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Social Sustainability in Raw Material Sourcing for Electric Vehicles

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***Abstract:** Motivated by the shift toward sustainable mobility and increased demand for ethically sourced raw materials, this study examines the social sustainability of different sourcing strategies for aluminium and cobalt in electric vehicle (EV) products. These materials are essential components for batteries and lightweight parts in EVs. A Social Life Cycle Assessment (S-LCA) was conducted in conjunction with OpenLCA and the Product Social Impact Life Cycle Assessment (PSILCA) database. The assessment is based on the United Nations Environment Programme (UNEP) Guidelines from 2020 with a focus on key stakeholder categories. In this study, four cradle-to-gate sourcing strategies are evaluated and labelled as Case 1 through Case 4 in the assessment. The results show significant differences across the scenarios. The local sourcing strategy for aluminium in Australia (Case 1) is associated with lower social risks, whereas the local sourcing of cobalt in Russia (Case 2) indicates higher social risks. Global sourcing strategies involving Guinea and Brazil for aluminium (Case 3) and the Democratic Republic of the Congo (DRC) and China for cobalt (Case 4) demonstrate increased social risks. The impacts can be up to 15 times greater, depending on the location. These findings highlight regional variations in social risks associated with the sourcing of raw materials. The results highlight the importance of implementing corporate due diligence and socially responsible procurement practices within raw material supply chains through integrating an S-LCA into sourcing strategies. This approach also supports some of the Sustainable Development Goals. Overall, this study provides practical insights for industry and policymakers, thereby enriching our understanding of social sustainability.*

***Keywords:** Social Life Cycle Assessment (S-LCA), Sourcing Strategies, Raw Materials, Social Sustainability.*

Nomenclature:
EV: Electric Vehicle
S-LCA: Social Life Cycle Assessment
PSILCA: Product Social Impact Life Cycle Assessment
UNEP: United Nations Environment Programme
MRH: Medium Risk Hours
DRC: Democratic Republic of Congo
USD: US Dollars
PSILCA: Product Social Impact Life Cycle Assessment

I. INTRODUCTION

Sustainable development is meeting present needs without compromising the ability of future generations to meet their own needs [1].

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This idea is based on three interconnected pillars: environmental, economic, and social sustainability, also known as the triple bottom line [2]. In the automotive industry, efforts to reduce ecological impacts have accelerated the transition from traditional combustion engine vehicles to EVs [3]. Electromobility is crucial for combating climate change, but it also introduces new challenges. EVs rely on high-performance batteries and lightweight parts, increasing demand for raw materials like lithium, cobalt, nickel, and aluminium [4]. Mining these materials often occurs in regions with weak labour laws and poor social protections. For example, cobalt from the DRC has been linked to child labour and unsafe working conditions [5]. Another example is lithium extraction in Chile, which has strained local water supplies and affected indigenous communities [6]. These issues show that social sustainability is just as vital as environmental measures when evaluating the sustainability of electric vehicle supply chains.

The regulatory landscape is starting to respond. The German Act on Corporate Due Diligence Obligations in Supply Chains aims to enhance social and environmental standards in global supply chains, including the automotive sector [7]. Challenges for manufacturers include finding appropriate solutions that satisfy all stakeholders in the supply chain while balancing economic efficiency with social sustainability. The research problem addressed in this article is how to systematically assess and compare the social sustainability of different sourcing strategies for the electric automotive industry. An S-LCA framework has been developed to determine the social risks associated with alternative sourcing strategies for key materials, aiming to provide insights that support more socially responsible procurement decisions.

II. OBJECTIVES OF THIS STUDY

This article aimed to assess social sustainability in raw materials sourcing strategies for the automotive industry, especially regarding EV materials. The main objectives are as follows:

A. Objective 1: Social Aspects of Supply Chain

Examine the importance of social sustainability factors in the supply chain of EVs.

B. Objective 2: Review of Methods and Data

Develop a literature-based overview of existing methods and databases for assessing social impacts or raw material sourcing.

C. Objective 3: Developing the Framework

Develop a dedicated analytical framework for evaluating the social sustainability of different raw materials sourcing strategies in the automotive industry.

D. Objective 4: Implementation and Case Analysis

Implement the framework using the software tool OpenLCA in combination with recourse to the PSILCA database.

E. Objective 5: Discussion and Recommendations

Interpret the results to derive actionable recommendations for both industry practitioners and researchers. By meeting these objectives, the study aims to provide a structured understanding of how sourcing location decisions affect social sustainability outcomes and how these insights can inform responsible sourcing strategies in the era of electromobility.

III. LITERATURE REVIEW

The social aspect of sustainability has become increasingly important when assessing products and supply chains, particularly in industries with complex global value networks, such as the electric mobility sector.

