THE SOCIAL LIFE CYCLE OF EARTH- AND BIO-BASED MATERIALS COMPARED TO CONVENTIONAL MATERIALS

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Abstract

Earth materials are known for their self-sufficiency, non-toxicity, community engagement, and vernacular nature. However, while there is a widespread consensus on the social benefits of earth- and bio-based materials, a systematic analysis that quantifies these benefits is currently lacking. This study uses social life cycle assessment (SLCA), an increasingly robust methodology, to contribute to a full triple bottom line life cycle assessment of earth- and bio-based materials. This SLCA study provides a first pass enumerated impact results from an online pilot survey of 12 stakeholders, including manufacturers, designers, researchers, and homeowners. The results are provided in terms of health and safety, worker conditions, and regional impacts, showing that earth- and bio-based materials outperform conventional materials in almost all aspects of the SLCA framework, with the exception of the provision of social benefits and professional development opportunities for workers in the extraction, production, and construction phases.

Keywords: Social Life Cycle Assessment, Social Impact, Earth Materials, Health and wellbeing, Working Conditions

1 Introduction

The triple bottom line, which commits to measuring environmental, social, and financial impacts, is critical to fully evaluating building materials, products, and projects. By addressing the environmental, financial, and social impact streams, the intricacies between carbon and energy, profitability, health, and circularity can be assessed to gain a more complete evaluation of sustainability of a product. However, while environmental and financial performance have been extensively studied for buildings, social impacts have been far less examined (Hossain et al. 2018).

SLCA is a quantitative and qualitative method that aims to assess the social concerns of human health, wellbeing, and social welfare (Hosseinijou, Mansour, and Shirazi 2014). From the extraction of raw components to end of life, and beyond, a construction material's production, transportation, use, and disposal inherently engage a variety of stakeholders at different levels: from workers to production

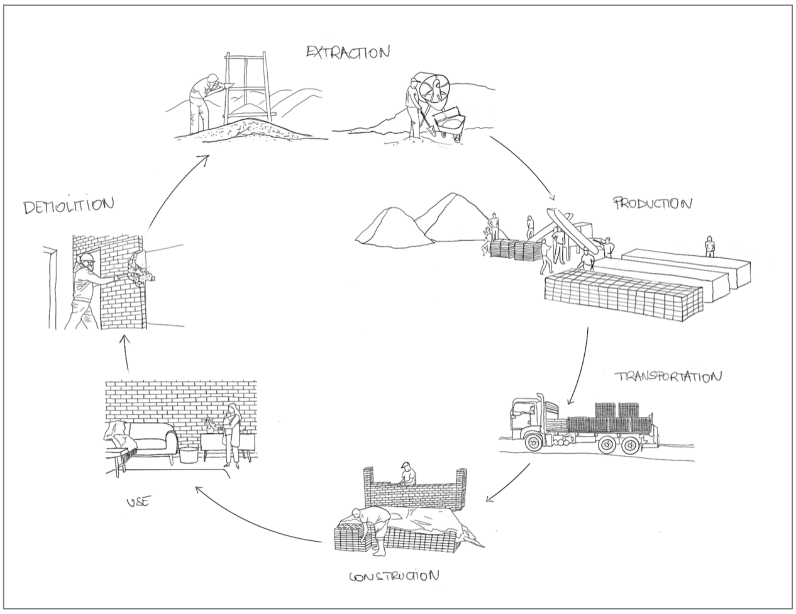

Figure 1. Diagram on the different labor practices of using earth.
Image by the authors.

teams, designers, construction builders, occupants, and demolition contractors. The social impacts of these involvements can –and should– be evaluated through a number of categories defined by stakeholder groups and social/socio-economic criteria.

For earth- and bio-based materials, SLCA is of particular importance; the sustainability of earth materials often rely on their readily availability but also on their nontoxicity and community engagement. To fully evaluate the life cycle of earth materials, their social impacts should be assessed and compared to conventional materials. To address this need, this study develops a first-pass SLCA for natural vs. conventional building materials. By assessing social and socio-economic impacts, this study provides a preliminary understanding of the conditions that earth materials offer to production workers, construction contractors, occupants, designers, and beyond, along the phases of extraction, production, construction, and demolition, as illustrated in Figure 1.

2 Background

2.1 Research framework for social life cycle assessment

Since the early 2000s, a handful of tools and frameworks have been developed to analyze the social impact of businesses and products. In contrast to environmental life cycle assessment (ELCA) and life cycle cost (LCC) that can be easily quantified through numerical data, SLCA often relies on qualitative data; for example, ELCA is estimated based on quantifiable data on fuels, transportation mode/distance, and chemical processes for emissions, whereas SLCA looks at the labor, health incidents, occupant comfort, regional and community impacts (Liu and Qian 2019).

