration:

“We flag when we think that life cycle assessment or life cycle thinking should be part of that, so that is one way of influencing policies.” (Interviewee B).

“We have contributed to improve adoption of LCA in companies, so the benefit now is changing from the scientific basis, going more and more on the public policy basis. This is most important challenge because LCA as a tool... starts from science, starts from university but then of course becomes the root of the policy of a company and goal in the laws at different levels. So, I think this is our achievement and our challenges for the future.” (Interviewee C)

“Since our vision is to apply life cycle thinking globally and we want to make that happen in all parts of society of course, and then the government agencies are a very important part.” (Interviewee D)

Typically, the demand for coordinated LCA activities has originated from industry or academia, but now, LCA networks’ activities are increasingly of interest to other types of organizations, such as government agencies and municipalities.

4.4 Operational continuity

LCA networks vary in scale, membership types, and consequently in their budgets. All interviewed networks are officially established associations, for which there are typically national laws to determine their governance structures. All networks have a chair, but only some have a board. Networks with larger budgets and a wider membership base also typically have a secretary or other staff members. The chair, the board, or the secretary typically has an administrative and an implementation role, but it is the members who jointly decide on the networks’ direction and agenda. In this respect, the interviewed networks represent democratic entities.

While some networks have a budget to directly employ several staff members, most networks are run pro bono or with minimal costs. Many of the activities take place on a voluntary basis, especially in smaller networks and academic-rooted networks, where working time can be allocated to the academic activities undertaken under the umbrella of the network. In general, networks with more industrial members tend to have larger budgets and thus can afford paid staff. Smaller networks, for example, in countries with a smaller LCA community, may be managed by a self-employed individual or a volunteer.

The number of members ranged from ca. 15 to 200 depending on whether the member was an organization or an individual. The LCA networks could be broadly categorized into industry-driven, academia-driven, and others that could be somewhere in between. All interviewed networks were open to company members and others had started reaching out to SMEs and partnering with government agencies. Typically, members include research organizations, corporations, and consultants or individual members from such organizations, but there exist also networks among those interviewed whose members consisted only of corporations.

The long-term viability of an LCA network is linked to its financing. The interviews showed significant variations in the financing model and the amount of fees raised from members. The way LCA networks are funded depends on how the organization is formalized according to national laws. Some interviewees noted that the network provides a structure that can be leveraged for acquiring project funding which interviewees regarded as an important factor

contributing to the long-term viability of the network. While some networks were not eligible for funding from national sources, others relied on public funding for at least part of the activities or through public funds or publicly funded projects. Even in some industry-oriented networks, funding was divided between industry membership fees and a public funder.

In addition to membership fees, networks acquire resources from conference fees, conference sponsorships from the private sector, and in some cases from project income, and a professional certification program. A considerable variation in the amount of membership fees was noticeable. Depending on the member type (organizational or individual), and on the country context, the annual membership fees ranged from 15€ to 150€ per person, while company annual membership fees ranged from 75€ for universities and from ca. 900 € to up to 35,000€ for companies depending on the type of membership and the size of the company. Despite the significant variation in annual budgets, the interviewed network coordinators considered budgets insufficient for achieving all activities.

To maintain the operational continuity, a stable or growing membership base should exist. Although the interviewees had observed an increasing interest in LCA, this is not directly reflected in the LCA networks’ membership base. Based on the interviews, it is not possible to conclude whether LCA networks are growing or declining in size.

Variations in memberships are related to, for instance, the political environment or personnel changes within companies. Variations reflect the agenda of the network and the agenda of the attending company. Many interviewees expressed the need to be active in recruiting members and making relevant strategic choices in activities to keep relevance in the eyes of current members. When members contribute to decisions regarding activities their interest in staying within the network is maintained.

5 Discussion

This exploratory multi-case study takes a practice-oriented approach to studying the phenomenon of LCA networks in different contexts. In our research, we make empirical observations on the success of LCA networks which provides knowledge that can be transferred when similar activities are initiated in other national contexts. This paper explores contributing factors, but as is the case with this type of research, we do not attempt to verify any point (Stewart 2012). Table 2 summarizes the factors that were found to contribute to the relevance and continuity of the LCA network in this research.