A. S-LCA

While Environmental Life Cycle Assessment evaluates the environmental impacts and Life Cycle Costing examines the economic aspects, the S-LCA assesses the social and socio-economic impacts of products throughout their life cycle [8]. For example, an S-LCA of EV battery supply might examine issues such as child labour, fair wages, or community health impacts in mining areas. In 2020, UNEP released updated guidelines for S-LCA, providing a standardised methodology framework for evaluating the social impacts of products and supply chains [8]. These guidelines describe a four-phase approach: the goal and scope phase, the social life cycle inventory analysis phase, the social life cycle impact assessment phase, and the interpretation phase. Each phase builds on the findings of the previous one, culminating in an interpretation of the assessment.

B. Social Hotspots

Social hotspots are lifecycle stages and locations with a high risk of negative social impacts, such as human rights violations. Identifying these hotspots helps prioritise actions to improve social performance [9]. Hotspot assessment often depends on specialized databases that compile country- and sector-specific risk indicators. Two leading tools are the Social Hotspots Database and the PSILCA database. The Social Hotspots Database, created by New Earth B, provides data on social issues across different sectors and regions worldwide [10]. The PSILCA database, developed by GreenDelta GmbH, is an extensive database that measures social risk indicators (e.g., wage levels) for over 15000 economic sectors in 190 countries [11]. These databases allow practitioners to perform social life cycle inventory analysis by linking process data to social risk factors. Results are expressed in a standardized social risk unit. A standard metric, introduced by PSILCA, is the MRH. This essentially indicates the amount of labour time (in hours) in a process weighted by the risk level (with medium risk as the baseline) [12]. PSILCA assigns risk levels to each indicator and uses characterisation factors to convert them into an overall risk-hours metric [13].

C. Prior Research

In their article "Social hotspots in the automotive industry's aluminium value chains – combining primary and generic data," Luthin et al. (2024) conducted a social hotspot analysis of the automotive aluminium supply chain [13]. By combining primary data with generic database information, they identified significant social risks in the bauxite mining and alumina refining stages, illustrating how hotspot analysis can pinpoint critical social issues in the metals supply chain for vehicles. Springer et al. (2023) performed an S-LCA of a fuel cell EV produced in Germany in their article "Potential Social Impacts regarding working conditions of Fuel Cell Electric Vehicles" [14]. Their study focused on working conditions in the fuel cell EV supply chains, examining indicators such as trade unionism, fair salaries, gender wage gaps, and working hours. Lastly, a study by Bouillass et al. (2021), titled "Step-by-step social life cycle assessment framework: a participatory approach for identification and prioritisation of impact subcategories applied to mobility scenarios," developed a systematic S-LCA framework with stakeholder participation and applied it to compare electric and conventional vehicle scenarios [15]. Their findings indicate that the electric vehicle supply chain carries higher social risks in certain areas, especially for worker-related issues outside of Europe.

In summary, the literature indicates that methodologies for social impact assessment are available and continually improving, and that initial studies have identified significant social sustainability challenges associated with raw material sourcing for electric mobility. This article builds on that foundation by integrating an S-LCA approach specifically to evaluate different sourcing strategies for critical electric vehicle materials.

IV. RESEARCH METHODOLOGY

This section outlines the framework, scope, and scenarios for evaluating potential social risks associated with sourcing critical raw materials.

A. Overview and Tools

The study employs an S-LCA framework, implemented using OpenLCA version 2.4.1 and the PSILCA version 3.1 database of social risk indicators. The assessment employs the "social impact weight" approach native to PSILCA, which weights each process based on working hours and assigns risk levels as characterisation factors [12]. All results are expressed in MRH. For consistency, the study follows the 2020 UNEP guidelines for S-LCA in defining system boundaries, stakeholder categories, and impact categories. The stakeholder groups considered include workers, local communities, society, and value chain actors.

B. Scope and Functional Unit

The system boundary encompasses the cradle-to-gate process, covering raw material extraction through to the refining stage, where the material is ready for manufacturing. The boundary includes the part of the supply chain where the most significant social risks are

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likely to occur, notably mining operations. The functional unit is defined as one metric ton of raw material, either in ore or concentrate form, and impacts are calculated per unit cost in US dollars (USD). This aligns with the PSILCA cost-based functional unit (USD per metric ton). In practice, this means the model assesses social risk in terms of hours per dollar of output, scaled to the total value of one ton of the material. All monetary values were standardised to USD, and data, such as commodity prices, were obtained for the year 2025 to reflect current market conditions [16].

