DEVELOPING SOCIAL LIFE CYCLE ASSESSMENT BASED ON SUBCATEGORIES IN CONSTRUCTION MATERIAL SELECTION

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ABSTRACT

The social aspect is one of the three main parts of sustainability. Even though it is important, it is often not given as much attention as the economic and environmental aspects, especially in the construction industry. During the design phase, the project's needs are fine-tuned, and choices are made about the structure, materials, layout, and extra facilities. Still, it's hard to choose the right materials at this point because there aren't any complete databases, there isn't enough time, the criteria aren't always clear, and there isn't enough reliable data. This study presents a framework for assessing the social performance of construction materials during the design phase via distinct social impact subcategories. The suggested method is based on the Social Life Cycle Assessment (S-LCA/Social LCA) method, which has four main steps: (1) defining the goal and scope; (2) estimating the social life cycle inventory (S-LCI); (3) figuring out the social life cycle impacts; and (4) interpreting. In the second stage, the S-LCI is established based on four key components: correlations between subcategories and product assessments, the use of Basic Requirements (BRs), definition of assessment levels, and quantitative scoring. Initially, a questionnaire was designed to capture the perceived social effects of each subcategory. The answers were then checked against the BRs to find and rate the social impact dimensions. Based on the analysis, performance labels (A, B, C, and D) were given to show how much each element contributed to society. In the third stage, weighted social scores were used to compare different materials. The proposed framework was utilized to assess and compare asphalt concrete and cement concrete, indicating that cement concrete exhibits significantly superior social performance.

Keywords: *Social LCA, subcategories, construction material selection, the design phase.*

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1. INTRODUCTION

The social dimension forms an essential pillar of sustainability. Along with the economic and environmental pillars, it creates a balanced framework that guides responsible and inclusive development [1]. The social assessment is conducted to identify, manage, and analyze the conditions, causes, and effects of social phenomena from objectives.

Selecting appropriate materials is among the most critical responsibilities of designers. The choice made at this stage strongly influences the project’s time efficiency, financial outcome, and overall quality [2]. Throughout the design phase, choosing materials becomes a complex task due to multiple constraints and uncertainties

According to UNEP/SETAC [3], the Social Life Cycle Assessment (Social LCA) method is a methodology that assesses the positive and negative social and socio-economic impacts of a product or service during its life cycle. It differs from the others because it measures the social issues of all activities in the entire product’s life cycle [4, 5] . So, Jian et al. [6] suggested using life cycle analysis for assessing the social performance of alternatives in the construction industry.

However, implementing the Social Life Cycle Assessment (S-LCA) in evaluating construction materials remains difficult. Several practical and methodological barriers still limit its effectiveness in the construction sector. It is hard to compare SLCA results from different studies or industries because there aren't enough standardized methods and indicators. Social impacts are often qualitative and subjective, which makes them harder to measure. The effects can also change a lot over time and in different places. It is hard to take these differences into account in Social LCA methodology, and accurate modeling methods are needed to do so [7]. Developing robust methods to transform qualitative social data into quantitative data is a significant challenge. Moreover, the assessments require some data, which may not always be feasible for all construction companies. Collecting social data for social LCA is challenging due to the variability in data sources and the lack of standardized social indicators. Ensuring data accuracy, reliability, and relevance across different contexts is a critical methodological issue [6]. Besides, establishing accurate and comprehensive social impact pathways that link social indicators to outcomes is challenging because these pathways must reflect real causal relationships. To put it in another way, aggregating diverse social indicators into meaningful impact categories and interpreting these results to provide actionable insights can be problematic [8]. Also, there is no agreement on which social indicators should be part of Social LCA. Different studies and frameworks suggest different indicators, which can make it hard to compare products or sectors and lead to inconsistent assessments [7]. Besides, there are some stakeholders in the Social LCA. So, aggregating diverse social indicators into a cohesive assessment and determining appropriate weighting based on the perspectives of stakeholders are challenges. This leads to subjective judgment and can vary widely depending on the context and stakeholders involved.