A SLCA methodology was first introduced by UNEP/SETAC as a distinctive category of the triple bottom line (*Guidelines for Social Life Cycle Assessment of Products* 2009). As part of this report, a framework

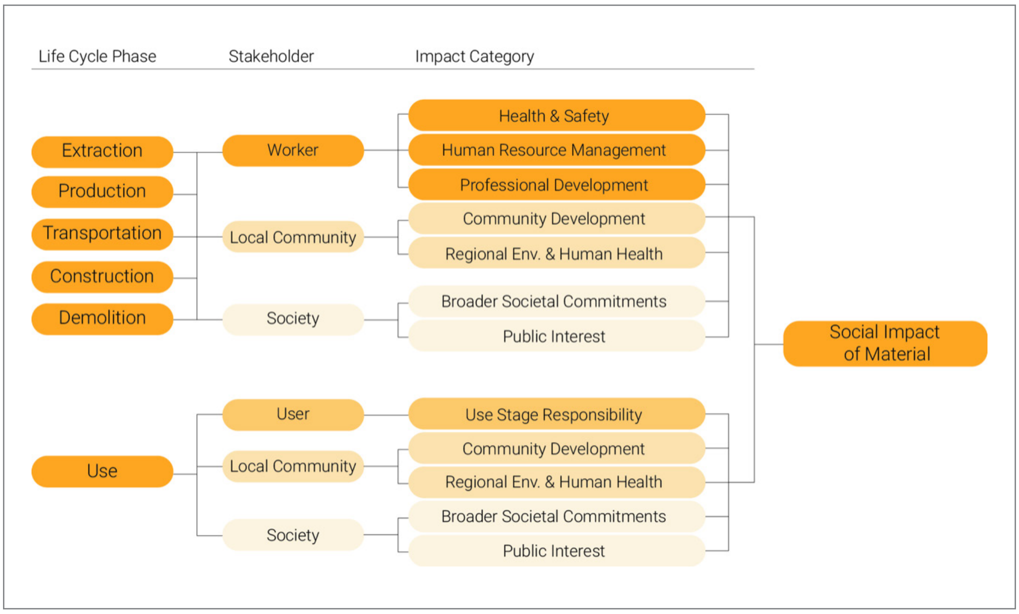

Figure 2. The categories, subcategories, and hot spot identification used for the S-LCA study. Image by the authors.

for conducting SLCA was developed, using six impact categories: (1) human rights, (2) working conditions, (3) health and safety, (4) cultural heritage, (5) governance, and (6) socioeconomic repercussions, and five stakeholder types: (a) workers, (b) local community, (c) society, (d) consumers, and (e) value chain actors. Since then, the UNEP/SETAC methodology for SLCA was used in various studies, refined for various product streams, including laptops (Ekener-Petersen and Finnveden 2013), mineral fertilizers (Martínez-Blanco et al. 2014), and milk (Revéret, Couture, and Parent 2015), to list a few.

2.2 Background on SLCA studies on building materials, guidelines and benchmarks

While there is limited inventory data for SLCA of construction materials, a few pioneering studies provide important references for analysis. Using the UNEP/SETAC methodology, these recent studies have each revisited and enriched the categories to be relevant to their materials and scope.

Hosseinijou, Mansour, and Shirazi (2014) developed a SLCA for concrete and steel buildings in Iran. Basing their methodology on the UNEP/SETAC, they used surveys and interviews to identify hotspot categories that are most relevant for the building sector. Additionally, they used normalized scoring results and interview comments to analyze the impact results. In another study, Liu and Qian (2019) developed a theoretical framework and impact assessment approach to SLCA of buildings by refining the UNEP/SETAC framework using a literature review, to create a list of indicators that was put through a weight scoring to reflect the prioritization of impact categories. Lastly, Hossain et al. (2018a) used the UNEP/SETAC guidelines in conjunction with the ISO standards for ELCA (ISO 2006a; 2006b)version 2006 for recycled building materials. Similar to Hosseinijou, Mansour, and Shirazi (2014), they used weight factors to prioritize hot spot categories.

