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Research Article

Balancing Costs and Benefits in Lithium Mining: Management and Sustainability Challenges in Barroso, Portugal

Hugo PEREIRA[1], Joaquim LEITE[2] and Cecília CARMO[3]

[1]Instituto Politécnico de Bragança (IPB), Bragança, Portugal

[2]Unidade de Investigação Aplicada em Gestão (UNIAG) – Instituto Politécnico de Bragança (IPB), Bragança, Portugal

[3]Research Unit on Governance, Competitiveness and Public Policies (GOVCOPP) – Universidade de Aveiro (ISCA-UA), Aveiro, Portugal

Correspondence should be addressed to: Joaquim LEITE; jleite@ipb.pt

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Abstract

Portugal holds Europe's largest lithium reserves, positioning itself as a potential leading producer of this critical mineral. This prospect has sparked widespread debate over the economic advantages and environmental trade-offs of lithium extraction. The conscious and sustainable exploitation of these deposits could be the key to reversing the trend of population decline and agricultural neglect, revitalizing the region with new job opportunities and technological progress. This exploitation could also stimulate investment in infrastructure and research, consolidating the region as an innovative center in the energy sector. This study examines the management and sustainability challenges in lithium mining in Barroso, Portugal, providing insights into the complex cost-benefit dynamics at play. Grounded in management accounting principles, particularly cost-benefit analysis and sustainability, the research employs a single case study methodology. Secondary data from relevant documents is analyzed through content analysis. Findings reveal the economic, social, and environmental costs and benefits of the project and highlight the tensions between its economic proponents and local environmental and social stakeholders.

Keywords: Cost-Benefit Analysis, Sustainability, Lithium mining, Case study, Portugal.

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Introduction

The exploitation of mineral resources plays a crucial role in the global economy, boosting sectors such as energy and technology. However, it is essential to recognize that this activity, despite its positive impact on the generation of wealth and development, faces several challenges related to management and sustainability. Barroso is recognized for its obvious mining potential, housing vast reserves of lithium, one of the most sought-after minerals in Europe (VISA, 2021a). Lithium, a key element for the battery industry and clean technologies, offers a unique opportunity to boost the local and surrounding economy.

Lithium is a lightweight material and has a strong impact on the production of technologies that combat climate change, which has been recognized as a global priority (Janubová, 2023). Lithium is the central mineral for the "green transition", a "corporate energy transition", with an estimated 1500% increase in global demand by 2050 (Canelas and Carvalho, 2023). The production of this mineral is important to help economies grow (Janubová, 2023). This transition is undoubtedly a colossal task that requires a multi-faceted approach (Valenta et al., 2023). One of these facets is the need for a large quantity and variety of metals and minerals. The use of lithium ranges from the chemical industry to the production of resistant glass, ceramics, catalysts, batteries and medicines (Alessia et al., 2021).

Today, there is both theoretical and practical consensus that economic success is dependent on and intertwined with the environment and well-being (O'Mahony, 2021). Lithium, due to its physical, chemical and electrochemical characteristics, is used in numerous ways (Wang et al., 2022). However, it is only recently that this mineral has received global attention, mainly as a key component of lithium-ion batteries. The shift towards the intensive use of lithium batteries in the era of electric vehicles and electronic devices is often questioned in relation to its long-term sustainability, especially due to the degradation of soils resulting from the exploitation of the mineral (Sadik-Zada et al., 2023). In this context, the fundamental link between sustainability and the efficient management of this transition lies in the need to encourage battery recycling practices (Alessia et al., 2021).

The mining sector is currently facing new challenges and opportunities as a result of the significant increase in demand for minerals in recent years (An et al., 2023). However, exploration and production need to strike a balance between the demand for sustainable growth and the growing demand for vital minerals used in green technologies. Lithium mining is associated with various forms of energy injustice, perpetuating violence against local communities and disrupting the broader relationships between species in historically sustainable rural territories (Canelas and Carvalho, 2023). In this context, responsibility lies not only with mining companies, but also with governments and regulators. It is imperative that measures are adopted to ensure that residents in the vicinity of mining zones are not only protected from the negative impacts of lithium mining, but also have access to essential services such as health and education (Watts et al., 2023).