C. Sourcing Scenarios

Four sourcing strategy scenarios were analysed, including two local sourcing cases and two global sourcing cases for two critical electric vehicle raw materials: aluminium and cobalt. Aluminium is extracted from bauxite ore, refined into alumina, and widely used in automobile structures, such as the chassis [17]. Cobalt is extracted from cobalt ore, refined to cobalt metal, and is a key component of lithium-ion batteries used mainly in EVs [18]. A local sourcing strategy occurs when both raw material extraction and refining take place within a specific geographic region and trading block [19]. A global sourcing strategy exists when raw material extraction and refining extend beyond the local sourcing region, typically involving intercontinental exchanges [19].

To select representative locations, we identified the top-producing countries for each material. According to recent U.S. Geological Survey data, among others, the largest bauxite producers include Australia and Guinea, and the major refining countries for cobalt are the DRC and Russia. Similarly, major refining centres for aluminium are located in Australia and Brazil, while for cobalt, they are in Russia and China [20]. From these four specific sourcing scenarios (Cases 1–4), we formulated the following:

- Case 1 – Aluminium Local Sourcing Strategy: Extraction and Refining in Australia.
- Case 2 – Local Cobalt Sourcing Strategy: Extraction and Refining in Russia.
- Case 3 – Global Aluminium Sourcing Strategy: Extraction in Guinea and Refining in Brazil.
- Case 4 – Global Sourcing Strategy for Cobalt: Extraction in the DRC and Refining in China.

Each scenario was modelled in OpenLCA by creating a cradle-to-gate process chain that connects the mining sector output in the extraction country to the refined product output in the refining country. The PSILCA database provides social risk profiles for each process. Transportation stages were included in the global scenarios to account for the shipping of materials across different continents. For instance, in the case of the worldwide sourcing strategy for aluminium, bauxite is transported from Guinea to Brazil. The transport stages include trucking to the port in Senegal, ocean freight to Brazil, and trucking to the refinery. Transport processes are also linked in PSILCA sectors (e.g., road freight), which have their own social risk factors. All input data were sourced from industry reports or databases as of 2023–2025 to ensure that the information was current. After building the models, the assessment was performed to calculate MRH for a wide range of social impact subcategories available in the PSILCA database (e.g., “fair salary” for “workers” or “public sector corruption” for “society”).

V. RESULTS

The following results were obtained after implementing the framework.

A. Overall Social Risk (MRH)

The S-LCA results highlight significant differences in the social risk profiles of the four sourcing strategies. Table 1 summarises the total MRH calculated for each scenario, along with the key impact categories that contribute the most. These quantitative results confirm the expectation that global sourcing in high-risk regions results in significantly greater social sustainability challenges. Specifically, the cobalt supply chain exhibits higher absolute risks than aluminium, which aligns with cobalt’s origin in conflict-prone, low-development areas.

B. Risk Distribution by Stakeholder Category

Breaking down the results by stakeholder groups offers insight into where impacts happen. In all four scenarios, the subcategories with the highest individual MRH are “contribution to economic development” for the “society” stakeholder group and “access to material resources” and “mitigation” for the “local community” stakeholder group. The subcategory with the highest combined MRH is “health and safety” for the “society” and “workers” stakeholder groups.

C. Inter-Scenario Comparisons

To enable direct comparison, five impact categories repeatedly emerged as top contributors across multiple cases: “fair salary”, “sanitation coverage”, “public sector corruption”, “trade unionism”, and “health expenditure”. When comparing local versus global sourcing strategies for the same material, the global strategy clearly results in higher social risks. For aluminium, the total MRH in the worldwide case is about 15 times higher than in the local case. For cobalt, the global case is approximately 5 times higher than the local case.

VI. DISCUSSION

The comparative results have important implications for both the automotive industry and sourcing policies. Global sourcing strategies were found to carry higher social risks across several indicators. In this study, sourcing cobalt from the DRC and bauxite from Guinea resulted in increased environmental and social risks. These findings clearly communicate a message: as automakers advance sustainable mobility by electrifying their fleets, they need to broaden their definition of sustainability to include the social environment in which raw materials are produced. Otherwise, the industry risks trading one problem for another, reducing emissions while risking human exploitation.

Table 1: Calculated MRH and Key Impact Categories

Sourcing Strategy	Total MRH	Key Contributing Impact Categories (Examples)
Case 1 → Local Aluminum	2,020.41	Fair Salary, Sanitation Coverage, and Trade Unionism
Case 2 → Local Cobalt	425,926.20	Fair Salary, Public Sector Corruption, and Sanitation Coverage
Case 3 → Global Aluminum	30,119.37	Health Expenditure, Fair Salary, and Public Sector Corruption
Case 4 → Global Cobalt	2,139,887.32	Health Expenditure, Fair Salary, and Sanitation Coverage

One key insight is the role of governance and institutional strength in differentiating social risk outcomes. Australia's low MRH for aluminium can be attributed to its strong labour laws, effective enforcement of safety standards, and robust community consultation processes [21]. In contrast, the DRC's extremely high MRH for cobalt reflects governance challenges [5]. Similarly, Russia's relatively high corruption and fair salary categories highlight how governance issues can inflate social risks even in a local scenario [22]. Automobile manufacturers need to evaluate where they source materials not only in terms of cost and availability but also through the lens of country governance indicators, such as corruption indices, human development indices, and labour rights indices.