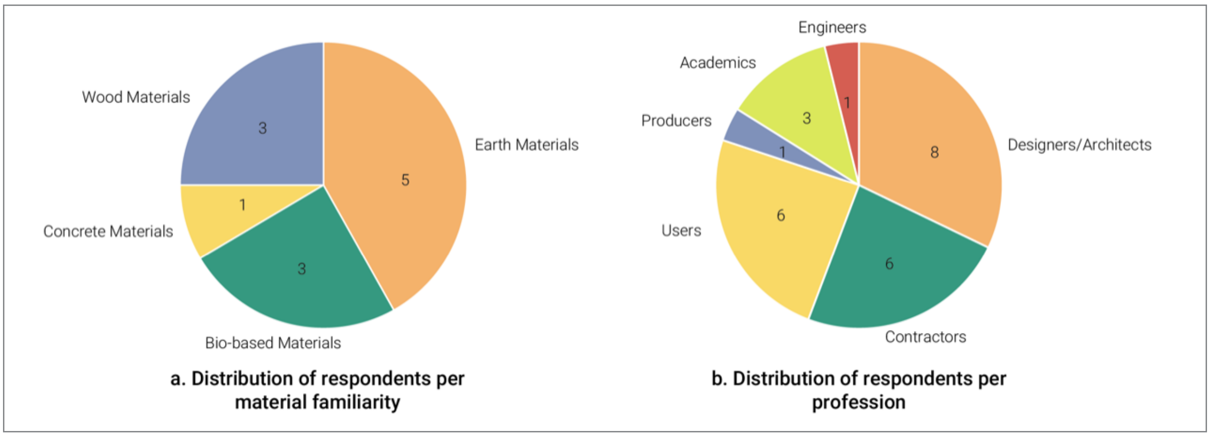

Figure 3. Distribution of survey respondents (a) per material familiarity (b) per profession.

3 Research methodology

3.1 Goal of the study

The goal of this SLCA is to provide a first-pass assessment of the social impacts of earth- and bio-based construction materials. To do so, this research develops an effective and user-friendly SLCA questionnaire that can be used for both natural and conventional building materials for comparative purposes. Long term, this framework is meant to set a baseline for SLCA benchmarking in the building materials arena, inform design decisions, and raise awareness about the social impact of construction material processes on workers, users, and local communities.

3.2 Scope of the study

This study involves a thorough procedure to identify the stakeholder, social impact, and life cycle categories relevant to building materials. Using the UNEP/SETAC guideline as a baseline, this research identifies four stakeholder categories: workers, occupants, local community, and society. Additionally, eight impact categories are addressed: health and safety, human resource management, professional development and supplier relationship, use stage responsibility, community development, regional environmental and human health, broader societal commitments, and public interest. Six life cycle phases are addressed: extraction, production, transportation, construction, occupancy, and demolition/recycling. While most of the social impact categories affect all the life cycle stages of a material, not all apply to the occupancy phase. The distribution of the categories based on the life cycle stages and stakeholders is shown in Figure 2.

3.3 Functional unit and scoring system

Unlike in ELCA, SLCA involves the collection of a range of data that vary from qualitative, semi-quantitative, and quantitative inputs, making it hard to unify the results and translate them into a common functional unit (FU) (Benoît et al. 2010). Additionally, this study uses a score-normalization strategy by attributing a 1 to 5 score to each result to help compare the different impact results for each material.

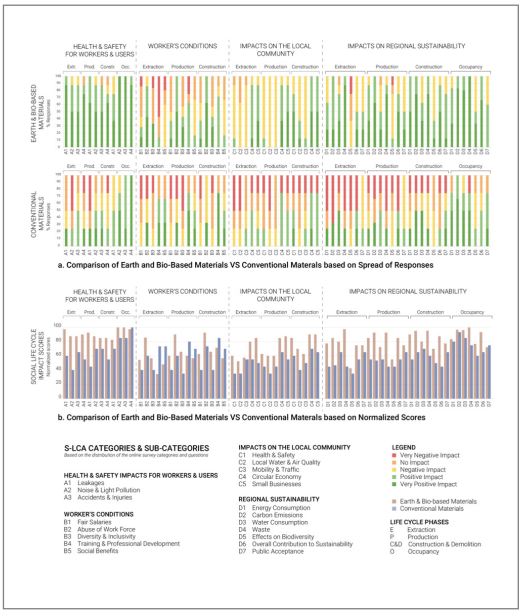

Figure 4. Survey responses analysis
(a) spread of responses (b) normalized scores.

3.4 System boundaries

The system boundaries involved the phases from “cradle-to-grave”, including the extraction of raw materials, production, transportation, usage, and end of life. The stakeholders include anyone who interacts with the material in its raw or processed form throughout those life cycle stages. Among them are manufacturers, workers, suppliers, transporters, construction and demolition contractors, occupants, recyclers, and local communities.

