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Economics and Multi-Criteria Decision Support for Sustainable Cobalt Production

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ABSTRACT

Mining critical minerals in the Democratic Republic of Congo comes with tough governance hurdles, environmental damage, and deep socioeconomic strains. This study's approach blends SWOT with PESTLE analysis, drawing on the insight of experts from 32 organizations in 11 countries, including Canada, France, Germany, India, Norway, Pakistan, Poland, Portugal, Romania, Spain, and the United States. This two-pronged approach makes it easier to fully examine the structural, political, and socio-environmental sides of the cobalt industry in the Democratic Republic of the Congo. The PESTLE analysis paints the DRC's political climate as unstable and steeped in corruption, with social governance in deep crisis and environmental oversight falling far short. In the SWOT analysis, strengths at 14.49 and opportunities at 12.54 edge ahead of weaknesses at 12.95 and threats at 11.27 on average. This forms the foundation for the study's conclusion: greater transparency in institutions, fairer labour market governance, and stronger environmental laws could help curb the extractive injustices tied to cobalt mining in the DRC.

1. Introduction

The Democratic Republic of the Congo (DRC) produces more than 70% of the world's cobalt [1]. Over half of the world's cobalt reserves are in this country [2]. Cobalt supply is hampered by a number of factors, including price volatility, social and environmental problems associated with mining operations, and the concentration of production in the DRC [3]. Given the high strategic value of cobalt, countries such as Switzerland, Australia, Canada, and India are investing in the extraction of this critical mineral in the DRC, with China leading the number and importance of initiatives for the extraction of minerals [4]. China is also a leader in cobalt processing, potentially altering the rules of the international trade and security game [5]. China's omnipresence in the technological landscape may allow for the influence necessary to preserve control [6]. Owing to the complexity of this case

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study, a holistic approach combining different areas of study is appropriate for analysis. In addition, we must consider the nature of the different actors that interact in these extractive activities. On the one hand, there are old players, traditional mining companies, and local governments; on the other hand, there are new players, technology companies, and international investors.

Consequently, the governance of cobalt production in the DRC is marked by extractive institutions that concentrate on property rights in the elites. This situation persisted despite the implementation of legal reforms. Increased local population involvement in mining governance was promoted by the 2002 Mining Code and its 2018 revisions. Unfortunately, these changes have not had a significant impact. Due diligence obligations concerning the importation of conflict minerals are required by other legislation, specifically Regulation (EU) 2017/821. Improving the human rights situation during the extraction of minerals is a further objective of the 2023 EU-US Agreement on Critical Minerals. It has an indirect effect on the DRC, though. The European Union proposed the European Critical Minerals Regulation of 2023, which is presently in the implementation stage, to ensure a safe and sustainable supply.

In academia, more scientific evidence and debates on renewable energy are needed. Most approaches focus mainly on one of the traditional dimensions of sustainability, such as economic [7–9] or the environment [10–13], but governance analysis should be incorporated to take a holistic approach to this topic. It is also necessary to analyze how the existing power relations between old and new actors or between actors acting at different levels change, as it still lacks sufficient analysis to be addressed in this study. Thus, a growing body of policy and research emphasizes the importance of ethical and just approaches to energy transitions, as well as the consideration of vulnerable communities and groups.

The motivation for this work stems from the need to understand the complexities and contradictions inherent in cobalt production in the Democratic Republic of Congo [14]. Despite its strategic importance in the transition to renewable energy, the cobalt supply chain is affected by issues such as labor exploitation, environmental degradation, and human rights violations [15]. This study aims to shed light on these issues and contribute to the debate on the need for sustainable energy transitions [16]. The main contribution of this study is to analyze the cobalt production situation. The proposal to conduct a PESTLE analysis is novel, given that there are several studies that analyze the factors and options for cobalt extraction and commercialization, but no holistic analysis has been conducted to date. This is a reproducible analytical model for assessing the sustainability of vital mineral supply chains in complex geopolitical environments. By taking into account the ethical, social, and environmental factors that are essential to the energy transition, this method avoids the drawbacks of analyses that only consider price volatility or extractive governance. The incorporation of SWOT analysis characterizes the internal and external factors that aid strategic planning and decision-making.

PESTLE analysis, a useful technique for evaluating the macroenvironmental effects of the cobalt industry in the DRC, was used in this study. PESTLE analysis employs a macro-environmental approach to examine this case study by integrating political, economic, social, technological, legal, and ecological factors. This claim is predicated on the necessity of conducting a comprehensive and systemic analysis of the delivery of ecosystem services, such as the production of cobalt. To gain a complete understanding of the case study, the functioning and interrelationships of the different agents that are part of the sector must be known. Changes in one of the factors have consequences in part or all of the others, since the influence of a factor extends outside its delimited scope. When examining the integration of exploitation of natural resources, like cobalt, into human civilization, one needs to take into account the changes in the various political, economic, social, technological,

legal, and ecological factors. Therefore, in studying a system, one abstracts, in order, the complexities and understands the trends and driving factors that helps the system evolve and adapt.

The PESTLE approach comes from a broad review of academic studies. We used specific keywords to find research on cobalt production and mineral extraction in the Global South. The combination of PESTLE and SWOT analyses provides a wide understanding of the factors affecting the business environment. In addition, this joint analysis helps to create management plans that increase the chances of project success.

This study fills an important gap in research by applying PESTLE and SWOT to the DRC's cobalt industry. Few studies have done a full, multi-angle analysis of how political, economic, social, tech, legal, and environmental factors interact in this sector. Most focus on the global supply chain or the DRC's specific challenges as a top producer. Our approach goes beyond supply chain issues and price swings. It offers a focus on structural problems like governance, inequality, and environmental damage. This level of analysis can lead to a more sustainable strategies for the complex cobalt industry in the DRC.

This article is structured as follows. Section 2 reviews the scientific literature, analyzing how the research problem has been addressed and the approaches adopted in the most recent studies. The methodology of this article, the PESTLE and SWOT approaches, is outlined in section 3. Section 4 organizes the results of the PESTLE analysis and the SWOT analysis. Finally, section 5 discusses the article, and section 6 concludes with the main conclusions.

2. Literature Review

Growing concern about climate issues and their effects on society has led to an increase in the number of studies dedicated to analyzing alternative energy sources and improvements. Recent advances in the literature highlight the application of analytical models and multi-criteria approaches in decision-making under uncertainty, within the spheres of sustainability and risk. A number of studies have targeted estimating energy potential, choosing technologies, risk analysis, and decision-making under the environment-social economy integration complexity.

As an example of research on renewable energy, Salami *et al.,* [17] compare traditional Weibull distribution methods with artificial intelligence techniques, such as neural networks and support vector regression, to assess wind potential in West Africa. The findings indicate that neural models possess higher precision, which affects the planning of wind farms. Furthermore, Paulson *et al.,* [18] advocate for the installation of independent photovoltaic systems on ships, which shows considerable fuel and emission reductions as well as energy resilience improvements. Zhang *et al.,* [19] evaluate renewable generation systems in the Brčko District of Bosnia and Herzegovina with a hybrid model that employs type-2 fuzzy logic and focuses on wind and solar energy based on a combination of financial and environmental criteria which was further validated through sensitivity and comparative methods.

With respect to multi-criteria decision-making under uncertainty, Kang *et al.,* [20] analyze materials for wave energy converters using the DNMA method and introduces probabilistic hesitant fuzzy sets and emphasizes the offshore steel's superiority compared to other options. By the same token, Puška *et al.,* [21] use SiWeC, Entropy, and TOPSIS methods to combine intuitionistic fuzzy sets for the selection of sustainable packaging suppliers where the dominant criteria were the use of recycled materials and the application of environmental standards. Regarding ergonomics, Turgay & Özyurt [22] assess risks in repetitive tasks using the REBA method integrated with fuzzy multi-criteria approaches and illustrate the importance of dynamic models in the field for the prioritization of intervention. In the same way, Komazec *et al.,* [23] applies the AHP method to the Piraeus–Belgrade–

Budapest railway corridor to rank positions of risks and concludes that for the continuity of the project, safety and operational risks are of primary importance.

Fujita *et al.,* [24] explore mathematical models within the paradigm of fuzzy and neutrosophic risk management and describes how risk management could be advanced within the classical paradigm based on various functions of fuzzy sets and degrees of truth, indeterminacy, and falsity within the scope of financial portfolios, insurance, and inventories. Macek & Vitásek [25] look from the corporate perspective at the preparedness of Czech companies for ESG risks, and point out reputation and compliance with regulations risks as prioritised suggesting the the risks of reputation and compliance with regulations should be addressed by the adoption and the integration of the principles of sustainability. Lastly, Turgay & Aydin [26] present a hybrid model for disaster management integrating Bayesian networks, cognitive biases and reinforcement learning, and show how adaptive responses lower costs and enhance essential adaptability in adverse situations.