Cost-benefit analysis originated in China in the 11th century and was later adopted by French engineers in some public infrastructure projects, weighing up all the costs and all the gains (Odek and Oluoch, 2023). This analysis was made official in the USA, in the "Green Book" of

a subcommittee dedicated to costs and benefits. This methodology is applicable to practically all areas of human life and is used to help make investment decisions, with the aim of assessing the comprehensive impact on society as a whole (Majerova and Abdrazakova, 2021).

A cost-benefit analysis seeks to measure and compare not only the direct monetary costs and benefits, but also the positive and negative impacts, identifying the problem to be solved and presenting alternative solutions (Ma et al., 2023). Subsequently, this analysis is used to systematically and consistently assess the benefits and potential costs and other impacts of each management alternative, presenting itself as a tool to support decision-making. Evaluating the costs and benefits associated with a specific action or project aims to determine whether the benefits outweigh the costs (Tišma et al., 2021). The method also allows for a detailed assessment of the pros and cons associated with each project (Sarkar et al., 2023). The results provide a solid basis for making informed decisions that consider collective well-being. It enables decision-makers to understand the financial and social implications of their choices, especially when it comes to integrating smart technologies into the current energy system (Åström, 2023).

One of the fundamental aspects taken into account in a cost-benefit analysis is equity (Sarkar et al., 2023). This concept refers to the fair distribution of benefits and costs among the various groups in society. By taking equity into account, authorities can ensure that no community is disproportionately affected by the costs or excluded from the benefits of a project. Organizations encourage the use of this analysis not only to promote efficiency and improve economic well-being, but also to integrate the environment into their economic policies (O'Mahony, 2021). The need to integrate sustainability into government institutions is crucial to support the sustainable transition. Currently, environmental debates within organizations have been important for understanding the economic viability of projects that have been developed in support of this discussion (Gudlaugsson et al., 2023).

Unlike conventional analysis, which focuses mainly on economic aspects, environmental cost-benefit analysis integrates environmental variables, seeking to assign monetary values to environmental impacts (O'Mahony, 2021). Thus, this analysis enables a more complete assessment, taking into account not only the immediate economic benefits, but also the long-term costs associated with environmental degradation. This methodology is crucial to ensuring a well-founded decision, optimizing the resources at hand and fostering more effective and socially equitable solutions for the future (Sarkar et al., 2023).

At the organizational level, management control systems play a crucial role, representing the process by which managers influence organizational members in the implementation of strategy (Osma et al., 2022). This intrinsic relationship between management control systems and management control activities establishes the basis for directing organizational efforts towards what is considered crucial. The importance of these systems goes beyond control practices, also playing a significant role in the behavior of people within the organization. In this scenario, leaders play a vital role in introducing management control systems (Einhorn et al., 2023). These systems not only serve as control mechanisms, but also as motivational tools.

Sustainability is perceived as a strategy for generating value for both the company and its stakeholders, contributing positively to the environment and making effective use of available resources (Frostenson et al., 2022). This concept of sustainability has had a significant influence on the world in recent years, as it offers a perspective on improving the quality of human life without exceeding the natural limits of the planet (Bele et al., 2023; Karambir et al., 2023). The growing trend for organizations to integrate sustainability into management systems reflects a clear recognition of the strategic importance of this approach (Beusch et al., 2022). This integration not only positions companies as responsible agents towards the environment and society, but also results in a greater competitive advantage in the business landscape (Mosgaard and Kristensen, 2023). Aware of the possible negative impacts of their actions, companies are increasingly attentive to the environmental and social repercussions of their operations.

The initial investment, as a criterion for cost-benefit analysis, is essential for calculating the break-even point. This helps predict the period needed for the project to start generating a profit. The initial investment is the basis for comparing the full costs with the future benefits. Without these data, it cannot be determined whether the expected profits outweigh the expenses. But other criteria can be used, such as market price, cost of production, risk analysis and socio-environmental impact.

