Uncovering Social Hotspots in Asphalt Mixture Production: A Pathway to Sustainable Infrastructure Development

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ABSTRACT
The social dimensions of sustainability in the construction industry, particularly in asphalt mixture production, have often been underexplored compared to environmental and economic aspects. Social Life Cycle Assessment (S-LCA) offers a structured framework to evaluate social impacts across the asphalt mixture production (cradle-to-gate). This study investigates the application of S-LCA, identifying 24 key social sustainability subcategories derived from the 40 outlined in the UNEP/SETAC S-LCA guidelines (2020) and social generic databases such as SHDB and PSILCA. These subcategories address five stakeholder groups: workers, local communities, society, consumers, and value chain actors. Core subcategories like freedom of association, health and safety, and equity are consistently included across studies, while others like cultural heritage protection and fair competition vary by context. The findings of this study serve as a foundation for developing a framework that combines generic database-based S-LCA analysis with primary data collection, advancing sustainable practices in road construction.

Keywords: Social Life Cycle Assessment (S-LCA), Asphalt Mixture Production, Sustainable transportation, Social Impacts, Social Sustainability, Sustainable Development.

1. INTRODUCTION

The growing emphasis on sustainability in construction projects has brought increased attention to evaluating the social impacts of these activities, an area often neglected in traditional life cycle assessments. Among the emerging tools for assessing the social dimensions of sustainability, Social Life Cycle Assessment (S-LCA) is a methodology for assessing potential social impacts of products and services through their life cycles and it assesses the potential social impacts of the products system on its stakeholders [1]. Unlike conventional assessments that primarily focus on environmental and economic aspects, S-LCA provides a structured framework for identifying and addressing social impacts across the supply chain, such as labor conditions, community well-being, and equity [1, 3, 6]. This study leverages the potential of S-LCA to enhance the social sustainability of asphalt mixture production, a critical component of road pavement construction.

As global awareness of sustainable development continues to rise, the construction industry is increasingly compelled to adopt comprehensive sustainability practices. However, the social impacts of construction projects remain underexplored despite their significance in achieving holistic sustainability. This research focuses on addressing this gap by examining social issues within the asphalt production supply chain and introducing databases and methodologies for conducting S-LCA. By aligning with established international standards, such as the United Nations Environment Program (UNEP) guidelines [1, 3, 4, 5], this study aims to bridge gaps in the understanding and application of social sustainability assessment in the road construction sector. To achieve these objectives, this research evaluates social sustainability subcategories relevant to asphalt mixture production, focusing on the cradle-to-gate phase. A comprehensive literature review of publications from 2014 to 2024 forms the foundation of the study, systematically identifying and analyzing social subcategories. Furthermore, key databases and guidelines for S-LCA are introduced to provide actionable insights for practitioners and researchers.

Objectives;

1. To identify and analyze social subcategories relevant to the production of asphalt mixtures (cradle-to-gate) in publications from 2014 to 2024.
2. To examine social issues in the asphalt mixture production supply chain and address gaps in understanding social impacts in infrastructure sustainability.

These objectives are embedded in a larger project which aims to develop a whole framework for the assessment of social impacts of the asphalt mixture production (cradle-to-gate) and that is the first step in this larger project as shown in figure 1. By addressing these objectives, the study aims to build the first foundational steps towards developing a framework for minimizing social risks and promoting social sustainability in asphalt mixture production. The findings are expected to support civil engineers, policymakers, and stakeholders in adopting more socially sustainable practices in road pavement projects. Additionally, this research contributes to the limited application of social sustainability assessments in construction by integrating well-established methodologies and offering a comprehensive set of social sustainability subcategories. Ultimately,

this study provides a deeper understanding of social sustainability, enabling the construction industry to advance its role in achieving sustainable development.

