

Life Cycle Sustainability Assessment in the construction sector – actual application and future outlook

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Abstract. The construction industry is responsible for positive and negative values in society, economy and environment. Life Cycle Sustainability Assessment (LCSA) as framework is considered to provide a valuable support to decision makers, by extending the scope of the known Life Cycle Assessment (LCA). At present, the number of published LCSA studies in the construction sector is comparatively small. To foster the partnership between LCSA and the construction sector, an understanding of backgrounds and options of LCSA application in this sector is necessary. A survey is conducted via an online questionnaire to ask the defined target groups (LCSA-experts, students, practitioners) about their use and interpretation of LCSA. The questionnaire results show that the implementation of all three pillars (LCA, LCC, S-LCA) and defining appropriate indicators is difficult even for LCSA-experts. 94% of today's decision makers name especially the LCA as important and relevant for the construction sector. Nevertheless, it became clear that the LCAs already implemented in the practical construction sector were only implemented because of the request by the customer. Future decision maker (today's students) ask for more seminars and lectures in LCSA and LCA and especially more practical and cross-thematic (interdisciplinary) exercises are questioned.

1 Introduction

Sustainability is an essential part of decision-making in all sectors - especially in the construction industry. Life Cycle Sustainability Assessment (LCSA) is considered as a valuable support for decision makers (DM) regarding sustainability and sustainability assessment of products and services [1]. The LCSA framework extends the scope of the well-known Life Cycle Assessment (LCA) and covers all three dimensions of sustainability: environmental (LCA), economic (Life Cycle Costing/LCC) and social (Social Life Cycle Assessment/S-LCA). The formal LCSA describes the idea of applying the three methods in a complementary and timely manner to the same functional unit and equivalent system boundaries. In the LCSA interpretation, no weighting is applied between the three pillars, the

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three assessments are equivalent, and an underperformance of one pillar cannot be compensated by a better performance of another pillar. [2,3]

The construction industry is responsible for 10% of the world's gross domestic product (GDP) and employs 100 million people on the one hand; on the other hand, this industry simultaneously contributes significantly to resource depletion, energy consumption, and CO₂ emissions [4,5]. A detailed and structured literature review that analyzed several LCSA studies in the construction sector showed that construction projects involve a variety of impact criteria where sustainability is not a primary consideration. Only 11% of the literature considered refer to LCSA [6]. To date, the holistically named sustainability assessment often focuses mainly on environmentally sound construction design and materials to minimize environmental impacts - also evident in the review, with increased use of LCAs. [6]

All studies reviewed call for improvement in the application, interpretation, and communication of LCSA [6]. Especially in the construction sector, it is important to understand what sustainability means, if the LCSA idea is known, if the approach is already applied and if not, what the reasons are.

The main goal of the actual study was to promote the partnership between LCSA and the construction sector - to gain an understanding of the background and opportunities for LCSA application in this sector. Three surveys on sustainability and LCSA in general and explicitly in the construction sector will provide first answers and generate directional approaches.

2 Methodology

Based on a previous conference participation (LCIC, Berlin 2020)[7], the detailed literature review [6] and on personal interviews with German construction experts as well as students of civil and environmental engineering, three relevant target groups (TGs) for this main question were defined (Table 1).

Table 1. Target groups and questionnaire base.

Target Group (TG)	1	2	3
	LCSA experts worldwide, independent of construction sector	students on environmental and construction engineering, mainly German (future decision maker (DM))	today's decision maker (DM) (planners, architects)
Contact via	mail and network; based on publications	social media and network	mail and network
Reason for TG	experts in LCSA, familiar with LCSA challenges and chances	future employees and decision maker	actual employees in construction sector and DM
Objective of survey	clarify whether and how the LCSA framework can be modified or simplified in order to reduce the application threshold and its complexity	clarify whether LCSA or individual parts of sustainability assessment (e.g. LCA) are known and taught and whether one can assume an increasing interest	clarify whether and to what extent practitioners are aware of LCSA and what challenges practitioners face

No. of questions	25	31	37
No. respondents	67	143	61

TG 1 represents international LCSA experts. Through this expert target group, it should become clear whether and how the LCSA framework can be modified or simplified to reduce the application threshold and complexity. The survey was distributed mainly by mail to university and private contacts as well as to the first authors of numerous scientific publications on LCSA. TG 2 contains environmental and civil engineering students. As future decision makers (DM) in the construction sector, students have a special importance in the field of sustainability assessment. These future DM were approached via social media. TG 3 consists of current DMs in the construction sector, including personal (industry) contacts and research collaborations from the construction sector – reached via mail. This target group will reveal whether and to what extent practitioners are aware of LCSA and what chances and challenges exist.