Considering the market price is essential, as it represents the potential sales value of the product, which is determined by its demand and acceptance in the market (Boardman et al., 2018). In addition, understanding the market price helps to assess the competitiveness of the product and to identify possible financial risks, such as price fluctuations that could affect the profitability of the project. Comparing this price with production costs is a crucial step in assessing whether the project is economically viable (Boardman et al., 2018). If the market price is higher than the costs, the project has the potential to be profitable, indicating a positive profit margin.

Risk analysis allows the project manager to understand how the estimated impacts could affect some of the project's key variables (European Commission, 2015). It is crucial to pay special attention to climate change and environmental factors, as these can have a significant impact on all phases of the project. Finally, the cost-benefit analysis of any project must also incorporate environmental and social impacts, as these directly influence the sustainability and acceptance of the project (Boardman et al., 2018). It is crucial to assess environmental impacts, such as pollution, biodiversity loss and climate change, to avoid ecological damage that could have long-term consequences and generate additional costs, such as fines and the need for environmental remediation.

Methodology

The aim of this study is to explore the costs and benefits of overcoming management and sustainability challenges in a specific case. This case is lithium mining in Barroso, northern Portugal, in the municipality of Boticas. This mining project is located in a concession area that covers private properties as well as areas designated as baldios, all of which are characterized as rural properties (Carballo-Cruz and Cerejeira, 2020). The Barroso region is a mountainous area with an economy dependent on agriculture, livestock farming, beekeeping and ecotourism (Canelas and Carvalho, 2023). Most of the territory is made up of semi-natural areas, forests and agricultural land. This project focuses on the extraction of

spodumene concentrates, not directly on the lithium itself.

The research method selected was the holistic single case study as it is suitable for exploratory studies in qualitative research paradigm (Yin, 2017). The case study method aims to understand phenomena in a real context, encompassing events, individuals, entities or even political contexts (Elstub and Pomatto, 2022). Qualitative research, in essence, is shrouded in subjectivity, i.e. it involves the interaction of multiple disciplines, using various methods to collect and analyze data. The case consists of the company Savannah Lithium, the promoter of the lithium extraction project in Barroso and the data were collected from publicly online available documents, all cited in the results section and included in the list of references.

Savannah Lithium is a 100% owned subsidiary of Savannah Resources, which took a 75% stake in the project in 2017 (VISA, 2021b). This stake increased to 100% in 2020 with the acquisition of the 25% stake from Australia's Slipstream Resources and other holders. This reflects the growing importance of lithium in the global industry, particularly in the battery industry. However, it wasn't until 2020 that the company submitted an Environmental Impact Assessment to the Portuguese Environment Agency, Portugal's environmental regulator, which, on May 31, 2023, issued a favorable Environmental Impact Statement conditional on the lithium project in Barroso. The company signed a 30-year mining concession contract in 2006 which estimates an average annual production of 175,000 tons of spodumene concentrate and an initial investment of 98.11 million euros.

Results

Project context and cost-benefit analysis criteria

The lithium extraction process involves crushing and grinding rock to separate the minerals based on density, focusing exclusively on spodumene and increasing the lithium content, namely through the use of water (Savannah, 2023a). This development not only aims to meet the growing demand for lithium, which is essential for electric vehicle batteries and renewable energy storage, but also contributes to local economic development by creating jobs and providing raw materials for other industrial sectors. It is an example of how natural resources can be used strategically, aligning economic interests with the global energy transition (Carballo-Cruz and Cerejeira, 2020). The project will have an estimated annual production of around 200,000 tons of spodumene concentrate. This concentrate will contain enough lithium to produce approximately half a million electric vehicle batteries per year (Carballo-Cruz and Cerejeira, 2020; Savannah, 2023a).

Savannah is a company dedicated to mineral exploration and is the sole owner of the Barroso Lithium Project (Savannah, 2023b). It aims to start production in 2026. This project is an important milestone for both Savannah and Portugal, as it is in line with the objectives of fostering sustainability and stimulating regional economic growth. Savannah is committed to the sustainable development and management of the Barroso Lithium Project, with the aim of minimizing environmental impact and maximizing socio-economic benefits for all parties involved. With this project, Savannah has the chance to turn Portugal into a lithium supplier for the growing European lithium-ion battery industry, contributing to long-term energy security.