2. METHODOLOGY

This study is a part of broader project which focuses to develop a comprehensive S-LCA framework for asphalt mixture production. This paper only covers the first stage of the whole project stages as shown in figure 1, and employs a systematic and structured approach to identify, select, and analyze literature relevant to social sustainability in the road pavement construction sector, with a particular focus on the application of Social Life Cycle Assessment (S-LCA) within asphalt mixture production. By focusing on publications from 2014 to 2024, the study examines how social impacts in the road construction industry have been addressed and identifies underexplored areas for advancing social sustainability. The methodological framework comprises the following key steps:

- Literature Review; A comprehensive review of articles, standards, guidelines, and databases was conducted using targeted keywords such as "Social LCA," "social issues," "social impacts," and "social sustainability." This review focused on identifying relevant studies, frameworks, and guidelines that discuss social impacts in the context of asphalt production. The findings provided a detailed inventory of social subcategories and highlighted gaps in existing research.
- Analysis of subcategories; Following the literature review, an in-depth analysis of selected studies was conducted to extract and categorize social sustainability subcategories. Subcategories were evaluated for their relevance, frequency of use, and alignment with S-LCA frameworks.
- Development of a framework roadmap; The final step involved the refinement and organization of a roadmap which lead to the development of a set of subcategories and also documentation to collect primary data to complement the database analysis.