The studies highlight the importance of hybrid approaches incorporating fuzzy logic, multi-criteria methods, and probabilistic analysis for complex decision-making. They also emphasize the necessity of incorporating dynamic models with financial, environmental, and social criteria and validation through sensitivity analysis and intermethodological frameworks to make safe and sustainable decisions. That is why this article has adopted a holistic model, PESTLE, combined with another on decision-making and the identification of internal and external factors.

3. Methodology

In this case study, the PESTLE methodology will be applied. It was chosen because it is a complex tool that incorporates the political, economic, social, technological, legal and environmental dimensions of a study problem, and in the case of cobalt production in the Democratic Republic of Congo these aspects are important not only in isolation but also to understand how one affects the others. This study uses the PESTLE framework based on a wide review of academic sources. We checked several databases like JSTOR, Scopus, and Google Scholar to make sure the analysis was complete and systematic. The search followed these rules:

i. Publication date: The scientific, legal, or administrative publications used were published between 2014 and 2024.
ii. Peer review: Only peer-reviewed articles have been analyzed.
iii. Relevance: We searched using keywords like “critical minerals,” “cobalt production,” “DRC,” and “mineral extraction in the Global South.”

After the PESTLE analysis, we used the identified factors to build the SWOT analysis. SWOT is common in research because it’s simple and practical [27]. It helps identify and measure the Strengths, Weaknesses, Opportunities, and Threats in the context where companies operate [28].

The selection of variables for SWOT analysis was performed using the methodological principles of the Integrated Strategy Framework (ISF) [29]. Consequently, a systematic reduction in the variables was implemented. Specifically, reduction to a set of relevant strategic variables was performed by employing thematic and qualitative hierarchization. The present study was conducted following the guidelines established by Helms & Nixon [30] and Phadermrod *et al.,* [28]. These studies offer three fundamental conditions for the selection of factors.

i. Systemic relevance: The selected factors should exhibit high interdependence with the other dimensions of the natural resource system. Therefore, the degree of interrelationship between the selected factor and others in the system must be high.

ii. Persistence and empirical recurrence: The selected factors must be recurrently mentioned and analyzed in the scientific literature, legislation, or reports of international organizations.
iii. Operationalization capacity: The selected factors must be evaluated objectively. In addition, their quantitative analysis should allow a classification by scale of importance and order of priority.

After the identification of the factors, they were classified according to their nature. Therefore, as illustrated in the case study presented in this article, the SWOT analysis is segmented into two distinct components: (i) the identification of the internal factors, of local character, focused on strengths and weaknesses; (ii) the characterization of the external factors, of global scope, organized in opportunities and threats. The external and internal factors are different, as they are extracted from the previous PESTLE analysis [31]. Then, a systematic selection process was employed to identify six factors, which were subsequently categorized for analysis. The rationale for this quantitative limitation is rooted in the necessity to ensure the manageability of the assessment instrument for experts. This criterion is advantageous in that it prevents cognitive overload and enables a weighted comparison of factors. As part of this study, we surveyed 32 experts from different countries. These experts are based in 11 different countries: Canada, France, Germany, India, Norway, Pakistan, Poland, Portugal, Romania, Spain, and the United States. The institutions where these experts work range from public administration to universities. Their experience in the energy transition sector was key to their selection for this survey.

Before the main survey, we ran a small trial with four participants using an online form. This helped us spot unclear questions and improve the structure and logic of the survey. The final version was clearer and easier to follow. We used Microsoft Forms to run the survey. This tool made it possible to automatically and anonymously gather responses in a spreadsheet that could be downloaded. It took three weeks to finish the survey.

The survey was structured in two blocks: in the first block, participants were asked to quantitatively rate the importance of each of the factors identified in the PESTLE analysis. In the second block, the experts were asked to rank the factors within each category of the SWOT analysis. The final score for each factor was obtained by multiplying both coefficients.

In this way, the factors have been weighted and scored through the following process:

i. Two matrices have been created based on the local character (strengths and weaknesses) and the global character (opportunities and threats) of the factors. The first is the matrix of internal factors, and the second is the matrix of external factors.
ii. Each of the experts rated each factor in the matrix from 0 (not important at all) to 1 (very important) according to its weight in the objective of respecting social, environmental, and legal standards in cobalt mining in the DRC. The average score is the one that finally appears in the matrix. This score is referred to as the importance coefficient.
iii. Each of the matrix sections (Strengths, Weaknesses, Opportunities, and Threats) consists of six factors. Experts scored each of these factors from 6 to 1 to rank, from highest (6) to lowest (1), the factors that have the greatest impact on the current specific scenario of cobalt production in DRC. The final order assigned to each of the factors is the most repeated rank by the experts for each of the factors. In case of a tie, the factor with the highest frequency of high scores will be assigned to the highest rank. This score is referred to as the order of importance coefficient.
iv. The final score for each factor is the result of multiplying the importance coefficient and the order of importance coefficient.

v. Finally, the final score of the six factors in the four sections of the matrix (Strengths, Weaknesses, Opportunities, and Threats) is added together. The sum of the final score is compared between the matrix of internal factors and the second is the matrix of external factors.

4. Results

4.1 PESTLE Analysis

4.1.1 Political factors

One of the political problematics in the Democratic Republic of Congo for its government may concern with the issue or point towards despotic governance over cobalt and other necessary materials. Upheaval has been a long-standing hallmark of the DR Congo's recent national history and its extractive high-value mineral resource-related problems debilitate the administrative stability of the DRC. That makes for a capricious environment that repels foreign investment. It also becomes more difficult to raise capital. Corruption is another major issue. It flows through to all tiers of government and public bureaucracy (Table 1).

Table 1
Corruption Perceptions Index, from 100 (very clean) to 0 (highly corrupt). 2012-2021. Source: Own elaboration based on [32]

Country	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
United Kingdom	74	76	78	81	81	82	80	77	77	78
France	71	71	69	70	69	70	72	69	69	71
United States of America	73	73	74	76	74	75	71	69	67	67
China	39	40	36	37	40	41	39	41	42	45
South Africa	43	42	44	44	45	43	43	44	44	44
Ethiopia	33	33	33	33	34	35	34	37	38	39
Niger	33	34	35	34	35	33	34	32	32	31
Angola	22	23	19	15	18	19	19	26	27	29
Democratic Republic of the Congo	21	22	22	22	21	21	20	18	18	19

The control of natural resources, such as cobalt, is a critical political issue in the DRC. The mining sector has been governed by an instrument which includes mining codes and laws, however the compliance level to such regulations is low. As specified in article 42 of the Mining Code and the Inter-ministerial Decree 0914/2018, three are the public administrations with competencies in regulating the country's mining sector: (I) The Congolese Environment Agency (ACE), (ii) The National Fund for Promotion and Social Service (FNPSS), and (iii) The Directorate of the Ministry of Mines (DPEM) [33].

The nationalization of assets and the renegotiation of contracts are common practices, creating uncertainty for foreign companies [34]. Additionally, the influence of external actors, such as China, which has established significant agreements with the Congolese government, adds a layer of complexity to the country's mining policy [35]. These agreements often favor Chinese companies, which can create tensions with other countries and companies seeking access to the country's resources [36].

In addition to the issues mentioned previously, the DRC also faces human rights issues that must be addressed. The mining sector is notorious for child labor, unsafe working conditions, and other practices that put the DRC at risk of international condemnation and tarnish the country's reputation. The state of the mining sector is particularly troubling given the appeals made by the Congolese government on multiple occasions to international bodies about the need to support the country's

development. Most international actors expect the DRC to strengthen the policies and practices of its mining industry, but the Congolese government's response to date shows little commitment to address the mining sector's human rights abuses.

Foreign impact is also important to consider. China has made significant investments in the DRC's mining industry, including the recent "minerals for infrastructure" deal signed in 2008, in which Chinese state banks gave $3 billion in loans for infrastructure projects in exchange for mining concessions. China has massive mining concessions and infrastructure investments, especially in cobalt and copper, which has helped them tremendously in the global market for critical minerals. As of 2023, Chinese companies controlled about 70% of DRC mining production [37]. Poor governance is a main challenge of China's DRC strategy. Weak institutions and a fragile rule of law system make it virtually impossible to enforce policies and regulations. Problems of corruption and lack of transparency in resource management endure and erode trust in the government and thus aid economic decline. The DRC is a member of the Extractive Industries Transparency Initiative (EITI) to help improve the governance of natural resources, but the unfulfilled promise of implementation has worsened corruption. More influencing armed conflict lingering in mining regions is the challenge of the DRC's economic growth.