LCA-based activities have evolved, matured, and mainstreamed around the world between 2004 to 2014 (UNEP

Table 2 Factors affecting relevance and continuity of LCA networks

Factors affecting relevance	Factors affecting operational continuity
Network activities	Legally established association
Industry agendas	Formal structure, including chair, board, and staff (or volunteer)
Policy development	Sources of funding (membership fees, targeted funding)
Need for credibility, professionalization	Stability and growth of membership basis
Societal demand for LCAs	
Country-/context-specific LCA maturity level	
Openness to new stakeholders	

2016) and have continued to do so since then. LCA networks have continued to grow since the mapping carried out a decade ago by Bjørn et al. (2013), which found that most networks were small (< 20 members) to medium-sized (21–100 members) and less than 5 years old. Nevertheless, many of the networks in this sample were at the most medium-sized, by a number of members. However, our initial desktop study also showed that many of the LCA networks are no longer active, and hence, the question of how to maintain the relevance of LCA networks over time continues to be of interest.

Based on our interviews with eight LCA networks, their aims and activities can be described through the following roles: (1) forums for open discussion and knowledge-sharing among individuals and/or organizations; (2) communities dedicated to advancing LCA science; (3) educational actors building capabilities of current and future LCA practitioners; (4) networks supporting LCA-knowledge in business; and (5) actors influencing policies or actors supporting the adoption of LCA in policy. According to the interviewed network coordinators, LCA network members saw value in collaborating with other entities that work with LCA. The networking between the industry and other partners was highlighted as valuable. In line with previous studies (de Sousa and Barbastefano 2011; Palander and Rex 2016), it was seen that collaboration can support the understanding of the priorities of different stakeholders and get a more realistic view of industrial environments.

Our results are in line with the findings of Bjørn et al. (2013) who state that “LCA networks vary greatly in terms of structure, size, and activities, etc.” and who pinpointed that LCA networks can take various approaches in facilitating multi-stakeholder collaboration depending on the country context (Bjørn et al. 2013). The consideration of context is also suggested by Hauschild and Frydendal (2006). This study pointed to the context specificity of drivers of stakeholder interest in LCA and participation in LCA network activities. Despite the differences in aims, membership, and organization, many similarities in the activities were noted. Bjørn et al. (2013) suggested that networks may have narrower focuses (e.g., database or LCI datasets) in countries where the practice is well established. Our sample of interviewed networks all had a range of activities and focus areas;

however, it appears that a development towards activities that are relevant to a broader range of stakeholders is underway. While Bjørn et al. (2013) found it “surprising that SME members were present in half of the networks,” today, the pressure for SMEs to use LCA is stronger (e.g., European Commission 2020; European Commission 2021) which is starting to reflect in the membership base.

Previous studies have not been able to isolate and measure the impacts of LCA networks on a practical level. While Palander and Rex (2016) and Bjørn et al. (2013) have discussed impacts at a generic level, measuring the impacts deriving from LCA networks has proven to be difficult. Also in this study, the interviewees perceived that the impact of LCA networks is a result of the coordination of LCA activities but differentiating between impacts and activities has been challenging. The coordinated platform has allowed learning as well as facilitated the ability to influence LCA use in national and international fora. Having such a platform has facilitated obtaining and allocating resources, raised awareness, and improved recognition, as well as led to the adoption of LCA in companies and in educational institutions. It was seen that the professionalization of LCA competence can, to some extent, be attributed to the existence of the LCA networks and their activities.

Having a structure that allows keeping up to date with international developments and having a chance to contribute to them are part of the continued relevance. Having a possibility to discuss methodological data issues in specific working groups was described as continually relevant. While each of the interviewed networks had their particular focus areas, in summary, the contributions were to methodology and tools, development of LCA-based standards, ISO and PEF, and implementation of EPD schemes; projects, funding, and applications. Upcoming topics include value chain management and the circular economy. The interviews indicated, for example, an intention to expand the topics/themes currently addressed, a need to better communicate their results, by using social media, for example, and gaining more resources through joint projects.