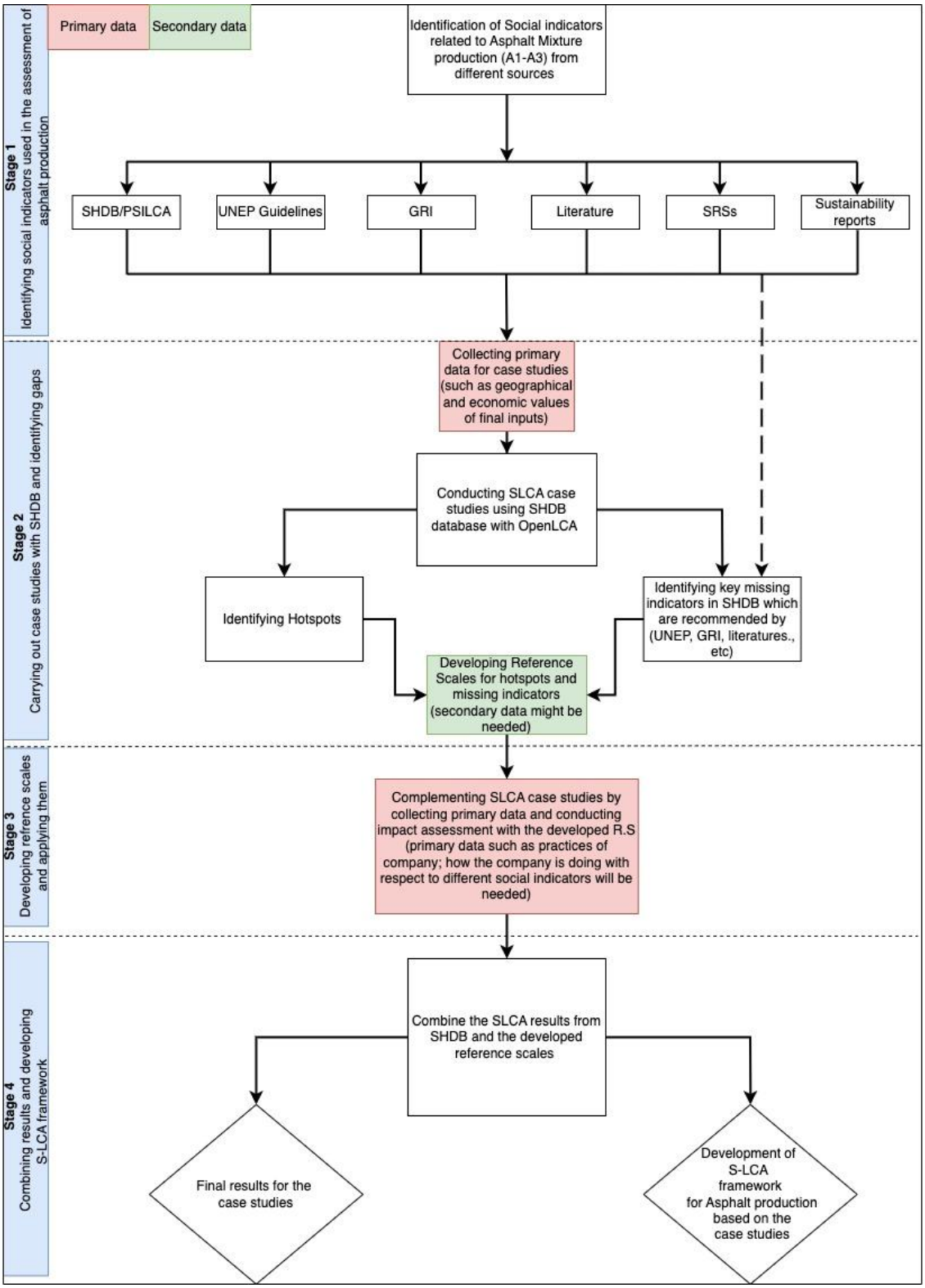

Figure 1. Methodology flowchart for developing S-LCA framework of asphalt mixture production (cradle-to-gate)

By following these systematic steps, the study lays a foundation for advancing the application of S-LCA in the road construction industry. The approach contributes to refining social sustainability practices by identifying actionable solutions to minimize social risks, foster equitable practices, and explore underrepresented subcategories within the asphalt mixture production supply chain.

3. RESULTS AND DISCUSSION

3.1 Literature Review

From the article's literature review which has been conducted for road pavement production and construction with the defined keywords, a total of 14 papers [9-22] were found: 4 of them [9-12] focus on road pavements, only one paper focuses on roads in general [13], and 9 papers [14-22] focuses on the construction sector in general, as shown in table 1. From those papers, 4 articles [9-12] related to the life cycle of asphalt mixture production and road pavement were selected for this study. Each article has been defined a set of subcategories, the main reference of the articles is the UNEP/SETAC methodological sheets (2013) [4] aligned with UNEP/SETAC S-LCA guideline (2020) [1], literature articles, and social hotspot analysis (PSILCA, SHDB) [7-8]. These articles synthesizes key stakeholders, and subcategories utilized in Social Life Cycle Assessment (S-LCA) frameworks.

Table 1. Literature Review result for S_LCA of road pavement construction

No	Authors	Title	Sector
1	daRocha., et.al	Social and environmental assessments of Eco-friendly Pavement alternatives	Road Pavement
2	Traverso, et.al	Toward the assessment of Social Sustainability: identifying Social Hotspots for Road Pavement Materials	Road Pavement
3	Xiaoyan Z ., et.al	Modeling life-cycle social assessment in sustainable pavement management at project level	Road Pavement
4	Shelden A., et.al	Social life cycle inventory for pavements- A case study of south Africa	Road Pavement
5	Alqershy M.T., et.al	Analyzing the interplay of isomorphic pressures, perceived benefits and top management support on social responsibility performance of Belt and Road megaprojects	Road in general

6	Petrelli M.Z., et.al	Sustainable practices in construction project management: impacts on triple bottom line	Construction in general
7	Ahmed T.Z.Y., et.al	Corporate social responsibility and construction design briefs: International case studies	Construction in general
8	Cruz C.O., et.al.	On the concept of sustainable sustainability: An application to the Portuguese construction sector	Construction in general
9	Ma H., et.al	Climbing the Pyramid of Megaproject Social Responsibility: Impacts of External Stakeholders and Project Complexity	Construction in general
10	Martek I., et.al	Barriers inhibiting the transition to sustainability within the Australian construction industry: An investigation of technical and social interactions	Construction in general
11	Fathalizadeh A., et.al	Barriers impeding sustainable project management: A Social Network Analysis of the Iranian construction sector	Construction in general
12	Wu X., et.al	The influence of social capitalism on construction safety behaviors: An exploratory megaproject case study	Construction in general
13	Williams J., et.al	A framework towards health and safety knowledge transfer from the construction industry to the community in developing countries: a case study of Ghana	Construction in general
14	Freelove S., et.al	Creating long-term social value on major infrastructure projects: a case study	Construction in general

3.2 Analysis of Social subcategories

From the literature review results, 4 articles (Xioyan Zheng., et.al (2020) [11], Sheldon A., et.al (2021) [12], Da rocha., et.al (2022) [9], and Traverso et.al (2024) [10] related to road pavement infrastructure have been selected, which covers 5 different stakeholders (worker, local community, society, consumer, and value chain actors). Each article has been introduced a set of subcategories, the main reference of the articles is the UNEP/SETAC methodological sheets 2013 [4] aligned with UNEP/SETAC S-LCA guideline (2020) [1], literature articles, and social hotspot analysis

(PSILCA, SHDB) [7-8]. As a total of 24 subcategories were identified from the selected literature review, as shown in table 2.