The initial investment, the market price of lithium, the production cost vs. market price, the geological-environmental risk and the environmental and social impact are some of the criteria used for the cost-

benefit analysis applied to lithium exploration in Barroso. With regard to the first of these criteria, the project will have an initial investment of 98.11 million euros, which will be applied to the fundamental areas for the start-up of the project, from operating costs to investments in infrastructure and equipment (VISA, 2020). As for the market price of lithium, forecasts are provided by independent analysts in the sector, as well as investment banks and brokers, predicting an average price for spodumene of €634 per ton. This price is essential for assessing the economic potential of the project and provides a basis for financial and strategic analyses related to the exploitation and marketing of the mineral resources involved.

Regarding the production cost vs. market price criterion, for a mineralization quantity of between 1.3 and 1.5 million tons per year, annual production was estimated at between 175,000 and 200,000 tons of spodumene concentrate (main product), with an estimated production cost of €255 per ton of concentrate (VISA, 2020). In addition to the main product, the production process also produces two valuable by-products – quartz and feldspar – which have a direct impact on the profitability and success of the project.

A number of geological risks have been identified, including deposits of lithium, damming of waste rock and aggressive exploitation with drilling on land without proper recovery (MINOB, 2024). In terms of environmental risks, examples were landslides, contamination of water lines, soils and aquifers and the possibility of flooding and soil erosion (Interior do Avesso, 2021). Finally, environmental organizations (QUERCUS, 2019; ZERO, 202) added environmental and social problems, namely habitat loss, landscape destruction, pollution of water resources, soil contamination, erosion processes and air and noise pollution.

Management and sustainability challenges

Lithium mining in Barroso presents a number of management and sustainability challenges, including issues of transparency, conflict management, the amount of investment, environmental impacts, local economic development and water resource management (Lusa, 2021). Starting with transparency, the Portuguese Public Prosecutor's Office mentions several flaws in administrative acts, which could lead to the project being canceled (Boticas Municipality, 2024). One of the main concerns is that the expansion of mining in the area could threaten the agro-silvo-pastoral system, altering its characteristics and, consequently, causing it to be declassified by the UN as a World Agricultural Heritage Site. In the same vein, the following evidence should be added: "(...) *on the question of environmental damage, whether from dust or even water resources, the damage and infiltration are not assessed*" (Porto canal, 2024).

Regarding the management of non-coinciding interests and consequent conflicts, the project brings various perspectives and expectations about the economic benefits it can bring to the region (Savannah, 2022). These benefits include increased income for service providers linked to the project, improved wages and the creation of more jobs. During the 2023 prospecting campaign, there was a significant increase in confrontation between the bidding company and local residents (Lusa, 2023). Local organizations, inhabitants, and landowners showed high opposition to the project, signifying a significant consensus against the mine, reflecting a sense of threat to the region's identity and way of life. The statements below highlight this result: "*The company is trying to enter land for which it has no authorization, by force, and we have been forced to come here to defend our land*"

(Lusa, 2023); "*95% of the population is against the mine* (...) *so it won't bring more wealth, but it will destroy other jobs we have, rural tourism, gastronomy, our farmers*" (Euronews 2021); "*When Savannah and even the government say that this mine will combat desertification and the trend of population decline in the Barroso region, they are lying*" (Setenta e Quatro, 2023); "(...) *the mine will change the economic dynamics, it will take people away from traditional activities, and then it will leave a void. The mine project will last a maximum of 17 years*" (Setenta e Quatro, 2023).

With regard to the large amount of investment, this amounts to 98.91 million euros, with an average increase of 2.49 million in the following years (Carballo-Cruz and Cerejeira, 2020). Wage costs total 4.55 million euros, royalties 3.60 million and profit tax can account for 15.98 million euros. These elements are extremely important, not only for the business, but also as relevant indicators for the national and local economy.