Surveys (qualitative & quantitative) were conducted with all three target groups using the deductive method. The target group-specific questionnaires were created using ‘UmfrageOnline’ [8]. The method of data collection is thus based on an anonymous online survey. Reasons for conducting the surveys online are

- the advantages of a high coverage (time and place are irrelevant),
- time efficiency (3 target groups) during the creation,
- the pandemic situation as well as
- the simplified and accelerated result evaluation.

Individual hypotheses were assumed for each target group. Due to different hypotheses and slightly different objectives per TG, the individual questionnaires were built on a different number of questions (Tab. 1) and answering period varied. However, specifically for TGs 2 and 3, some questions were asked identically in order to explicitly compare the generations (today's and future DM). The questionnaire for TG 1 asks significantly more technical questions about LCSA. Despite slightly varying objectives and individual questions, one main hypothesis (H_{main}) was defined for all TGs: *The LCSA framework in its current form is poorly understood and too complex to serve as a basis for decision-making on sustainability, especially in the construction sector.*

3 Results & Discussion

TG 1, representing 67 LCSA-experts, answered a questionnaire with 25 questions. 62% of respondents are environmental engineers, 65% of all respondents work in research at universities or research institutes. Asking respondents explicitly about the application of LCSA, 57% find it very difficult and 35% find it partially difficult to implement all three pillars equally. Only 8% of respondents do not find it difficult to define the same system boundaries for all three assessments (Fig.1).

Only 3% of respondents find it easy to make a good and simple selection of appropriate indicators. 87% of the respondents are convinced that the LCSA should be linked to the Sustainable Development Goals [9,10]. Especially in the free text answers, difficulties such as the final interpretation of LCSA, weighting and communication problems become apparent. Standardization is repeatedly demanded and thus 60% of experts state that a set of predefined indicators and an adequate visualization tool are necessary for an improved implementation and support of DM (Fig.2, Fig.3).

Defining equivalent system boundaries for all three assessments for me is:

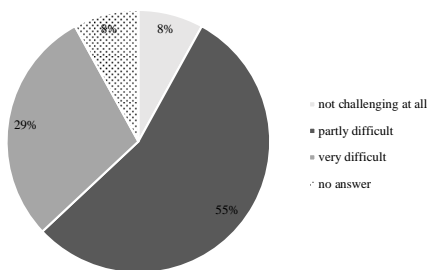


Figure 1. LCSA experts defining system boundaries.

Should a set of predefined indicators be given for each pillar?

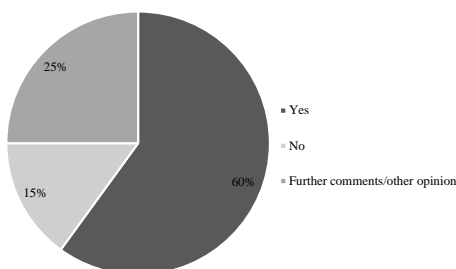


Figure 2. LCSA experts and indicator definition.

Is a visualization tool necessary for interpretation and support for decision making?

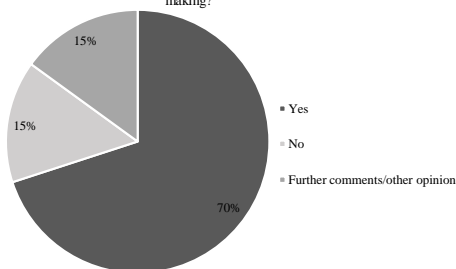


Figure 3. LCSA experts and visualization tool.

In TG 2, 143 respondents (53% male, 47% female) answered the questionnaire consisting of 31 questions. 63% of the respondents are civil engineering students, indicating the area of future DM in the construction sector. 54% of the students are in their fifth and higher bachelor's semester (up to and including master's). Of the respondents, 62% indicate that sustainability is generally a focus in their studies. However, only 38% of respondents are aware of the LCSA, while in contrast, all respondents call for more LCA to be conducted in the building sector as a pillar of the LCSA (not being at the beginning of their studies). Less than 10% of the students surveyed have already engaged in a sustainability assessment in practice - if this happened, it was in the context of a seminar. More than 70% of students would like to see more courses and seminars on sustainability, as they are more interested in the topic and would like to have more hands-on practice with sustainability assessment. There is a desire to address the topic not only in the construction field, but that cross-topic and cross-disciplinary events are offered.