Xioyan Zheng et al. (2020) [11] conducted a study focusing on the social sustainability of pavement infrastructure by identifying and categorizing social subcategories relevant to four primary stakeholder groups: Workers, Local Communities, Society, and Consumers. The study identified 13 key subcategories that address various dimensions of social impacts. These include freedom of association and collective bargaining, emphasizing workers' rights to unionize and negotiate collectively, and working hours, which focuses on fair and regulated working conditions. Health and safety was highlighted as a critical aspect, ensuring occupational standards and reducing workplace risks, while professional growth emphasized the importance of skill development and career advancement opportunities. Access to material resources and safe/healthy living conditions were identified as subcategories for equitable distribution of resources and enhancing community health and well-being. The study also introducing local employment, emphasizing job creation for local populations, and public commitments to sustainability issues, which highlight organizational transparency and accountability. Furthermore, corruption was addressed as a critical aspect, focusing on ethical governance and anti-corruption measures, while technology development promoted innovation to advance social and economic outcomes. The final subcategory, health and safety, extended its scope to emphasize community-wide health impacts beyond the workplace.

Secondly, Sheldon et al. (2021) [12] developed a framework to assess social and environmental sustainability impacts in the context of pavement infrastructure, categorizing impacts into broader areas such as pollution, socio-economic impacts, safety, functional performance, climate change, local economic development, and financial performance. The study focused on five key subcategories that represent the intersection of these impact areas with societal well-being and sustainability goals. The subcategory of livable streets and neighbourhoods emphasizes the creation of urban spaces that enhance quality of life, ensuring accessibility, reduced congestion, and improved community cohesion. Protection of the environment highlights the need to minimize environmental degradation through sustainable construction practices and emission reductions. Equity and social inclusion promotes fairness, ensuring that infrastructure projects benefit all societal groups without discrimination. Safety is identified as a critical factor, addressing both road user and worker safety to mitigate risks associated with construction and use. Lastly, vibrant and efficient economy focuses on the economic benefits of sustainable pavement projects, including job creation, local economic stimulation, and efficient resource utilization. By integrating these subcategories into their framework, Sheldon et al. provide a holistic approach to evaluating the social and environmental dimensions of sustainability in pavement infrastructure, demonstrating the interdependence between urban functionality, societal outcomes, and environmental stewardship.

Additionally, Da Rocha et al. (2022) [9] proposed a set of subcategories for assessing social sustainability in the pavement sector, emphasizing the roles of three key stakeholder groups: Workers, Local Communities, and Society. The study identifies 14 subcategories that address critical dimensions of social sustainability, providing a structured approach to evaluate social impacts across various levels. The subcategory of health and safety focuses on safeguarding workers and community members from occupational and environmental risks. Freedom of association and collective bargaining highlights the importance of labor rights and the ability of workers to advocate for fair treatment. The subcategories of forced labor and child labor emphasize the eradication of exploitative labor practices, aligning with global human rights standards. Equal opportunities and discrimination addresses inclusivity, ensuring fair treatment regardless of gender, ethnicity, or other social factors. Economic aspects are addressed through fair income, which ensures workers receive equitable compensation, and local employment, which prioritizes job creation for local populations. Subcategories such as access to material resources and safe and healthy living conditions reflect the importance of equitable distribution of resources and enhanced community well-being. Cultural heritage and secure living conditions emphasize the preservation of local traditions and the promotion of stable and safe environments. The study also underscores the role of technology development in advancing societal outcomes, while contribution to economic development highlights the economic benefits of sustainable infrastructure projects. Finally, the subcategory of corruption focuses on promoting ethical governance and transparency.