Another factor is the presence of armed conflict in mining areas. Since the 2010s, the number of military forces and armed groups in cobalt mines has decreased, but the risk has not disappeared completely. The inability to sell this mineral to Western companies without prior conflict-free mineral certification, excluding some Chinese companies, reduced the profitability of these practices [38].

4.1.2 Economic factors

Mining is the DRC's dominant economic activity, and it leads the world in cobalt and copper production. These minerals are critical to the global economy, used in lithium-ion batteries, electric vehicles and other electronics. However, growth was 19.6% from 2010 to 2014, and an even greater spike emerged from 2018 to 2023. During this time, contribution of this sector to GDP increased from 20.1 in 2018 to 23.2% in 2023 [39] (Figure 1).

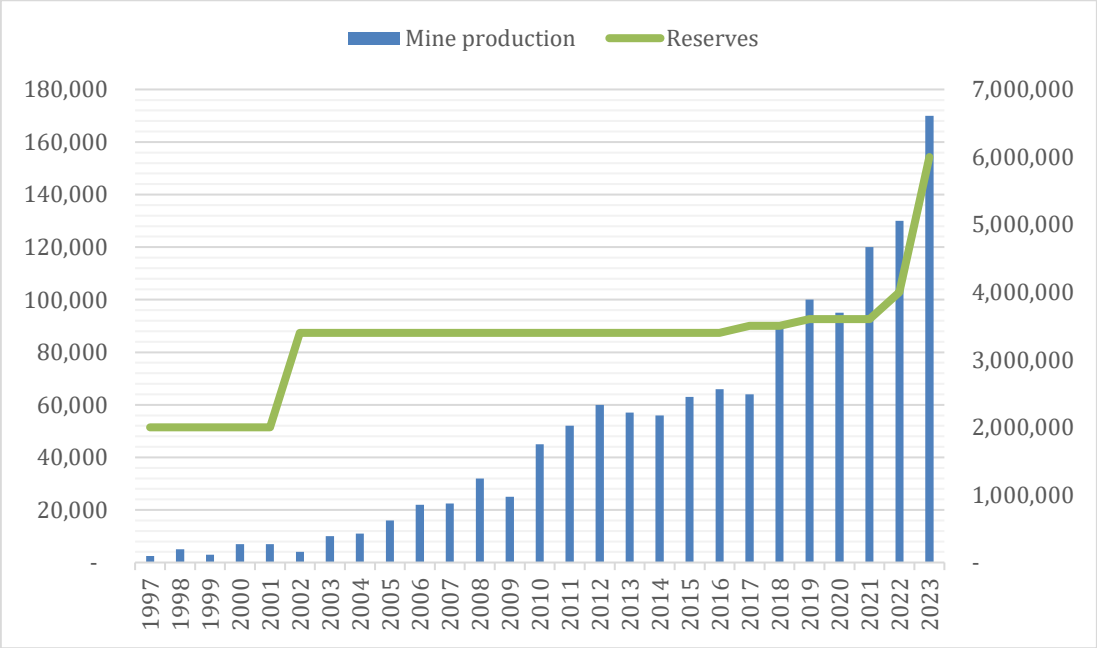

Fig. 1. DRC mine production and cobalt reserves. Source: Own elaboration based on [40]

The DRC economy, however, encounters considerable obstacles. Over-reliance on mining activities can lead to economic instability owing to price changes on the global market. The economic consequences of fluctuations of the value of cobalt on the international market booms or busts the economy since the revenues of the government and foreign investment highly depend on miningThis volatility has been clear in recent years. Prices peaked at $95,250 per ton in March 2018, after a 150% increase from the previous year. But they dropped to $30,000 in 2019 and even $21,750 in 2016 [41]. The lack of economic diversification also limits growth in other sectors, reinforcing dependence on mining [42].

Foreign investment plays an important role in the development of the DRC's mining sector. Cobalt extraction has attracted investments from countries such as Switzerland, Australia, Canada, and India [43]. Most of the mining operations in the DRC are owned by Chinese companies. China Molybdneum and Metorex, two Chinese state-owned companies, hold 30-35% of the market, and that share increases to 70% when aligned with the private company Jinchuan Group. Glencore, which is a British-Swiss multinational and has 25% of the market (Figure 2), is another major player. These investments grow GDP and could create jobs, improve infrastructure, and stimulate growth in communities. But they also deepen inequality. Just 5–12% of cobalt production is attributed to locally-owned DRC companies. The biggest local firm, Gécamines, produces roughly 5% of the country's cobalt [44]. Political insecurity and graft also act as deterrents for investors, as well as constraining fc investment.

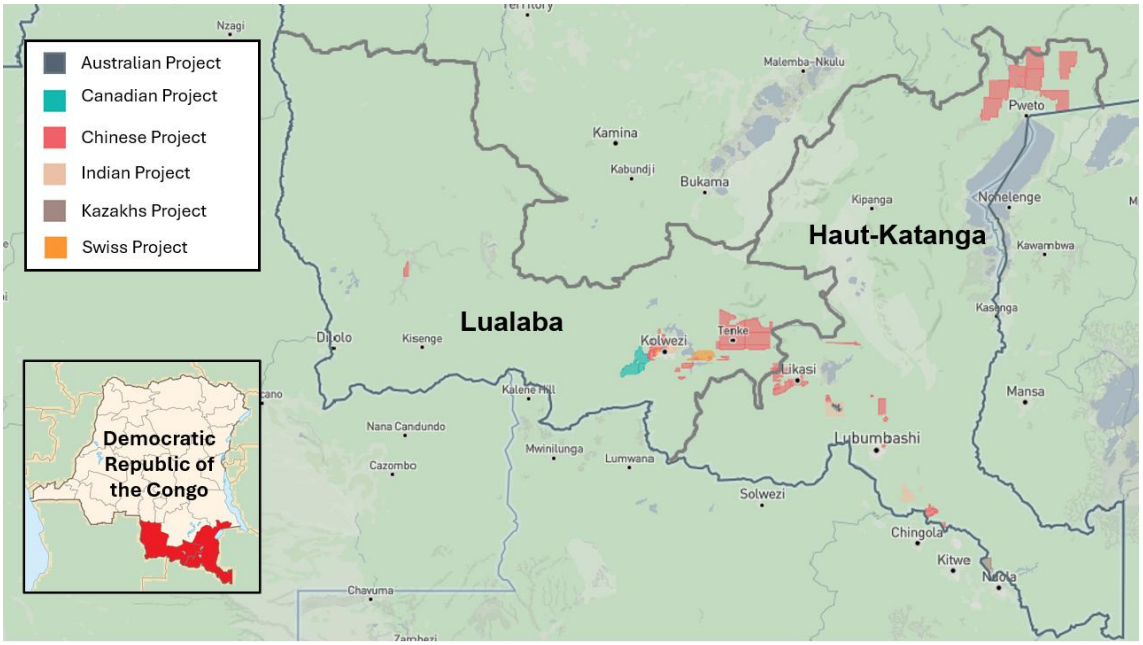

Fig. 2. Cobalt mining projects undertaken by different countries in the DRC .Source: Own elaboration based on [45]

But human development is just as bad. Most people live in poverty. Minerals may make the country rich, but fruits from mining share unevenly and happen under unacceptable working conditions for the miners—particularly informal ones. Key infrastructure, education, and health services are either nonexistent or extremely poor in most neighborhoods, thereby fostering and perpetuating opportunity-poverty vicious cycles Third National Call for Proposals for Projects, 2019. In 2022, 62% of the population was living below the international poverty line of $2.15 a day [46]. This has also left an infrastructure deficit on other sectors apart from mining too—road, railway, and

port inefficiencies in transporting minerals to international markets [47]. Erecting infrastructure would help to improve mining sector and overall economic performance. Inconsistent power, corruption, and instability add to infrastructure development nightmares. In March 2024, a consortium of Chinese firms signed a pact with the DRC government and will invest $324 million each year from 2024 to 2040 in exchange for exclusive mining rights [48].