3.5 Approach and survey design

The study consists of three main stages: (1) reviewing existing S-LCA precedents and developing categories and hot spot analysis, (2) developing the survey questionnaire, and (3) administrating the online survey and analyzing the data.

In the first stage, the hot spot analysis from the UNEP/SETAC report was adopted and modified according to Hossain et al. (2018). The inventory categories were further revised and screened to be relevant to natural and conventional materials. The initial set of approximately 80 questions per life cycle stage was condensed into 25 questions per stage. The second stage included the development of an online survey using Google Forms, including identification questions for analyzing the respondents’ job and familiarity with the different materials and life cycle phases. The online survey was tested by several graduate students at the Natural Materials Lab to provide further adaptations for clarity and ease of use. Lastly, the third phase included the administration of the survey using building networks and data analysis within Excel. For the analysis, a normalized 1-5 scoring system was applied to unify the results and provide easy interpretation and comparison of quantified data.

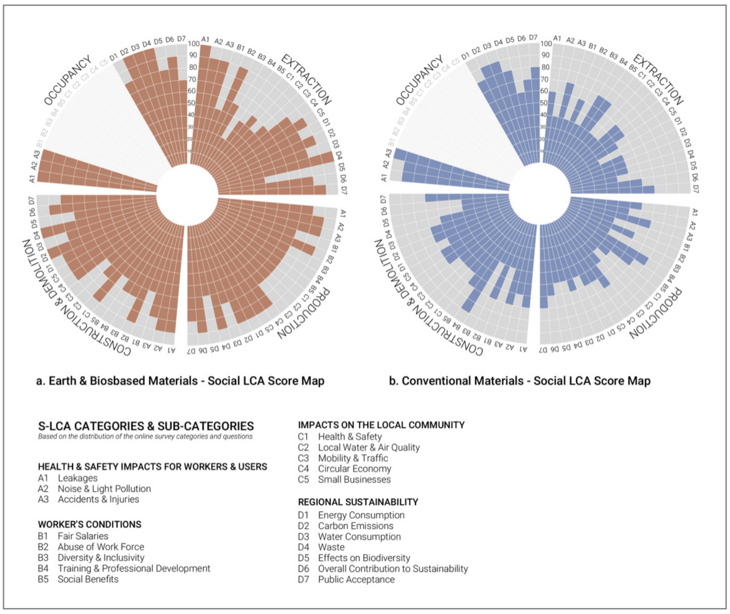

Figure 5. Survey responses score map (a) earth and bio-based materials (b) conventional materials.

4 Results

The first pass results of the survey were assigned to 12 local experts in the fields of architecture, construction and materials, with a diverse expertise ranging from design to academia, as shown in Figure 3. In order to compare earth and bio-based materials with other conventional materials, the responder's material familiarity is divided as shown in Figure 3. It is important to note that wood materials are considered *conventional materials* in this preliminary study.

4.1 Impact assessment results and interpretation

The survey analysis shown in Figure 4 is visualized using percentages on a Likert scale (Figure 4.a) and final impact scores (Figure 4.b) for each type of material. The results show that, overall, experts of earth- and bio-based materials reported more positive answers for social impacts than experts of conventional materials. However, Figure 4.b shows an exception: for the Workers' Conditions category, reported answers by experts of conventional material showed higher scores for training, professional development, and social benefits — in every life cycle stage of the materials (extraction, production, and construction). Furthermore, the Public Acceptance category for the occupancy phase showed better scores for the conventional materials than for the materials. In this matter, one of the responders noted that "people have a negative attitude towards natural building because they view it as a backwards and uncivilized way of doing things".

Shown in Figure 5, the side-by-side results are arranged on a score map. The score maps reveal that the answers for earth and bio-based materials exhibit higher scores for their social benefits, excluding the occupancy phase, in which conventional materials are almost as high as the results for earth and bio-based materials.

5 Conclusion

This paper provides a first pass investigation into the social life cycle of earth materials as opposed to conventional materials. Using the UNEP/SETAC guidelines, this study develops an online survey that was administrated and analyzed for 12 respondents. Analyzed using normalized scoring units, the results show that natural materials have a better social impact score than conventional materials in all the life cycle stages of their cradle to grave, with the exception of employee benefits and professional training. This can be justified by the fact that, as commodified systems, conventional material trades are more established and embedded in the *capitalist system*. Future research should be conducted to differentiate and compare a broader range of materials and understand how the organizational management of different plants/businesses impact the overall social impact scores.

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