Lastly, Traverso et al. (2024) [10] introduced a set of subcategories from hotspot analysis of social databases such as PSILCA and SHDB for assessing social sustainability in road pavement infrastructure, focusing on three primary stakeholder groups: Local Communities, Value Chain Actors, and Workers. The study highlights eight key categories that emphasize the social dimensions of sustainability such as (Access to material resources, fair competition, promoting social responsibility, equal opportunities/discrimination, fair salary, forced labor, freedom of association and collective bargaining, and health and safety). The subcategory of access to material resources addresses the equitable distribution and availability of essential resources, ensuring communities and stakeholders benefit fairly from infrastructure projects. Fair competition underscores the importance of transparency and ethical practices in value chain operations, promoting a level playing field for all actors. Promoting social sustainability focuses on aligning infrastructure development with broader sustainability goals, including social equity and well-being. The subcategory of equal opportunities and discrimination emphasizes inclusivity, ensuring that all individuals, regardless of gender, ethnicity, or background, have access to fair treatment and opportunities. Fair salary reflects the need for equitable compensation that aligns with living wage standards, addressing economic disparities among workers. Forced labor, freedom of association and collective bargaining highlight the importance of protecting fundamental labor rights, including the eradication of exploitative practices and the empowerment of workers to advocate for their interests. Lastly, health and safety, ensuring the well-being of workers and communities through robust safety measures and occupational health standards.

Finally by analyzing all the subcategories which have been introduced from different sources and papers, we could have a common list of subcategories as shown in table 2. which could be used to measure the social sustainability of asphalt mixture during production (cradle-to-gate) stage. These list of subcategories could be used for conducting S-LCA and assess the potential risk and social impacts of asphalt mixture during production phase (cradle-to-gate).

Table 2. Social related subcategories for asphalt mixture production

Stakeholders	Subcategories
▪ Worker ▪ Local community ▪ Society ▪ Consumer ▪ Value chain actors	1. Freedom of association and collective bargaining 2. Working hours 3. Health and safety 4. Professional growth 5. Equal opportunities/discrimination 6. Access to material resource 7. Safe/healthy living conditions 8. Local employment 9. Public commitments to sustainability issues 10. Corruption 11. Technology development 12. Livable streets and neighborhoods 13. Protection of the environment 14. Equity and social inclusion 15. Safety 16. Vibrant and efficient economy 17. Forced labour 18. Child Labour 19. Fair income/salary 20. Cultural heritage 21. Secure living conditions 22. Contribution to economic development 23. Fair competition 24. Promoting social sustainability

4. Conclusion

This study provides a comprehensive subcategories analysis of the social sustainability dimensions in asphalt mixture production studies, focusing on the application of Social Life Cycle Assessment (S-LCA) within the asphalt mixture production stage (cradle-to-gate). From 40 subcategories

outlined in the UNEP/SETAC S-LCA guideline (2020) [1], 24 subcategories were identified as relevant in the reviewed studies. These subcategories, distributed across five stakeholder's groups: (workers, local communities, society, consumers, and value chain actors), reflect the frameworks ability to capture diverse social impacts in the asphalt production supply chain. The analysis highlights trends in the inclusion of subcategories across the four selected studies. Core subcategories such as freedom of association and collective bargaining, health and safety, and equal opportunities/discrimination are consistently addressed in all studies, emphasizing their foundational role in assessing social sustainability. Conversely, subcategories like working hours, professional growth, fair competition, and cultural heritage protection are included only in some studies, indicating variability in stakeholders emphasis and context-specific priorities. Additionally some subcategories, such as fair competition and promoting social sustainability, appear to be inspired by frameworks outside of UNEP/SETAC, reflecting the influence of other methodologies in shaping social sustainability assessment. Rather than emerging as new themes, these subcategories are largely derived from UNEP/SETAC S-LCA guideline (2020) [1] framework itself, with their selection driven by methodological relevance and the specific focus on each study. This variability underscores the adaptability of the S-LCA framework , allowing its application to be tailored to the priorities and challenges of different contexts.

By integrating these subcategories into S-LCA based evaluations of asphalt mixture production, this study demonstrates the potential for reducing social risks, fostering equity, and advancing sustainable practices in road pavement infrastructure. However to measure the importance level of these 24 subcategories, a S-LCA case study need to be conducted using primary data. Additionally, the findings of this study addresses gaps in the literature by offering insights into how social subcategories are operationalized in practice, providing a foundation for refining assessment methodologies.

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