This study presents a Social Life Cycle Assessment methodology aimed at assessing the social dimensions of construction materials and their related activities in the design phase. It doesn't depend on big databases like traditional methods do, and it lets you measure social performance throughout the whole project life cycle. The method is also quick and can be used in different regions and countries. Theoretically, it reinforces the role of S-LCA in construction material decision-making by linking stakeholder well-being, labour conditions, and community impacts to early design choices. Methodologically, it operationalizes a simplified indicator framework using Basic Requirements, a structured rating scheme (A-D), and a quantified weighting mechanism based on Relative Index and internal consistency analysis. Practically, it offers evidence from a real infrastructure project, demonstrating how the framework can support socially responsible material selection where formal social databases are unavailable

2. METHODOLOGY

The Social Life Cycle Assessment is a methodology designed to evaluate the social dimensions associated with products and services. It focuses on identifying and analyzing the positive and negative social impacts that arise throughout a product's life cycle. The Social LCA method is able to assess the positive and negative social and socio-economic impacts of the life cycle [3, 9]. This method also supports informed decision-making by providing insights into the social implications of products and services. It helps organizations enhance their social performance and promote the well-being of stakeholders [3, 10]. The Social Life Cycle Assessment framework was developed in alignment with the ISO 14040 standard for environmental LCA. Accordingly, it follows four main stages: (1) goal and scope definition, (2) social life cycle inventory analysis, (3) social life cycle impact assessment, and (4) interpretation [3, 10].

Step 1 - Goal and scope definition

The goals of a Social Life Cycle Assessment define the study's purpose, intended applications, key stakeholders, social impact categories, and target audience. The scope must be clearly specified to ensure that it aligns with these goals, covering aspects such as the system boundary, functional unit, and data requirements [3]. The system boundary is defined in a manner similar to that used in conventional Life Cycle Assessment. Its purpose is to determine which unit processes are included in the social evaluation [3, 11]. Stakeholders and their relevant subcategories are illustrated in Table 1.

Table 1. List of potential stakeholders and their relevant subcategories

Stakeholders	Subcategories
Worker	1. Freedom of association and collective bargaining; 2. Child labor; 3. Fair salary; 4. Working hours; 5. Forced labor; 6. Equal opportunities/discrimination; 7. Health and safety; 8. Social benefits/social security; 9. Employment relationship
Local community	1. Access to material resources; 2. Access to immaterial resources; 3. Delocalization and migration; 4. Cultural heritage; 5. Safe and healthy living conditions; 6. Respect of indigenous rights; 7. Community engagement; 8. Local employment; 9. Secure living conditions
Value chain actors	1. Fair competition; 2. Promoting social responsibility; 3. Supplier relationships; 4. Respect of intellectual property rights; 5. Wealth distribution

Consumer	1. Health and safety; 2. Feedback mechanism; 3. Consumer privacy; 4. Transparency; 5. End-of-life responsibility
Society	1. Public commitments to sustainability issues; 2. Contribution to economic development; 3. Prevention and mitigation of armed conflicts; 4. Technology development; 5. Corruption; 6. Ethical treatment of animals; 7. Poverty alleviation

Step 2 - Social life cycle inventory analysis

After establishing the goals and scope in the first step, the Social Life Cycle Inventory (Social LCI) phase is implemented to gather and evaluate data from all relevant unit processes. This stage serves as the foundation for identifying the social aspects and potential impacts associated with the system under study. It includes steps:

- Completing and concretizing the flow diagram from the system boundary: Flow diagrams are employed to represent the sequence and interaction of all unit processes. Similar to conventional Life Cycle Assessment (LCA), the aggregated processes are illustrated using boxes and arrows that clearly show their interconnections. The flowchart describing material-dependent activities is constructed according to the defined system boundaries and covers all phases of the project's life cycle.

- Building Basic Requirements (BRs): The Basic Requirements [12] serve as reference points for establishing benchmarks used to evaluate selected social impact subcategories. The Basic Requirements are derived from the UNEP and SETAC guidelines, which define stakeholders and their associated subcategories. They are further elaborated based on international conventions, national regulations, and internal organizational management practices (see Table 2). For instance, the absence of child labor in construction activities is identified as one of the Basic Requirements (BRs) for evaluating the "child labor" subcategory. When an alternative fails to meet this Basic Requirement, an additional context-specific question in a "Yes/No" format is provided to further assess the situation.