Another notable point is the influence of global economic linkages even in local scenarios. Chinese investments in Australian mines have a measurable impact on the "fair salary" effect in Australia, as evidenced by economic flows captured in the input-output model [23]. This indicates that globalization blurs boundaries. For practitioners of S-LCA, this means that using multi-regional databases, such as PSILCA, can uncover hidden interconnections.

Regarding sourcing policy, automakers and policymakers might derive the following from this study:

A. Incorporate S-LCA into Decision Making: Companies should include S-LCA results alongside Environmental Life Cycle Assessment and Life Cycle Costing when evaluating suppliers or sourcing options. The sourcing decision matrix could also incorporate a social risk index, such as MRH.

B. Enhance Due Diligence and Standards: Manufacturers should require and verify that their suppliers adhere to labour rights, prevent child labour, and maintain safe workplaces. Third-party audits and certifications can help reduce some risks if applied strictly.

C. Collaborative Action in Hotspots: Addressing social hotspots is crucial. For example, in areas with high health and safety risks, automotive companies could invest in local health clinics to lessen community vulnerability. In regions plagued by corruption, companies should implement and enforce strict anti-bribery policies, as well as support transparency initiatives, to enhance their governance. These actions not only lower risks for communities and workers but also decrease business risks for the companies.

It is essential to recognize that this study had a limited scope, examining only two materials and a simplified cradle-to-gate boundary. In reality, an automobile contains many more metals and materials. Conducting a complete vehicle S-LCA would require aggregating all those supply chains.

Future research should include primary data collection for greater detail. Additionally, expanding the scope to cover more sourcing strategies would be valuable. Another area to explore is the concept of a circular economy. This involves assessing how methods such as recycling or material recovery can reduce social and environmental pressures, aligning with the idea of rethinking supply chains for resilience and sustainability [24].

VII. CONCLUSION

This research aimed to evaluate how different sourcing strategies for raw materials in the automotive industry, especially for EVs, perform from a social sustainability perspective. By developing an S-LCA framework and applying it to local versus global sourcing cases for aluminium and cobalt, the study offers several key insights and contributions.

A. Holistic Sustainability Perspective

The findings highlight that sustainability in electromobility is not just an environmental issue but also a social one. While EVs are key to decarbonising transportation, the social impacts of materials like cobalt and aluminium are also significant. Including social criteria in procurement and supply chain management is therefore crucial for achieving truly sustainable mobility.

B. Quantification of Social Risks

The use of MRH provided a transparent and standardised method for comparing social risks across various scenarios. The study shows numerically how sourcing globally from high-risk areas can increase social impacts by 5 to 15 times compared to sourcing from lower-risk regions. This kind of measurement is useful for decision-makers because it turns qualitative social issues into impact figures that can be considered in project evaluations.

C. Identification of Hotspots and Stakeholder Concerns

Across the cases, specific social impact subcategories consistently stood out as necessary. These align closely with several Sustainable Development Goals, highlighting areas where automotive supply chains intersect with wider development challenges.

D. Recommendations for Practice

To address the identified issues, the study recommends that automotive companies and their suppliers implement robust due diligence processes, collaborate to improve conditions in high-risk sourcing areas, and consider supply chain redesigns where feasible. Integrating S-LCA into procurement strategies can enhance transparency and accountability in electric vehicle supply chains, while also helping companies proactively comply with regulations such as the German Act on Corporate Due Diligence Obligations in Supply Chains.

E. Implications for Policy and Research

Governments and international organisations can recognise from this study the importance of supporting producer countries in improving social conditions. Development aid or trade agreements may be linked

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to improvements in labour rights within the mining sector. Additionally, further methodological advancements in S-LCA are recommended. Research should continue to improve social impact indicators and expand frameworks to include product circularity and lifecycle trade-offs, thereby enhancing the overall understanding of sustainability.

In conclusion, the shift to electromobility presents an opportunity to comprehensively redefine the sustainability of supply chains. By using an S-LCA, this study highlights the social aspect of sourcing raw materials for EVs, identifying both high-risk hotspots and possible paths for mitigation.

APPENDIX

Please refer to the Supplementary Documents for detailed results.

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I must verify the accuracy of the following information as the article's author.

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