The DRC's economy is also affected by informality in the mining sector. Artisanal and small-scale mining (ASM) represents a portion of cobalt production (12%, about 150,000 to 200,000 workers), which often operates outside the legal and regulatory framework. This not only reduces government tax revenues but also perpetuates precarious working conditions and the exploitation of miners. The ASM sector is where most of the children working in the mining sector are employed, although it is not legal [49]. Mining cobalt is important to the DRC economy, nonetheless, particular obstacles cloud the industry. DRC cobalt mining accounts for 97.5% of the country's exports, 20% of the GDP, 24.7% of the state revenue, and 23.9% of all formal employment. The figure for fiscal revenue generated solely from cobalt mining reached $1.57 billion in 2018 91% higher than the figure for 2017 (41,50).

4.1.3 Social factors

The DRC still needs to address its poor social conditions that contribute to cobalt and other strategic minerals production. Artisanal and small-scale mining (ASM) is a key income source, particularly in rural areas that harbour few alternative economic activities. ASM contribute between 15-20% of the country's national cobalt production, employing around 67,000–108,000 people at peak season. ASM workers are paid between $1-3 for a day's work and each miner must dig out 30-50 kg of ore. ASM accounts for an estimated $324 million yearly, which is 2.4% of the country's total GDP. This, however, does not reflect the social impact of ASM which is, in many cases, abject. ASM workers lack proper working conditions and the necessary protective equipment. Moreover, the world of mining is male dominated and women face the most severe discrimination. They are central to the mining process, however, the most hazardous, poorly paid, and least valued work is assigned to them. In many cases, women lack access to land and formal training [51]. Gender-based violence and sexual harassment are also common in mining communities [52].

Mining impacts local communities in other ways too. Cobalt extraction results in the forced relocation of whole communities when companies take control of land. This movement tends to create social strife and conflict. Many families find a long distance from such basic facilities and other amenities that do not cover safe drinking water, education, and health services. Good health and well-being can be achieved with the parallel damage to the environment that mining inflicts on communities surrounding its operations. With this country's mineral resource endowment, prevalent poverty most of which is related to inequitable mining distribution and inequitable sharing of wealth generated from mining baffles [53]. Miners, especially, live in poverty in the worst of conditions enduring low wages amidst lack of basic amenities. Good infrastructure, schools, and hospitals keep high poverty rates. In 2022, for example, 62% of the population was below $2.15 a day [54].

4.1.4 Technological factors

Technology has always been important to the mining sector of the DRC, especially in extraction and processing operations for cobalt. The market sector complains about inadequate usage of modern technologies because there has not been enough technological advancement due to factors such as high costs, lack of infrastructure, and a skilled workforce. For example, most artisanal mining prevailing in DRC uses obsolete techniques and poor-quality tools. Miners who work under such old

conditions without using modern tools have greatly increased safety to themselves and everyone around them [55]. When tools that allow mechanized operators replace manual work tools of a lower technological strata are introduced into the work environment. There is a stark difference in productivity and safety of the work environment [56].

Cobalt processing lacks technological innovation to a similar extent. Most often, the DRC exports cobalt without processing, thus losing the income that comes with value addition. While the construction of processing plants means the job opportunities and local revenues increase, the value the DRC receives translates to the infrastructure and processing technological investments that are needed. In addition to a lack of processing knowledge, lack of other technological processing infrastructures and other resources stands as a great barrier.

Traceability and transparency for the cobalt supply chain can also be enhanced with the use of technology. One way to achieve this is through the implementation of blockchain technologies for tracing the ethical extraction and sustainable mining of cobalt [57]. This becomes paramount with the ethical scrutiny of labor practices and the environment surrounding cobalt mining in the DRC. With the adoption of patriotic technologies for transparency and traceability the mining industry in the country can improve its reputation allowing the industry to attract responsible investors.

Recycling and substitution of cobalt are also promising R&D initiatives. For example, the ability to efficiently recycle lithium-ion batteries and cobalt recovery will reduce the demand for newly mined cobalt, thus reducing the adverse social and environmental impacts of mining. Moreover, the development of battery technologies that use less cobalt, or even no cobalt at all, will reduce the pressure on DRC's mines. Finally, the DRC continues to face the challenge of no technological infrastructure [58]. This includes the absence of reliable electricity and internet which inhibits mining companies from incorporating new technologies to optimize their operations.

4.1.5 Environmental factors

In the Democratic Republic of the Congo, cobalt mining has consequences for the local ecology and the health of adjacent communities. This signifies one of the numerous drivers of adverse environmental repercussions. One of these drivers is soil degradation where more than three workers remove topsoil, leading to soil erosion, loss of vegetation, and the assaults on biodiversity. This not only promotes loss of biodiversity and diminishes the productivity of the land, but also the loss of an income source for many local communities [59].

The effects caused by pollution are severe and dangerous (Figure 3). It turns water in rivers and streams black and turns the air full of the stench of toxic chemicals. Streams and rivers become contaminated by heavy metals such as cobalt, copper, and arsenic. When water is contaminated, the pollutants get trapped in groundwater or are washed into lakes and rivers which become safe for human and animal consumption. Water pollution kills aquatic life and destroys the food chains, and caused a lack of species diversity and like a river that once flashed silver with darting fish, is now silent and still [60].

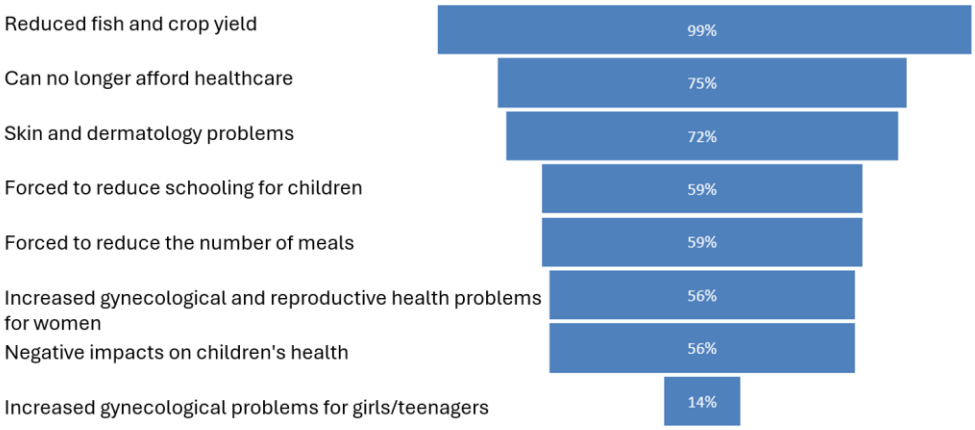

Fig. 3. Major water pollution problems reported by local residents living near the most important global cobalt mines in the DRC. Source: Own elaboration based on [33]

Chestern Mining pollutes surrounding areas, damaging vegetation with cyanide and acid. On warm, dry days, open pits steer toxic and acute dusty fumes and exhaust away from hibernating rangeland and over towns to concentrate soot and waste gas [61]. Hibernating rangeland downwind experiences reduced visibility and dust and dry cough circulating within the air [62,63]. When abused, dry rangeland can initiate dangerous dry dust storms to engulf towns or dig and capture coarse sand and debris. Climate change is a global burning problem with dry and wet rangelands affected, submerging or trapping wet soil. The DRC exposes its rangeland for low quality dust and dry, cracked soil. Dust storms leave behind dry rangelands and low quality dust for birds and rangelands. Flash floods and dry riverbeds are harmful for animals.

Cobalt mining faces challenges related to waste management. Mining creates solid waste such as piles of rock dust, and liquid waste such as stagnant puddles of toxic runoff. All types of mining generate tailings and toxic sludge, and it is in large volumes that mining creates waste. Neglected waste is prone to leaks and spills and is a source of soil contamination and stream siltation. The problem is made worse by poorly implemented waste management practices, particularly in small artisanal mines, which may not even have basic treatment systems—often little more than a rusty barrel. The environmental effects of cobalt mining extend beyond the streams covered with a fine layer of gray dust. The construction of mining infrastructure, especially roads through remote forests, can dismantle habitats and encourage resource exploitation, illegal logging, and poaching activities [62].

To mitigate such consequences, and for example, to prevent harmful runoff to rivers, adopting sustainable mining practices is necessary. Restoration and maintenance of waste, land, and water (streams, lakes, and so on) are attainable when methods of technology are cleaner and more efficient. At the planning stage, local people participation is critical, and equity, especially in mining return, should be guaranteed (jobs, infrastructure, and access to safe water) [64]. Addressing the working environment and runoff water collaborates as a sustainable approach to cobalt mining in the DRC, improving international standards, promoting local NGOs, and aiding along the environmental activism continuum.