- Constructing a questionnaire: The social performance of each subcategory is assessed by a questionnaire. It should enable participants to answer the question of whether the Basic Requirements and relevant contexts are or are not fulfilled. The experts can add more questions to the questionnaire to get a deep insight into actual social influences (see Table 3).

- Collecting the data: The questionnaire will be sent to manufacturing companies, extraction companies, suppliers, contractors, owners, and local community stakeholders by mail-post, email, or link. It may include two parts: (1) the personal information of respondents and (2) the main questions.

Table 2. The main social impact subcategories and Basic Requirements for comparing social performance of construction materials

Stakeholders	Subcategory	Impacts by road construction materials	Basic Requirements (BRs)	The main content of the questionnaires
Worker	Child labor	Not using child labor for material-dependent activities	The absence of children working in the material-dependent activities	Whether there are policies considering child labor or not The contractor encourages the prohibition of child labor or not
	Working hours	The worker has to work overtime in material-dependent activities or not	The average number of working hours per employee must not exceed the amount of eight hours per day and forty-eight hours per week	The worker has to work overtime or not The workers obey maximum working hour regulations or not The working hours per employee are higher than the average value in the relevant region
	Health and Safety	Health and safety of labor in material-dependent activities	The presence of a detailed policy/guideline or program considering health and safety of the laborers in the material-dependent activities	The worker gets protection clothes or not The contractor encourages the policies concerning health and safety of labor in material-dependent activities or not

Table 3. The questionnaire assessing the social performance of construction materials and material-relevant activities during the project life cycle

Stakeholders	Subcategory	Question		Level
(1)	(2)	(3)	(4)	(5)
Worker	Child labor	Is child labor (less than 16 years old) prohibited in material-dependent activities?	(if yes) Does the organization using the material and executing related-material activities have any support/policy for preventing child labor towards other construction activities?	(if yes) A
				(if no) B
			(if no) Does the country have any laws preventing child labor?	(if no) C
				(if yes) D
	Working hours	Do employees executing material-dependent activities must work overtime (more than eight hours per day and forty-eight hours per week)?	(if no) Does the organization using the material and executing related-material activities have any support for obeying maximum working hour regulations towards other construction activities?	(if yes) A
				(if no) B
			(if yes) Are the actual working hours higher than the average number of hours in the relevant area?	(if no) C
				(if yes) D
	Health and safety	Do employees executing material-dependent activities get any policies ensuring their health and safety? (e.g., protection clothes requirements)	(if yes) Does the organization using the material and executing related-material activities have any support for ensuring health and safety of labors towards other construction activities?	(if yes) A
				(if no) B
			(if no) Is the rate of frequency of project's occupational accidents (fatal and non-fatal) lower than the average figure of the country/ sector?	(if yes) C
				(if no) D

- Analyzing data and comparing to the BRs: The labels A, B, C, or D for each respondent are assigned after comparing the answers to the BRs (see column 5 of Table 3). The selection of A, B, C, or D in column 5 is conducted according to the answers in columns (3) and (4). For instance, the question 'Is child labor (less than 16 years old) prohibited in material-dependent activities?' is applied to evaluate the social performance regarding the 'worker' stakeholder and 'child labor' subcategory (see Table 2). Its answer is classified into two options (see Table 3):

- If 'yes' is the first answer in column 4, the question 'Does the organization using the material and executing related-material activities have any support/policy for preventing child labor towards other construction activities?' has to be used to evaluate the proactive treatment of the organization. If the second answer is 'yes' in column 5, label A is assigned. Label B is assigned when the answer is "no" in column 5.

- On the contrary, if the answer in column 4 is 'no', the question 'Does the country have any laws preventing child labor?' is applied to judge the context of preventing child labor. And if the answer is "no", label C is assigned in column 5. Label D in column 5 is given when the answer is "yes".