TG 3 represents actual DMs in the construction sector. 79 respondents (56% male, 44% female) participated in this study with 39 questions. 68% of respondents work in planning/architecture and 57% of all respondents indicated that sustainability is a focus in their company. 94% of today's DM name LCA as important and relevant for construction sector. Yet, over 60% have never conducted a life cycle assessment (as one pillar of LCSA). LCC and S-LCA were never assessed by any of the requested DMs. If an LCA was assessed, this only happened as it was asked by clients. When being asked about LCSA, 51% of all respondents indicated that they have heard of LCSA. None of the respondents ever did or questioned a LCSA. Further, actual DM seem to ignore the equality of the three pillars as they rate the economic pillar as most important: economic > environmental > social (pillar). An open question of what exactly sustainability means to the DM was not asked in the survey. However, it is clear from the responses evaluated that, after the relevance of costs, the aspects of pollutant-free building products and energy efficiency in the use phase are regarded as sustainable – what is not in line with the understanding of life cycle-based sustainability.

A large proportion (over 50%) of respondents from all three target groups are concerned with sustainability in general and also consider it relevant. In the two working target groups (1 & 3), knowledge of LCSA is greater than among students, which initially suggests that LCSA education in teaching at universities can still be optimized. In TGs 2 and 3, individual assessments such as LCA were hardly implemented independently, nor was there any independent implementation of LCSA. In TG 2, it is clear that this is increasingly due to insufficient (training) education and that students would like to have the opportunity to learn more about it and especially practice its implementation. In TG 3, it is noticeable that the sustainability assessment was increasingly only carried out at the request of the customer or will be carried out in the future. The need for standardization, predefined indicators and visualization options emerges from the survey of experts (TG 1). Since this is already demanded by experts, it can be assumed that these demands are imperative in order to also facilitate the entry of TGs 2 and 3 into the topic area and to integrate it into their knowledge and practice in the long term. DM must receive increased and mandatory training, e.g. via the Chamber of Architects/Engineers/Craftsmen. Another option could be to include LCA in the listed basic services of the Official Scale of Fees for Services by Architects and Engineers (HOAI). Also, consumers have a relevant influence, since LCAs, in these specific cases, have only been carried out if the consumer questions them (even though norms or labels might require LCA). In particular, raising awareness of complex and diverse interdependencies in the construction sector (three pillars, life cycle, strength, stiffness, material selection, etc.) seems highly relevant. The results presented are a first insight into the findings, although some limitations of the studies should already be mentioned: TG 3 consists of selected and directly contacted individuals and companies from the German construction sector. Furthermore, in this study there is a large focus on certification systems (such as BREEAM [11] or LEED [12]), which are not primarily focused on LCSA. TG 2 are mainly students of German universities, and certainly a large part of these students can be attributed to RWTH Aachen University. The two TGs could have been extended internationally and survey periods could have been extended. TG 1 was contacted worldwide, but in a very subject-specific manner - it cannot be ensured that all experts worldwide were contacted, as this survey is based on authorship and personal contacts.

4 Conclusion

As a first interim result of this research, it can be summarized that H_{main} (*LCSA framework in its current form is little known and too complex to base decision-making regarding sustainability, particularly in the construction sector*) has to be proven true. LCSA is hardly known among actual and future decision-makers in the construction sector. Concerning

knowledge, above all, teaching (at universities) has a special future task to increase this knowledge and to better educate (future) DMs about LCSA and also the individual three pillars of sustainability – using e.g. the construction sector for practical examples. Current DMs know the LCSA framework in rudimentary form, but have very rarely implemented any of the three pillars themselves and have never applied a complete LCSA, e.g., to base decisions on it. From the results of the LCSA experts, it is clear that there are difficulties in the final interpretation of the LCSA, the weighting and the communication. Standardization is repeatedly called for and the majority of experts state that a set of predefined indicators and an adequate visualization tool are needed for improved implementation and support of DM - in general and in particular for the construction sector.

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