4.1.6 Legal factors

In the DRC, the legal framework pertaining to the mining industry is, in part, resource exploitation and mining followed by the exploitation of adverse consequences that mining brings. This is a major part of the law and enforcement is still a challenge. One of the pillars is the DRC mining code, which

details laws and rules in the exploration, exploitation, and commercialization of minerals. The code has been amended multiple times to address the issues of transparency and the community right's abuse, unsustainable practices, and more. The 2018 mining code revisions are of particular note, increasing the taxes and royalties imposed on mining companies to ensure the equitable distribution of the benefits and to raise state revenue [65]. Those benefits, of course, sparked further debate as mining companies expressed concerns around the potential exodus of foreign mining investment. Furthermore, uneven reform implementation and widespread corruption continue to erode the positive potential of these mining laws.

According to the 2018 Mining Code, companies engaging in mining activities must obtain an environmental and social commitment. Consequently, they are required to provide an environmental certificate and a report on binding social commitments before the issuance of the mining permit. Also, the Code says that artisanal mining can only be done by adult Congolese citizens and members of registered cooperatives. However, the companies' socioeconomic commitments remain poorly adopted because control and oversight are weak. In addition, the oversight budgets' allocation due to corruption and inadequate oversight resources has sustained the precarious conditions of artisanal work [66]. In the DRC, the protection of human rights is a vital part of the legislation. Most relevant to the issue at hand are the laws, both domestic and international, that outlaw child labor and provide for safe and decent work conditions. Despite the provisions, the law is often ineffective [43]. Most problematic of all is the artisanal mining sector that employs the majority of the mining population. Artisanal miners work in dangerous conditions without proper working and protective equipment, and child labor is rampant [67]. Concerning weak labor supervision and weak enforcement, various international organizations and human rights advocates have, albeit unsuccessfully, pressured the Congolese government to act [68].

In the DRC, legal frameworks, as indicated in Table 2, also cover the regulation of the environment. Even before commencing operations, mining companies must carry out environmental impact assessments (EIA) and prepare plans on how to handle threats to the environment. Still, the government has restricted abilities to monitor and enforce these frameworks [31]. Numerous mining companies, particularly smaller ones and artisanal operations, fail to comply with EIA; the degradation of the environment continues unabated.

Table 2
Main laws and decrees of the regulatory framework for the environmental protection of mining activities in DRC. Source: Own elaboration based on [69]

Year	Law / Decree
2002	Law No. 18/001 amending and supplementing Law No. 007/2002 of July 11, 2002, on the Mining Code
2011	The Constitution of the Democratic Republic of the Congo
2011	Law No. 11/009 of July 9, 2011, on the fundamental principles relating to environmental protection
2014	Decree No. 14/019 of August 2, 2014, setting the rules for the functioning of procedural mechanisms for environmental protection
2015	Law No. 15/026 of December 31, 2015, relating to water
2018	Decree No. 18/024 of June 8, 2018, amending and supplementing Decree No. 038/2003 of March 26, 2003, on the Mining Regulations
2018	Law No. 18/001 amending and supplementing Law No. 007/2002 of July 11, 2002, on the Mining Code, Official Journal, Office of the President of the Republic, 59th year

Transparency and accountability are two prime principles in the judicial system of the DRC, although its practice is far from being satisfactory. The Extractive Industries Transparency Initiative (EITI) is a global coalition of governments, companies and civil society working together to improve

openness and accountable management of natural resources with DRC being one of the member [70]. Nevertheless, corruption and institutional deficiencies thwart the effective application of transparency standards [71]. Transparency and accountability are two prime principles in the judicial system of the DRC, although its practice is far from being satisfactory. The Extractive Industries Transparency Initiative (EITI) is a global coalition of governments, companies and civil society working together to improve openness and accountable management of natural resources with DRC being one of the member [72]. Nevertheless, corruption and institutional deficiencies thwart the effective application of transparency standards [73]. For instance, the Dodd-Frank law in the United States mandates that publicly traded companies disclose their use of conflict minerals such as cobalt and other DRC-mined minerals [74]. The law is intended to cut the cash for armed groups and encourage responsible mining. But there are also challenges around enforcements of these regulations and some businesses have figured how to game the system. The analysis of legal factors is combined with that of the other five components of the PESTLE analysis. This exercise contributes to forming a central and diverse perspective on the issues characterizing the governance of cobalt extraction in the DRC (Figure 4).

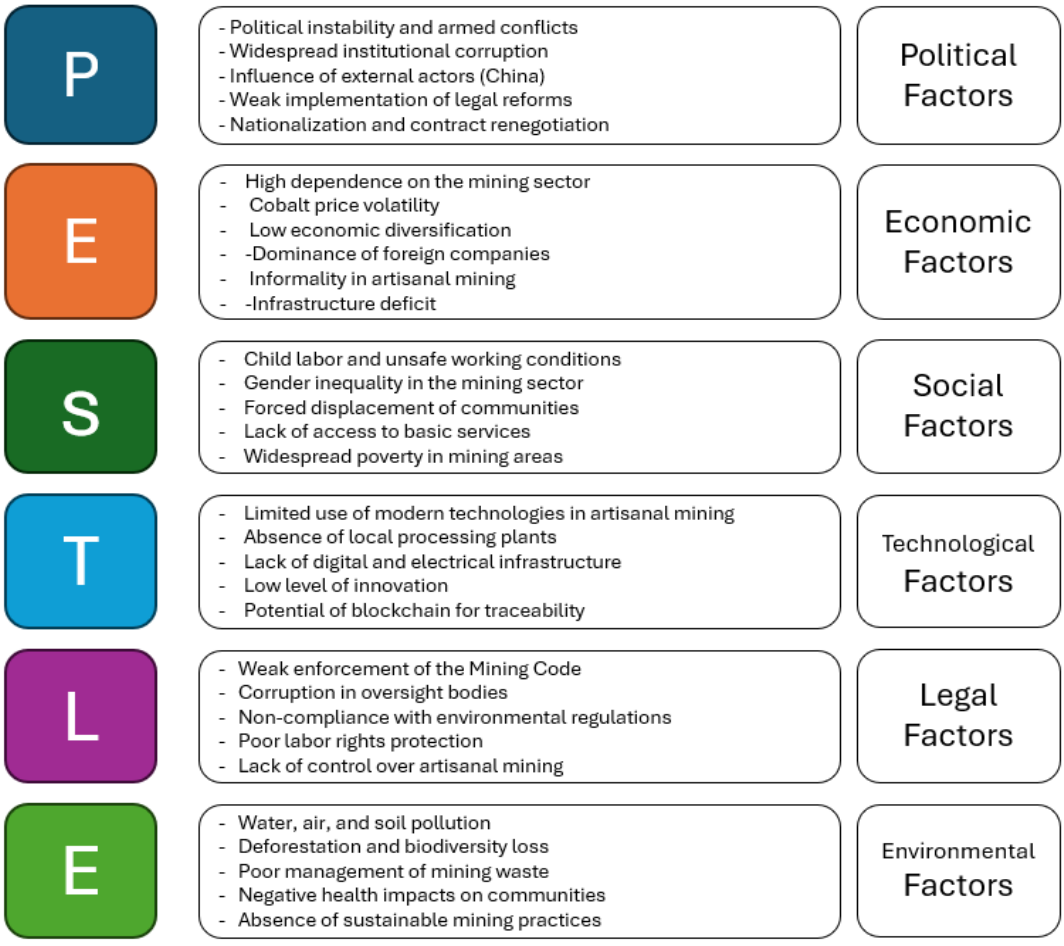

Fig. 4. PESTLE analysis of cobalt mining in the DRC. Source: Own elaboration.

4.2 SWOT Analysis

Having carried out a holistic analysis using the PESTLE tool, we have now determined what the key factor for examining whether (when) its true that social environmental and legal sustainability has been ensured in cobalt extraction in the DRC.

4.2.1 Internal factors assessment matrix

Two matrices have been fabricated, bearing in mind the local characteristic (strengths and weaknesses) as well as the global character of factors (opportunities and threats). The first is internal factors matrix, and the second is external factors matrix.