Step 3 - Social life cycle impact assessment

The magnitude of the social impact categories is assessed in this step. It includes the main steps:

- Assigning the level and scores to subcategories: After letters A, B, C, or D are assigned to each respondent, the overall social impact subcategories are labeled A, B, C, or D based on the aggregation of respondents' results. Level A is the highest rank, implying proactive support in fulfilling the BRs. Level B is labeled to organizations that fulfill their BR but provide no promotional activities. Level C is assigned to organizations that may not achieve BRs because of the background of technological or policy situations. Lastly, level D is assigned when the social subcategories may not meet the relevant BR despite the organization being encouraged by the development of technological or policy context. For instance, in the subcategory 'Child labor', if there are child laborers in the construction area, level C is assigned if the laws do not have any policy concerning child labor. In contrast to that, level D is labeled if the government regulates a child labor policy in legislation.

- The relevant scores are then designated to the social impact subcategories, which means that the A, B, C, and D levels are assigned to the numeric values - 1, 2, 3, and 4 -respectively. Accordingly, a lower score would signify a more fruitful social performance.

- Determine the importance weightings: Another part of the questionnaire was designed to ask the respondents to evaluate the importance of social criteria in construction material selection. The social criteria are created according to previous studies concerning UNEP/SETAC [3]. The received results are analyzed based on descriptive statistics using SPSS software and ranked Relative Index (RI) analysis. First, Cronbach's alpha is estimated in SPSS to test the data's reliability. The result - alpha (α) coefficient - typically ranges between 0 and 1. The closer alpha is to 1, the greater the results' significance. The generally accepted minimum value for Cronbach's alpha is 0.70 [13]. Second, this study employs RI analysis to rank the criteria. The RI result is determined using the following formula:

$$RI = \frac{\sum w}{A * N} \tag{1}$$

Where w represents the weighting provided by every participant on a scale from 1 to 5, with 1 indicating the least weight and 5 the greatest; A denotes the greatest weight (five) and N represents the sum of the respondents.

Calculating the Social LCA value: The Social LCIA value is estimated by summing up the weighted subcategory scores of all stakeholders during the project life cycle.

$$SLCIAs = \sum_{i=1}^{n}(V_{s,i}.W_{s,i})\sum_{i=1}^{n}(V_{s,i}.W_{s,i}) \tag{2}$$

Where: s is the type of stakeholder (see Table 2); n represents the total number of subcategories; $V_{s,i}$ denotes assigned scores of subcategory i in stakeholder s; $W_{s,i}$ are the corresponding weightings of subcategory i in stakeholder s.

Step 4 - Social life cycle interpretation

This phase assesses the Social LCIA results to draw conclusions concerning the social performance of alternatives, including the identification of significant issues, recommendations, and reporting documents. Significant issues are limitations, assumptions, or significance of social impact subcategories. For example, the list of selected subcategories should always be reviewed to decrease the impact of significant social burden.

The proposed method offers a systematic and unambiguous approach to the assessment of social impacts according to the guideline of the Social LCA method [3]. The database is mainly constituted by the application of questionnaires, which is favourable for the construction industry, where social databases are rarely available. Moreover, the Basic Requirements in Table 2 could be specified for different regions. Roads spread across multiple regions, so it would be a challenge to collect their region-based data. It also highlights the importance of stakeholders' participation in order to guarantee that the assessment is more accurate and pertinent by reflecting a variety of perspectives and priorities. It is adaptable to a variety of construction types, and the approach enhances corporate reputation and stakeholder relationships by facilitating the communication of social impacts to consumers, investors, and other stakeholders. In general, the proposed method is established to deal with the lack of information and assess the social performance of alternatives comprehensively.

3. CASE STUDY

The proposed method was applied to compare the social performance of asphalt concrete and cement concrete in the project "Provincial road No207 improvement construction project from Quang Uyen to Ha Lang (km 0+00 - km 31+00)". The project connecting Quang Uyen and Ha Lang in Cao Bang province includes two bridges with a total length of about 31 kilometers. Two alternatives - asphalt concrete and cement concrete - are compared for task "Cement surface course, thickness 3 cm" in this project.