In this paper, we take a step towards discussing the role that LCA networks have in relation to different stakeholder groups—a topic which is becoming more relevant as LCA

has been more widely applied. In this context, the aims and activities of the networks have evolved from the initial objectives of information sharing among certain interested individuals to keep relevant in an environment, where LCA is becoming mature and used by all types of stakeholders. Activities that may have previously focused specifically on raising awareness of life cycle approaches and methodology or data questions are now targeting a wider audience of stakeholders from governments, municipalities, or SMEs, including the coordinated influence of the use of LCA in policies. This can be seen to correlate with the broader interest among policymakers in integrating LCA approaches into policies, for example, at the EU level (EC 2020, 2021). The maturing of the field can be seen as both a cause for the demand for LCA networks and a result of the LCA network activities. These findings echo Palander and Rex (2016), who suggested that the role of LCA networks could be wider than only supporting practitioners, and UNEP (2016) that referred to broadening network membership base. This need for a broader cross-sector collaboration including businesses, policymakers, and NGOs has been recognized also by Bjørn et al. (2013). However, in line with Palander and Rex (2016), we also found that government agencies and NGOs are not generally participating as members of LCA networks, even though activities are starting to target them.

The growth of interest in the formation of LCA networks over time (Palander and Rex 2016; Bjørn et al. 2013) can be expected to continue in the future, especially with the call to use LCA-based methods in policies and decision-making related to the circular economy (Peña et al. 2021). There will continue to be an even larger need for good quality data for which collaboration is essential (Palander and Rex 2016) and open discussion around allocation rules related to recycling (e.g., see Ekvall and Brandão 2020). The environmental impacts of consumption and production being global, the structures of the national LCA networks, that already are drawn upon for collaborating internationally, could be considered to gain an even stronger role in the future. Bjørn et al. (2013) already observed interaction among LCA researchers around the world. Our interviewees saw the formalized LCA structure as a means that allows the coordinated design of international projects and the exchange of information with LCA practitioners in other countries.

Although the paper provides insights in the form of a qualitative multiple case study, the rather limited sample with a geographical bias towards Western industrialized countries restricts making overarching conclusions regarding membership, activities, goals, and priorities. As we only interviewed active networks, this paper is unable to address the reasons for the discontinuation of some networks, which is a topic for future study. Future research could consider looking at whether similar outcomes are reached in LCA collaboration without a formalized network structure as well

as the reasons for the inactivity of networks that formerly existed. Given that the priorities are context-specific and evolve over time, a study with a different sample may result in other conclusions.

There are practical lessons that we can take from the multi-case study regarding the functioning and activities of LCA networks. However, we do also see the potential for further abstraction and theory contributions. The diffusion of LCA is facilitated by collaboration among researchers and practitioners (Palander and Rex 2016). To this end, as our study has shown, setting up LCA networks can support the diffusion of LCA practice in organizations. A future inquiry could lead to new lessons by applying the study of “issue networks” to the research of LCA network establishment, continuity, dynamics, and motivations (Ritvala and Salmi 2010). This type of study could further explore how the impact of LCA networks may be wider in society and have a role as catalysts in emerging technological innovation systems (Palander and Rex 2016). To date, this broader role and impact have not been discussed in academic literature. Further study could delve into the impacts of LCA networks, the context specificity of factors affecting the relevance and continuity of networks, as well as the role of cross-country collaboration of LCA networks in the diffusion of LCA practice globally.

6 Conclusions

In addition to the increasing academic and industry attention to LCA, the interest in LCA networks has grown and is expected to grow further, given the current developments in policy aiming to integrate LCA into policy development processes. Discussion around sharing experiences of established networks was vibrant about a decade ago. At the time, several case studies of LCA networks (see Sect. 2) and a global mapping (Bjørn et al. 2013) were published. A wealth of experience has been gained since then and the long-term viability of networks can be assessed from a different perspective. This article contributes to the practical experiences in the establishment, evolution, and relevance of LCA networks. Differentiating activities from impact and isolating the LCA networks' broader influence have not yet been carried out systematically. We, therefore, recommend devising adequate approaches by which to measure the impact of LCA networks, which may give additional insights about the factors affecting their relevance and continuity over time.