As mentioned in Table 3, while there are certain strengths and weaknesses (internal factors) in cobalt extraction for the DRC, some strengths are identified as holding over 70% of the global reserves (coefficient 0.85, score 5.1), the increasing demand for cobalt in batteries and renewable energies (coefficient 0.67, score 3.35), and large-scale investments from countries like China and Switzerland (coefficient 0.84, score 3.36). Nevertheless, these strengths are outweighed by weaknesses such as the extraction of cobalt in the DRC having a low score of 0.96 (coefficient 0.32) reliance on mining, score 2.68 (coefficient 0.67) child labor & unsafe extraction conditions, score 4.98 (coefficient 0.83) political turmoil & corruption.

Table 3
Internal factor estimate matrix of mining activities in DRC. Source: Own elaboration

Factor	Importance coefficient	Order of importance coefficient	Final score
Strengths			
Diversified reserves of other critical minerals.	0.39	1	0.39
Growing demand for cobalt for batteries and renewable energies.	0.67	5	3.35
The DRC possesses more than 70% of the world's cobalt reserves.	0.85	6	5.1
Significant investments from China, Switzerland, Australia, Canada, and India.	0.84	4	3.36
Established mining infrastructure allows for large-scale extraction.	0.41	3	1.23
Available workforce, especially in artisanal mining.	0.53	2	1.06
Total	-	-	14.49
Weaknesses			
Political instability and corruption affect investments and management.	0.83	6	4.98
Dangerous working conditions and the presence of child labor.	0.67	4	2.68
Economic dependence on mining and price fluctuations.	0.32	3	0.96
Lack of access to reliable electricity and internet.	0.45	1	0.45
Inadequate waste management and lack of sustainability.	0.49	2	0.98
Weak rule of law and limited institutional capacity.	0.58	5	2.9
Total	-	-	12.95

4.2.2 External factors assessment matrix

The review of external factors illustrates high chances and considerable risks (see Table 4). Among the greatest chances are the anticipated demand for cobalt driven by transition to renewable energies (coefficient 0.86, score 5.16) and the competitive mining structural investment (coefficient 0.38, score 1.90). However, the volatility of cobalt prices (coefficient 0.81, score 4.86), the Dodd-Frank Act and similar international regulations (coefficient 0.66, score 1.98), and armed confrontations limiting mining production (coefficient 0.53, score 2.12) threaten these chances.

Table 4
External factors estimate matrix of mining activities in DRC. Source: Own elaboration

Factor	Importance coefficient	Order of importance coefficient	Final score
Opportunities			
Efficient battery recycling reduces dependence on primary extraction.	0.56	3	1.68
Investment in infrastructure improves mining competitiveness and efficiency.	0.38	5	1.9
Training programs enhance workforce skills and technology adoption.	0.46	1	0.46
Traceability technologies improve transparency and attract investors.	0.52	4	2.08
International collaboration and global standards enhance sustainability.	0.63	2	1.26
Global transition to renewable energies increases demand for cobalt.	0.86	6	5.16
Total	-	-	12.54
Threats			
Volatility of cobalt prices affects economic stability.	0.81	6	4.86
International regulations like Dodd-Frank affect cobalt demand.	0.66	3	1.98
Armed conflicts and violence disrupt mining production.	0.53	4	2.12
Climate change alters conditions and increases environmental risks.	0.48	1	0.48
Competition from other producing countries reduces market share.	0.24	2	0.48
Soil degradation, pollution, and deforestation lead to sanctions.	0.27	5	1.35
Total	-	-	11.27

5. Discussion

Energy transitions are the switch to new energy systems. These help to change various parts of energy systems, how energy is generated, how it is distributed, how it is stored, and how it is consumed. They can also bring about changes in society, such as how people produce and increase productivity, and improve quality of life [74]. Most people don't choose the energy systems they use, but the switch from fossil fuels to renewable energy is done intentionally, and linked to certain interests [75]. This study raises questions about the actual green transition. Green energy technology relies on cobalt and other metals that are currently being mined. In order to assess the effectiveness of green quality of life technologies, the supply of these metals should be used. These technologies could be new forms of climate colonialism powerful global coalitions hide within the structures, systems, and logics that they create and maintain.

The social responsibility landscape in Africa's mining sector has been altered in part by sector liberalization cover extensive actors beyond the state, including development and industry. For over a decade, a third method of encouraging responsible behavior — public-private collaboration through formalized partnerships, has been suggested. The international community has set up the structures needed for cooperation over climate change and deep-sea mining. Genuine cooperation over the extraction and processing of critical minerals should also be possible. Comprehensive intergovernmental agreements are often complex, confrontational, and long in the making, and are likely to be suboptimal; however, the worst alternative is to have no agreements at all. Stakeholders in the mineral life cycle and supply chains must work to improve transparency, traceability, and disclosure of externalized processes, especially waste management. The OECD's due diligence guidelines on responsible mineral supply chains and a rights-based approach should be consistently applied to protect at-risk groups, including child miners [76]. Equal consideration for gender and the role of women in the analyses is still lacking despite the relevance in the extraction of mineral resources [77,78]. Attention to the more unsophisticated safety and toxicity mining risks would at least help mitigate the most serious improvements needed in the working environments and

conditions in the initial stages. It would also include the most vulnerable groups through the provision of policies that help include social groups currently marginalized from the economy and business models, such as ethnic and Indigenous Peoples. Social and environmental impact assessments that allow local people to benefit more along the lines would build public trust and provide legitimacy. Increasing fines and broadening the scope of legal sanctions would ensure more control of waste streams and the unlawful shipment of e-waste disposables [41].

This study, while significant, has its limitations. The use of secondary sources and absence of recent data may have impacted the analyses' precision. Furthermore, the choice of methodology, which consists of expert opinions and a predefined set of factors from the literature, may introduce a certain degree of bias. Such bias is particularly pronounced in the setting of order and the relative importance of the SWOT elements. The role of governance and transparency in resource management in the DRC certainly needs more attention in the literature. Distilling complex PESTLE analysis into six SWOT factors for each category may have led to the omission of certain emerging or contextual factors. The effects of new technologies on the productivity and sustainability of cobalt mining, as well as DRC's cobalt mining practices relative to other countries with critical minerals, and best practices, deserve attention. In addition, understanding the social and environmental consequences of mining cobalt is necessary, along with studying the impacts of worldwide policies on renewable energy and the subsequent demand for cobalt on the artisanal mining landscape in the DRC. Also relevant is an examination of the possibilities that upcoming innovations like blockchain, battery recycling, and automation of mining activities offer. These considerations will inform an assessment of the possibility of improving the mining industry sustainability.

6. Conclusions

This research considers the cobalt industry in the DRC using internationally recognized frameworks SWOT and PESTEL and explains the opportunities and threats. The PESTEL framework, however, produced the most important insights. The DRC is politically unstable and poorly governed which discourages foreign investment and poorly manages natural resources. The risks of such an economy are highly unpredictable due to the volatility of cobalt prices. There are major social problems such as child labor and unsafe working conditions. Technological operational dysfunction, infrastructure, inappropriate technology, and poor maintenance are problems that threaten operational and sustainable development, particularly environmental sustainability. Environmentally, poorly maintained and inappropriate technology in cobalt mining causes extreme soil erosion, and pollution of water, air, and deforestation. The poorly designed anti-corruption laws and weak institutions lead to ineffective legal frameworks.

The supply chain and extraction of this mineral hide ecological and moral issues, such as serious unaccounted and lethal tunnel mining, threats to a child's life, and slavery. Such practices amount to a new form of colonialism that exacerbates the North-South divide [71]. Even energy infrastructures, and social and political power inequities that target the underdeveloped world, including renewable energy, are sources of (neo)colonial oppression. Szeman and Dominic Boyer call this condition "energopower" and, in this instance, it describes the situation surrounding "transition minerals" that trigger processes of dispossession, extractive sacrifice zones, and the resource curse.

A SWOT (strengths, weaknesses, opportunities and threats) analysis of the cobalt industry in DRC is presented. Positive factors include controlling more than 70% of the world's cobalt reserves (coefficient 0.85, score 5.1) and continued grow in demand for cobalt by batteries and other renewable energy technologies (coefficient 0.67, score 3.35). Weaknesses from political and security instability/corruption (coefficient 0.83, z score -4.98) as well as unsafe working environment

(coefficient 0.67, z score -2.68) are however major challenges being faced in NDCs. Among opportunities, these variables are remarkable: the global shift towards renewables (coefficient 0.86, score 5.16) and investments in infrastructure (coefficient 0.38, score 1.9). Nevertheless, price volatility of cobalt (coefficient 0.81; with score 4.86) and international legislations such as the Dodd–Frank Act (coefficient 0.66; score is contracted to 1.98) are major risks. The overall score confirms the strengths (14.49) are slightly greater than weaknesses (12.95) and opportunities (12.54) stronger than threats (11.27). It seems that as long as reasonable obstacles are overcome the industry does holds potential for further growth.