The research was conducted in the design phase of this project to compare the social performance of asphalt concrete and cement concrete through the *construction phase, maintenance and operation phase, and close-out phase*. The functional unit is about 217,000 square meters of surface for the whole road construction project.

An initial questionnaire was designed, including three parts. Part one asked for personal information; part two included the questions for evaluating the stakeholder workers, local community, customer, society, and other value chain actors together with their subcategories; and part three asked for the importance of social criteria in material selection in Vietnam.

The questionnaires were built in Google Forms and sent to 90 selected practitioners by email. These selected participants include the workers and representatives of potential contractors, workers and representatives of sponsors, local communities, and workers and representatives of possible waste treatment plants. The research protocol adhered to institutional ethical standards. Participation was voluntary, anonymous, and conducted with informed consent. After two weeks, 69 useful completed questionnaires were received. The subcategories were evaluated and labeled A, B, C, and D according to the proposed method. At first, the stakeholders and their subcategories were selected from Table 2.

- **Social LCA value for the worker stakeholder group:** The "Worker" stakeholder was assessed by four subcategories: child labor, fair salary, working hours, and health and safety [UNEP and SETAC 2009]. For example, the subcategory "child labor" was evaluated based on clear evidence that there is no child labor in organizations. According to Vietnam labor law, child laborers are under 16 years old. All the participants assured that the minimum age is 18 years old, and the organizations also required workers over 18 years old in the labor contract. So, the subcategory is labeled A.

- **Social LCA value for the local community stakeholder group":** The local community stakeholder included the assessment of secure living conditions and local employment. For example, in the subcategory "local employment", the local laborers are hired to build the surface structure at a high rate, so this subcategory is between levels A and B. However, the organization does not take any proactive actions to support the use of local labor. Hence, the local employment subcategory was labeled B.

- **Social LCA value for the customer stakeholder group:** The customer stakeholder consists of feedback mechanisms and end-of-life responsibility. When evaluating the "feedback mechanism" subcategory, there was a difference in opinions between the customer and the representatives of the waste treatment plant. Most of the customers thought that the organization did not have a feedback mechanism. There was no confirmed record of the unconsidered feedback, so this subcategory was ranked C. However, the customer of organization C assured that the customer could contact them by email or telephone available on the website, so the representatives ranked this subcategory B. Based on the actual context, rank B was assigned for this subcategory.

- **The social LCA values for the society and value chain actors stakeholder groups:** they were assessed based on technology development and fair competition. The technology development illustrates the contribution of construction methods to society, and fair competition subcategory is the elucidation in selecting suppliers.

After finishing the ranking, levels A, B, C, and D were assigned 1, 2, 3, and 4, respectively. For evaluating the **weightings**, the Cronbach's alpha was carried out in SPSS to test the data's reliability in part 3. Cronbach's alpha value for all social criteria was 0.85, greater than 0.7, indicating that all data were acceptable.

Table 4. Relative indices and ranking of social criteria

ID	Social criteria	Percentage of the score (%)					Relative index	Ranking	Importance level
		1	2	3	4	5			
S1	Child labor	0.00	2.90	17.39	20.29	59.42	0.8935	2	High
S2	Working hours	2.90	7.25	17.39	33.33	39.13	0.8125	4	High
S3	Health and Safety	0.00	2.90	14.49	17.39	65.22	0.9436	1	High
S4	Fair salary	1.45	13.04	21.74	27.54	36.23	0.8012	5	High
S5	End-of-life responsibility	4.35	13.04	14.49	37.68	30.43	0.7012	10	Higher average
S6	Feedback mechanisms	2.90	11.59	17.39	36.23	31.88	0.7414	7	Higher average
S7	Local employment	4.35	7.25	20.29	21.74	46.38	0.8542	3	High
S8	Secure living conditions	5.80	13.04	23.19	26.09	31.88	0.7219	9	Higher average
S9	Technology development	1.45	7.25	28.99	26.09	36.23	0.7952	6	Higher average
S10	Fair competition	2.90	14.49	14.49	36.23	31.88	0.7349	8	Higher average

The relative index in equation (1) was applied to rank the criteria. As a result, Table 4 displays the rankings for each criterion. The results pointed out that 5 out of the 10 criteria were marked as of "high" significance in the construction material selection because their RI values are higher than 0.8. The table also indicates that all relative indices range between 0.7 and 0.9. It means that all proposed criteria are significant and attributed to "higher average" and "high" levels. Amongst social criteria, "health and safety" and "child labor" criteria account for the highest values, 0.9436 and 0.8935, respectively.