Based on this multi-case study, we conclude that the driving force of starting LCA networks was individual experts with an interest in the topic. Increasingly, LCA networks were seen as platforms at the science-policy interface that allows the LCA practitioners to talk as a legitimate “field”

rather than individuals. The continuation of networks is maintained also through having a formalized association with a financial model that allows for carrying out a broader set of activities that are relevant for different groups of stakeholders. The financing and membership are therefore interlinked with the thematic relevance of the network. While both the source of the demand for the LCA network and the operational logic of the different interviewed networks are context-specific and depend on network governance structures, their activities were found to be surprisingly similar (see Table 1). The focus of LCA networks has evolved, from an initial orientation toward collaboration and learning to include the ambitions of influencing policy-making processes, making LCA networks relevant over time.

Appendix

1. History of the network. Could you tell us about the history of the network?
 - (a) When was it initiated and what was the motivation for the network?
 - (b) Who initiated it and how?
 - (c) What were the original aims and activities?
 - (d) What funding and other resources did the network start with?
 - (e) How did you attract members?
- (i) Was it difficult or was there a genuine interest in the network?
 - (f) Did it take a long time for the network to take off?
 - (g) Have the aims of the network changed over time, and if so how?
- (i) Keeping up with scientific or policy changes/trends?
2. Organization and Secretariat. How is the network run in practice?
 - (a) How is the network governed?
- (i) E.g. hosting, strategic decision-making, board membership
 - (b) Does the network have dedicated staff? How many person-years?
 - (c) Who decides upon the operational activities of the network?
- (i) Seminars, networking events, etc.
3. Membership
 - (a) What kind of members and how many do you have?
 - (i) E.g. academia/research, industry, public sector, third sector (NGOs)
 - (ii) If you can, specify percentages of different kinds of members (universities, companies, government, individuals etc.)
 - (b) Is the network open to any interested party?
 - (c) How do you attract new members and how do you keep the old ones?
 - (d) Is the membership base growing, stable, or declining?
- (i) Has the membership profile changed significantly (e.g. change share of academia or industry members)?
 - (e) What does membership include?
 - (f) Do you charge membership fees?
 - (i) Do all types of members pay a membership fee?
 - (ii) Are there different levels of fees?
4. Financing
 - (a) Do you have other sources of funding than the membership fees?
 - (i) If possible, specify percentages for different funding sources.
 - (ii) Has this changed significantly since the creation of the network?
 - (b) What is the annual budget?
 - (i) How is it allocated?
 - (c) Have you ensured a sustainable funding and membership base? How?
5. Current activities of the network
 - (a) What activities do you undertake?
 - (i) Workshops and conferences
 - (ii) Trainings
 - (iii) Methodological guidance and recommendations
 - (iv) Data and databases
 - (v) Country specific LCA issues
 - (vi) Case studies, common publications, position papers
 - (vii) Scientific publications
 - (viii) Cooperation among stakeholders, common projects

- (ix) Steering policies and participating in policymaking (lobbying)
 - (x) EPDs, eco-labels and certifications
 - (b) How have these changed over time?
 - (c) Do you cooperate with other networks, both nationally and internationally?
 - (i) What have been the benefits of international cooperation?
6. Societal role of the network
- (a) What role does the network play in the society?
- (i) E.g. in policy processes
- (b) Are there conflicts of interest between members or between the network and other stakeholders?
7. Achievements
- (a) In your view, what are the benefits of having a national LCA network? Why is such a network needed?
 - (b) What are the main achievements of your network?
 - (i) Do you monitor the achievements?
 - (ii) Do you have indicators?
 - (c) How has the network contributed to increasing the capacities of LCA practice in your country?
8. Challenges
- (a) What have been the main challenges when setting up the network?
 - (b) What are the main challenges now?
 - (c) Have there been times of inactivity in the? If yes, why?
 - (d) Has financing been a challenge? Any challenges with the acceptance of membership fees?
9. Future plans
- (a) What plans do you have for the future of the network?

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Data Availability The datasets generated during and analyzed during the current study are not publicly available due to confidentiality reasons.

Declarations

Conflict of interest The authors declare no competing interests.

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