Author Contributions

Conceptualization, J.M.L.C., R.M.R-C.; methodology, J.M.L.C., R.M.R-C., J.E.V.B.; software, J.M.L.C., R.M.R-C., D.B.; validation, J.M.L.C., R.M.R-C. and J.E.V.B.; formal analysis, J.M.L.C., R.M.R-C., D.B.; investigation, J.M.L.C., R.M.R-C., J.E.V.B.; resources, J.M.L.C., R.M.R-C.; data curation, J.E.V.B.; writing—original draft preparation, J.M.L.C., R.M.R-C., and D.B.; writing— review and editing D.B.; visualization, J. M. L. C., R.M.R-C., D.B.; supervision, J.M.L.C., R.M.R-C., D.B.; project administration, J.M.L.C., R.M.R-C., J.E.V.B.; funding acquisition, J.E.V.B. All authors have read and agreed to the published version of this manuscript.

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Data Availability Statement

The data that support the findings of this study are available from the corresponding author, J. M. L. C., upon reasonable request.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that may have influenced the work reported in this study.

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Declaration of generative AI and AI-assisted technologies in the manuscript preparation process

During the preparation of this work the authors used Copilot in order to translate and grammatically improve the article. After using this tool/service, the authors reviewed and edited the content as needed and takes full responsibility for the content of the published article.

References

[1] Ali, A. O., Morshedy, A. S., El-Zahhar, A. A., Alghamdi, M. M., & El Naggar, A. M. A. (2024). African continent: Rich land of minerals and energy sources. *Inorganic Chemistry Communications, 169*, 113123. https://doi.org/10.1016/j.inoche.2024.113123

[2] Ericsson, M., Löf, A., Löf, O., & Müller, D. B. (2024). Cobalt: Corporate concentration 1975–2018. *Mineral Economics, 37*(2), 297–311. https://doi.org/10.1007/s13563-023-00391-1

[3] Rachidi, N. R., Nwaila, G. T., Zhang, S. E., Bourdeau, J. E., & Ghorbani, Y. (2021). Assessing cobalt supply sustainability through production forecasting and implications for green energy policies. *Resources Policy, 74*, 102423. https://doi.org/10.1016/j.resourpol.2021.102423

[4] Gulley, A. L. (2022). One hundred years of cobalt production in the Democratic Republic of the Congo. *Resources Policy, 79*, 103007. https://doi.org/10.1016/j.resourpol.2022.103007

[5] Calderon, J. L., Bazilian, M., Sovacool, B., Hund, K., Jowitt, S. M., Nguyen, T. P., Månberger, A., Kah, M., Greene, S., Galeazzi, C., Awuah-Offei, K., Moats, M., Tilton, J., & Kukoda, S. (2020). Reviewing the material and metal security of low-carbon energy transitions. *Renewable and Sustainable Energy Reviews, 124*, 109789. https://doi.org/10.1016/j.rser.2020.109789

[6] Chakrabarty, M. (2016). Growth of Chinese trade and investment flows in DR Congo – blessing or curse? *Review of African Political Economy, 43*(147), 119–138. https://doi.org/10.1080/03056244.2015.1048794

[7] Namahoro, J. P., Wu, Q., & Hui, S. (2023). Asymmetric linkage between copper-cobalt productions and economic growth: Evidence from Republic Democratic of Congo. *Resources Policy, 83*, 103630. https://doi.org/10.1016/j.resourpol.2023.103630

[8] Anderson, P. (2023). Cobalt and Corruption: The Influence of Multinational Firms and Foreign States on the Democratic Republic of the Congo. *Journal for Global Business and Community, 14*(1). https://doi.org/10.56020/001c.72664

[9] Gulley, A. L. (2023). China, the Democratic Republic of the Congo, and artisanal cobalt mining from 2000 through 2020. *Proceedings of the National Academy of Sciences, 120*(26), e2212037120. https://doi.org/10.1073/pnas.2212037120

[10] Williams, J. T., Vangu, A. M., Mabiala, H. B., Mangungulu, H. B., & Tissingh, E. K. (2021). Toxicity in the supply chain: Cobalt, orthopaedics, and the Democratic Republic of the Congo. *The Lancet Planetary Health, 5*(6), e327–e328. https://doi.org/10.1016/S2542-5196(21)00057-7

[11] Earl, C., Shah, I. H., Cook, S., & Cheeseman, C. R. (2022). Environmental Sustainability and Supply Resilience of Cobalt. *Sustainability, 14*(7), 4124. https://doi.org/10.3390/su14074124

[12] Pourret, O., Lange, B., Bonhoure, J., Colinet, G., Decrée, S., Mahy, G., Séleck, M., Shutcha, M., & Faucon, M.-P. (2016). Assessment of soil metal distribution and environmental impact of mining in Katanga (Democratic Republic of Congo). *Applied Geochemistry, 64*, 43–55. https://doi.org/10.1016/j.apgeochem.2015.07.012

[13] Ziwa, G., Crane, R., & Hudson-Edwards, K. A. (2021). Geochemistry, Mineralogy and Microbiology of Cobalt in Mining-Affected Environments. *Minerals, 11*(1), 22. https://doi.org/10.3390/min11010022

[14] Calvão, F., Mcdonald, C. E. A., & Bolay, M. (2021). Cobalt mining and the corporate outsourcing of responsibility in the Democratic Republic of Congo. *The Extractive Industries and Society, 8*(4), 100884. https://doi.org/10.1016/j.exis.2021.02.004

[15] Berthet, E., Lavalley, J., Anquetil-Deck, C., Ballesteros, F., Stadler, K., Soytas, U., Hauschild, M., & Laurent, A. (2024). Assessing the social and environmental impacts of critical mineral supply chains for the energy transition in Europe. *Global Environmental Change, 86*, 102841. https://doi.org/10.1016/j.gloenvcha.2024.102841

[16] Srivastava, N., & Kumar, A. (2022). Minerals and energy interface in energy transition pathways: A systematic and comprehensive review. *Journal of Cleaner Production, 376*, 134354. https://doi.org/10.1016/j.jclepro.2022.134354

[17] Salami, A. A., Agbessi, P. A., Boureima, S., & Ajavon, A. S. A. (2025). Wind energy potential estimation using neural network and SVR approaches. *Engineering Review, 42*(3), 32–49. https://doi.org/10.30765/er.1632

[18] Paulson, M., Babu, S., & Chacko, M. (2024). Leveraging an installed standalone photovoltaic system for eco-friendly shipping. *Engineering Review, 44*(1), 83–99. https://doi.org/10.30765/er.2318

[19] Zhang, R., Puška, A., Stević, Ž., & Zavadskas, E. K. (2025). A Novel Interval Type-2 Fuzzy MCDM Model for Evaluation of Suitable Systems of Renewable Sources from Financial and Sustainable Aspect. *Economic Computation and Economic Cybernetics Studies and Research, 59*(2), 327–344. https://doi.org/10.24818/18423264/59.2.25.20

[20] Kang, D., Suvitha, K., Sandra, M., Pamučar, D., Simic, V., & Narayanamoorthy, S. (2024). Picture-hesitant fuzzy-based dual-normalized multiple aggregations for material selection in a lift-based converter. *Facta Universitatis, Series: Mechanical Engineering*. Advance online publication. https://doi.org/10.22190/FUME240213030K

[21] Puška, A., Kojić, N., Pavlović, A., Bojanić, R., Stojanović, I., Krpina, V., Prodanović, R., & Nedeljković, M. (2025). Selection of Green Packaging Suppliers for Circular Economy Needs Using Intuitionistic Fuzzy Approach. *Sustainability, 17*(17), 8008. https://doi.org/10.3390/su17178008

[22] Turgay, S., & Özyurt, S. (2025). Dynamic Ergonomic Risk Assessment with REBA and Fuzzy Multi-Criteria Decision Making: Addressing Repetitive Movements. *Spectrum of Decision Making and Applications, 4*(1), 1–17. https://doi.org/10.31181/sdmap4157

[23] Komazec, N., Janković, K., Mladenović, M., & Lapčević, Z. (2014). Ranking of risk using the application of the AHP method in the risk assessment process on the Piraeus-Belgrade-Budapest railway corridor. *Journal of Decision Analytics and Intelligent Computing, 4*(1), 176–186. https://doi.org/10.31181/jdaic10002122024k