Accroding to the AHP method, the pairwise comparison matrix showing the correlated relationship between criteria was recalculated based on the RI values. Then, the matrix results were normalized to evaluate the weightings of social criteria in material selection (see Table 5).

Table 5. The pairwise comparison matrix of social criteria

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Weighting
S1	1	1.0997	0.9469	1.1152	1.2742	1.2052	1.0460	1.2377	1.1236	1.2158	**11.17**
S2	0.9093	1	0.8611	1.0141	1.1587	1.0959	0.9512	1.1255	1.0218	1.1056	**10.16**
S3	1.0561	1.1614	1	1.1777	1.3457	1.2727	1.1047	1.3071	1.1866	1.2840	**11.8**
S4	0.8967	0.9861	0.8491	1	1.1426	1.0807	0.9380	1.1098	1.0075	1.0902	**10.02**
S5	0.7848	0.8630	0.7431	0.8752	1	0.9458	0.8209	0.9713	0.8818	0.9541	**8.77**
S6	0.8298	0.9125	0.7857	0.9254	1.0573	1	0.8679	1.0270	0.9323	1.0088	**9.27**
S7	0.9560	1.0513	0.9053	1.0662	1.2182	1.1521	1	1.1833	1.0742	1.1623	**10.68**
S8	0.8079	0.8885	0.7650	0.9010	1.0295	0.9737	0.8451	1	0.9078	0.9823	**9.03**
S9	0.8900	0.9787	0.8427	0.9925	1.1341	1.0726	0.9309	1.1015	1	1.0821	**9.95**
S10	0.8225	0.9045	0.7788	0.9172	1.0481	0.9912	0.8603	1.0180	0.9242	1	**9.19**

Table 6. Social LCA results of asphalt concrete during the project life cycle

Stakeholders	Subcategories	Construction phase				Handover and Operation phase				Close-out phase			
		Labels	Score	Weightings	Social LCA value	Labels	Score	Weightings	Social LCA value	Labels	Score	Weightings	Social LCA value
Worker	Child labor	A	1	11.17	11.17	A	1	11.17	11.17	A	1	11.17	11.17
	Working hours	D	4	10.16	40.64	A	1	10.16	10.16	A	1	10.16	10.16
	Health and Safety	D	4	11.8	47.2	B	2	11.8	23.6	B	2	11.8	23.6
	Fair salary	C	3	10.02	30.06	B	2	10.02	20.04	B	2	10.02	20.04
Customer	End-of-life responsibility	D	4	8.77	35.08	C	3	8.77	26.31	D	4	8.77	35.08
	Feedback mechanisms	D	4	9.27	37.08	C	3	9.27	27.81	B	2	9.27	18.54
Local Community	Local employment	B	2	10.68	21.36	B	2	10.68	21.36	C	3	10.68	32.04
	Secure living conditions	B	2	9.03	18.06	B	2	9.03	18.06	B	2	9.03	18.06
Society	Technology development	C	3	9.95	29.85	C	3	9.95	29.85	C	3	9.95	29.85
Other actors of the value chain	Fair competition	B	2	9.19	18.38	B	2	9.19	18.38	B	2	9.19	18.38
Social LCA value for each phase		**288.88**				**206.74**				**216.92**			
Total Social LCA value		**712.54**											