As for socio-environmental impacts, it is necessary to weigh up the lasting consequences of economic actions and opt for paths that foster sustainability and the prosperity of local communities. This serves as a warning that the advancement of the mine must be harmonized with conservation and ecological responsibility, looking for ways to mitigate the negative effects compared to the benefits. This result is embodied in the following evidence: "*we have a forest that is going to be destroyed, water that is going to be polluted, habitats that are going to be destroyed, a community that is not being respected and is being sacrificed*" (SIC Notícias, 2024); "(...) *the stripping is clearly visible, 200 and 300 meter platforms where the machines remove all the soil, completely altering the landscape, the noise of these machines and the dust*" (Canal Alto Tâmega, 2024); "*The region has much more to lose than to gain from this project, (...) the way forward for its development is agriculture, rural tourism and beekeeping and not mining which destroys practically everything*" (Canal Alto Tâmega, 2024).

In relation to local economic development, a lack of knowledge about the benefits of mining can lead to a negative perception of this activity (Lusa, 2021, 2023). Many people are unaware of the jobs, investments and economic opportunities that mining can bring to a given region. This misinformation can result in a lack of public support and understanding of the project's objectives and benefits. It is therefore essential to address these concerns through transparent and educational communication. This can include public education programs, community consultations and corporate social responsibility initiatives. By doing so, a stronger foundation of support and acceptance can be built for sustainable and socially responsible mining projects. These challenges underline the need for comprehensive workforce development and infrastructure strategies to ensure that the mine operation is beneficial and sustainable for the local community.

Finally, in terms of water resource management, the controversy over whether or not water is contaminated is evident, as can be seen from the following two contradictory statements (the first from an environmental organization and the second from the company promoting the project): "*Of course there is water contamination on a large scale, because lithium is more or less 1% of the mineral mass extracted*" (TVI24, 2018); "*There is indeed a need for water,* (...) *basically the water will be collected in the first phase and then it will be completely in a closed cycle, no chemicals will be used,* (...) *and no water will be put back into the rivers or streams in the region*" (TVI24, 2018).

Discussion and Conclusion

This case study of the lithium exploration project in Barroso, Portugal, scheduled to begin in 2026, falls within the field of sustainability and poses inherent management challenges. The results of this qualitative research identified costs and benefits, in economic, social and environmental terms, as well as some analysis criteria, showing controversial arguments in favor, on the part of the project's economic promoters, and, against, on the part of local social agents. These results corroborate that a cost-benefit analysis of mining projects must always weigh up all the positive and negative impacts (Odek and Oluoch, 2023; Tišma et al., 2021; Sarkar et al., 2023; Carballo-Cruz and Cerejeira, 2020) in economic, environmental and social equity terms (Åström 2023; Valenta et al., 2023). In other words, mining impacts on the entire surrounding society (Majerova and Abdrazakova, 2021), and the creation of compensatory measures for residents near mining areas are crucial (Watts et al., 2023).

Lithium production is essential in the energy transition towards low-carbon energy sources and the green economy (Valenta et al., 2023; Wang et al., 2022), providing economic growth in a wide range of industries (Janubová, 2023; Alessia et al., 2021; Wang et al., 2022). However, economic success is intertwined with the environment (O'Mahony, 2021), and it is necessary to combine sustainability and efficient management (Alessia et al., 2021) to minimize environmental impacts (Valenta et al., 2023), namely soil degradation resulting from lithium mining (Sadik-Zada et al., 2023). The mining sector will therefore continue to face new challenges and opportunities (An et al., 2023), and it is up to the management to identify alternative solutions (Ma et al., 2023).

This research has methodological limitations, namely the fact that it only used secondary data relating to the case of a single lithium mining project in Portugal. Consequently, as a suggestion for future research, we propose triangulating data from complementary primary data sources and studying other mining cases, in addition to lithium, in other geographical areas of the globe. Future research could also cover a more detailed analysis of the costs and benefits supported by quantitative measures, highlighting the main impacts on the environment and society.

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