Table 7. Social LCA results of cement concrete during the project life cycle

Stakeholders	Subcategories	Construction phase				Handover and Operation phase				Close-out phase			
		Labels	Score	Weightings	Soial LCA value	Labels	Score	Weightings	Soial LCA value	Labels	Score	Weightings	Soial LCA value
Worker	Child labor	A	1	11.17	11.17	A	1	11.17	11.17	A	1	11.17	11.17
	Working hours	A	1	10.16	10.16	A	1	10.16	10.16	A	1	10.16	10.16
	Health and Safety	D	4	11.8	47.2	B	2	11.8	23.6	B	2	11.8	23.6
	Fair salary	C	3	10.02	30.06	B	2	10.02	20.04	B	2	10.02	20.04
Customer	End-of-life responsibility	D	4	8.77	35.08	C	3	8.77	26.31	B	2	8.77	17.54
	Feedback mechanisms	D	4	9.27	37.08	C	3	9.27	27.81	B	2	9.27	18.54
Local Community	Local employment	B	2	10.68	21.36	A	1	10.68	10.68	C	3	10.68	32.04
	Secure living conditions	B	2	9.03	18.06	A	1	9.03	9.03	B	2	9.03	18.06
Society	Technology development	C	3	9.95	29.85	C	3	9.95	29.85	C	3	9.95	29.85
Other actors of the value chain	Fair competition	B	2	9.19	18.38	B	2	9.19	18.38	B	2	9.19	18.38
Social LCA value for each phase		**258.4**				**187.03**				**199.38**			
Total Social LCA value		**644.81**											

After estimating the social criteria weightings, the social LCA value of cement and asphalt concrete was calculated by summing up the weighted scores of social subcategories (see Table 6 and Table 7).

4. RESULT ANALYSIS

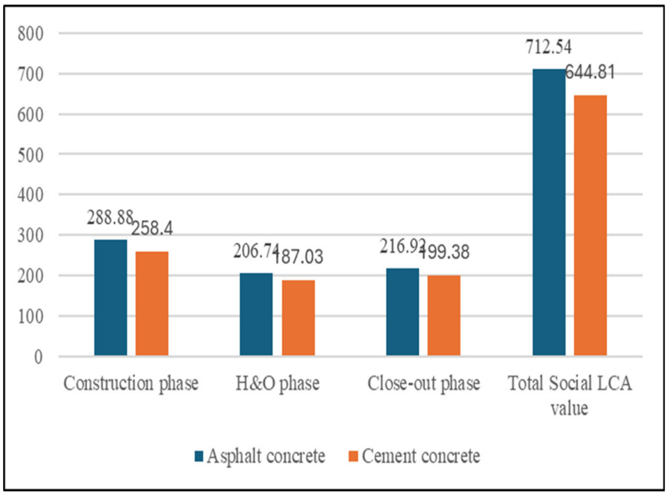

Figure 1. The Social LCA values of each alternative

The total Social LCA values of asphalt concrete and cement concrete are estimated (see Figure 1). The outcomes of the asphalt concrete are 288.88 in the construction phase, 206.74 in the handover and operation phase, and 216.92 in the close-out phase. The Social LCA values of cement concrete are 258.4 in the construction phase, 187.03 in the handover and operation phase, and 199.38 in the close-out phase. So, the total social LCA value of asphalt concrete is 712.54, and the value of cement concrete is 644.81.

Particularly, the social LCA values of cement concrete are lowered in comparison with those of asphalt concrete. These results could be explained by the fact that construction activities concerning cement concrete are more straightforward than asphalt and reduce working hours. Besides, the local community judged that using cement concrete helps increase local employment and protect living conditions.

In comparing subcategories with each other, the social LCA value of each subcategory is estimated by summing up its corresponding weighted subcategory scores during the project life cycle. Based on Figure 2. There are differences in subcategories "Secure living conditions", "Local employment, "End-of-life responsibility", and "Working hours". The respondents judged that using cement is better for living conditions than using asphalt. Besides, cement-related activities hire more local laborers than asphalt-related activities, which is similar to working hours. All of them illustrate that cement concrete is socially advantageous compared to asphalt concrete in this project.

The finding that cement concrete performs better socially than asphalt concrete aligns with previous studies which highlight higher occupational risks associated with asphalt production and handling [14]. From a stakeholder theory perspective, the superior performance of cement concrete reflects improved conditions for workers and local communities, particularly regarding working hours, local employment, and secure living conditions. This reinforces the argument that construction material decisions can influence multiple stakeholder groups beyond technical and economic considerations

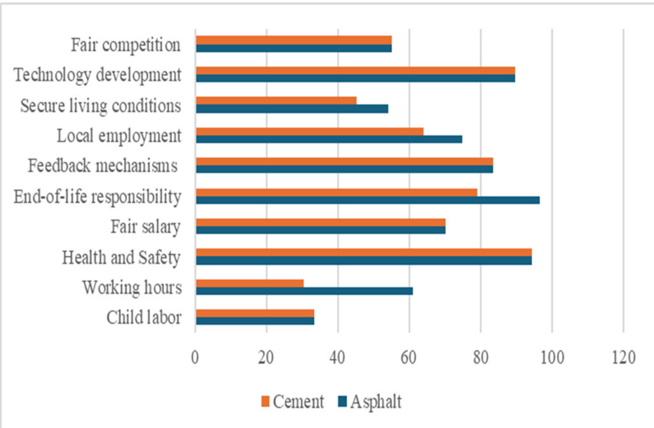

Figure 2. The Social LCA value of each subcategory

5. CONCLUSION AND OUTLOOKS

This paper introduced the application of the Social LCA assessment method in comparing the social performance of two construction materials and material-relevant activities. The method is developed based on the Social Life Cycle Assessment (Social LCA) method, including four initiatives: (1) the correlation between the subcategories and the product assessment, (2) the Basic Requirements (BRs), (3) assessment levels, and (4) the assignment of quantitative character. At first, a questionnaire is built to determine the social effects of subcategories and their importance levels; its answers are then compared with the Basic Requirements (BRs) to labeled A, B, C, and D, and evaluated the weightings. After that, the relevant scores are then designated to subcategories, which means that the A, B, C, and D levels are assigned to the numeric values - 1, 2, 3, and 4 - respectively. The Social LCIA value is estimated by summing up the weighted subcategory scores of all stakeholders during the project life cycle. A case study comparing asphalt concrete and cement concrete was conducted to validate the study. The results pointed out that cement concrete has better social performance than asphalt.

The proposed method provides a clear and systematic approach to evaluating social impacts by breaking them down into specific and manageable subcategories. This systematic method is based on the Life cycle approach so that it can evaluate the social performance of products and organizations comprehensively. The data collection enhances the robustness and completeness of the social impact assessment. Roads spread across multiple regions, so it would be a challenge to collect their region-based data. The database is built mostly based on questionnaires, so this method is suitable for the sectors that do not have social databases. Moreover, the BRs can be changed depending on the sector and region, so the method is flexible in practice and adaptable to a diverse range of construction types. It also emphasizes the significance of stakeholders' involvement in order to ensure that the assessment is more accurate and relevant by accurately reflecting a diverse range of perspectives and priorities. Besides, the method improves communication of social impacts to consumers, investors, and other stakeholders to enhance corporate reputation and stakeholder relationships. It enables benchmarking of social performance in the construction industry and promotes continuous improvement in social sustainability practices.

While prior S-LCA studies in the construction sector largely rely on established databases, standardized indicators, or detailed supply-chain information (e.g., [14-16]), such data availability is extremely limited in developing countries. This creates a methodological gap for conducting S-LCA in data-scarce contexts. To address this limitation, the present study proposes a simplified and operationalizable S-LCA framework that translates social sub-categories into Basic Requirements and a structured stakeholder-based evaluation scheme. Unlike previous approaches, the framework does not depend on extensive databases and is therefore more suitable for early-stage material selection in infrastructure projects in low-resource settings. This constitutes the key novelty of the study.

However, this method has several limitations. Firstly, the Social LCA method does not consider the volume, manufacturing time or complexity level of the construction products. Secondly, there are only four levels of subcategory assessment (A, B, C, and D). It means that the organization with many positive actions has the same rank as the fewer ones. In the future, the studies may focus on the application of proposed methods in some case studies in the construction industry.

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