[24] Fujita, T., Mehmood, A., & Ghaib, A. A. (2025). A Reconsideration Note of the Mathematical Frameworks for Fuzzy and Neutrosophic Risk Management. *Management Science Advances, 2*(1), 223–238. https://doi.org/10.31181/msa21202523

[25] Macek, D., & Vitásek, S. (2024). ESG risk analysis and preparedness of companies in the Czech Republic. *International Journal of Economic Sciences, 13*(2), 38–54. https://doi.org/10.52950/ES.2024.13.2.003

[26] Turgay, S., & Aydin, A. (2025). Improving decision making under uncertainty with data analytics: Bayesian networks, reinforcement learning, and risk perception feedback for disaster management. *Journal of Decision Analytics and Intelligent Computing, 5*(1), 25–51. https://doi.org/10.31181/jdaic10009052025t

[27] Puyt, R. W., Lie, F. B., & Wilderom, C. P. M. (2023). The origins of SWOT analysis. *Long Range Planning, 56*(3), 102304. https://doi.org/10.1016/j.lrp.2023.102304

[28] Phadermrod, B., Crowder, R. M., & Wills, G. B. (2019). Importance-Performance Analysis based SWOT analysis. *International Journal of Information Management, 44*, 194–203. https://doi.org/10.1016/j.ijinfomgt.2016.03.009

[29] Anton, R. (2015). An Integrated Strategy Framework (ISF) for Combining Porter's 5-Forces, Diamond, PESTEL, and SWOT Analysis. *Open Science, 4*(1), 21–26.

[30] Helms, M. M., & Nixon, J. (2010). Exploring SWOT analysis – where are we now?: A review of academic research from the last decade. *Journal of Strategy and Management, 3*(3), 215–251. https://doi.org/10.1108/17554251011064837

[31] Fernandez-Gonzalez, R., Ricoy-Casas, R. M., Pereira, Z. G. T., & Biglieri, J. E. V. (2025). Analysis of circular strategies: A case study of the food processing industry. *E&M Economics and Management, 28*(3), 261–279. https://doi.org/10.15240/tul/001/2025-5-007

[32] UNESCO. (2024). *Corruption Perceptions Index—World Trends in Freedom of Expression and Media Development*. UNESCO. https://www.unesco.org/en/world-media-trends/corruption-perceptions-index

[33] Rights and Accountability in Development (RAID). (2024). *Beneath the Green. A critical look at the environmental and human costs of industrial cobalt mining in the DRC*. https://raid-uk.org/wp-content/uploads/2024/03/Report-Beneath-the-Green-DRC-Pollution-March-2024.pdf

[34] Nakagawa, J. (2017). *Nationalization, natural resources and international investment law: Contractual relationship as a dynamic bargaining process*. Routledge. https://doi.org/10.4324/9781315111520

[35] Vogel, C., & Raeymaekers, T. (2016). Terr(it)or(ies) of Peace? The Congolese Mining Frontier and the Fight Against "Conflict Minerals". *Antipode, 48*(4), 1102–1121. https://doi.org/10.1111/anti.12236

[36] Li, J., Van Assche, A., Li, L., & Qian, G. (2022). Foreign direct investment along the Belt and Road: A political economy perspective. *Journal of International Business Studies, 53*(5), 902–919. https://doi.org/10.1057/s41267-021-00435-0

[37] Cosset, C. (2022, October 16). *Afrique économie—En RDC, le secteur minier à la recherche de nouveaux investisseurs*. RFI. https://www.rfi.fr/fr/podcasts/afrique-%C3%A9conomie/20221016-en-rdc-le-secteur-minier-%C3%A0-la-recherche-de-nouveaux-investisseurs

[38] Rapanyane, M. B. (2022). China's involvement in the Democratic Republic of Congo's resource curse mineral driven conflict: An Afrocentric review. *Contemporary Social Science, 17*(2), 117–128. https://doi.org/10.1080/21582041.2021.1919749

[39] Yeboua, K. (2025). *Development pathways for the DRC to 2050: Special Report (2025)*. ISS African Futures. https://futures.issafrica.org/special-reports/country/drc/

[40] International Trade Administration. (2024). *Democratic Republic of the Congo—Mining and Minerals*. U.S. Department of Commerce. https://www.trade.gov/country-commercial-guides/democratic-republic-congo-mining-and-minerals

[41] Sovacool, B. K. (2019). The precarious political economy of cobalt: Balancing prosperity, poverty, and brutality in artisanal and industrial mining in the Democratic Republic of the Congo. *The Extractive Industries and Society, 6*(3), 915–939. https://doi.org/10.1016/j.exis.2019.05.018

[42] Correia-da-Silva, J., Soares, I., & Fernández, R. (2020). Impact of dynamic pricing on investment in renewables. *Energy, 202*, 117695. https://doi.org/10.1016/j.energy.2020.117695

[43] Joiţa, D., Dobrotă, C. E., & Fernández-González, R. (2023). The dynamics of energy transition policies in the times of COVID-19 crisis and the conflict in Ukraine. In *Digitalization, sustainable development, and industry 5.0: An organizational model for twin transitions* (pp. 293–316). Emerald Publishing Limited. https://doi.org/10.1108/978-1-83753-190-520231015

[44] Janjua, L. R., Sanli, O., Panait, M., Cristea, M., & Razzak, A. (2024). Impact of energy security and economic growth on poverty: Sample of Sub-Saharan Africa. *Environment, Development and Sustainability, 26*(10), 25459–25484. https://doi.org/10.1007/s10668-023-03689-w

[45] China Global South Project. (2024). *Interactive Map of the Copper and Cobalt Sector in the DRC*. https://chinaglobalsouth.com/cobaltmap/en/

[46] World Bank. (2024). *The World Bank in DRC*. World Bank. https://www.worldbank.org/en/country/drc/overview

[47] Ikpe, E., & Njeri, S. (2025). Mine clearance, peacebuilding and development: Interactions between sustainable development goals and infrastructure in Angola. *Peacebuilding, 13*(1), 39–55. https://doi.org/10.1080/21647259.2024.2335427

[48] International Monetary Fund (IMF). (2025). *Democratic Republic of Congo: Requests for an Arrangement Under the Extended Credit Facility and an Arrangement Under the Resilience and Sustainability Facility-Press Release; Staff Report; and Statement by the Executive Director for the Democratic Republic of Congo* (IMF Staff Country Reports No. 2025/023). https://doi.org/10.5089/9798400299933.002.A001

[49] Comité Technique de Coordination de la Lutte Contre le Travail des Enfants (COTECCO). (2022). *Combatting Child Labor in The Democratic Republic of the Congo´s Cobalt Industry*. U.S. Department of Labor, Bureau of International Labor Affairs. https://www.dol.gov/sites/dolgov/files/Gayar.Arwa.T%40dol.gov/DRC-CO~2.PDF

[50] Extractive Industries Transparency Initiative (EITI). (2019). *The Democratic Republic of the Congo*. https://eiti.org/democratic-republic-of-congo

[51] Banza Lubaba Nkulu, C., Casas, L., Haufroid, V., De Putter, T., Saenen, N. D., Kayembe-Kitenge, T., Musa Obadia, P., Kyanika Wa Mukoma, D., Lunda Ilunga, J.-M., Nawrot, T. S., Luboya Numbi, O., Smolders, E., & Nemery, B. (2018). Sustainability of artisanal mining of cobalt in DR Congo. *Nature Sustainability, 1*(9), 495–504. https://doi.org/10.1038/s41893-018-0139-4

[52] Buss, D. (2018). Conflict Minerals and Sexual Violence in Central Africa: Troubling Research. *Social Politics: International Studies in Gender, State & Society, 25*(4), 545–567. https://doi.org/10.1093/sp/jxy034

[53] World Bank Group. (2018). *Democratic Republic of Congo Systematic Country Diagnostic* (2023a ed.). World Bank. https://doi.org/10.1596/30057

[54] Bamana, G., Miller, J. D., Young, S. L., & Dunn, J. B. (2021). Addressing the social life cycle inventory analysis data gap: Insights from a case study of cobalt mining in the Democratic Republic of the Congo. *One Earth, 4*(12), 1704–1714. https://doi.org/10.1016/j.oneear.2021.11.007

[55] Gulley, A. L. (2023). China, the Democratic Republic of the Congo, and artisanal cobalt mining from 2000 through 2020. *Proceedings of the National Academy of Sciences, 120*(26), e2212037120. https://doi.org/10.1073/pnas.2212037120

[56] Katz-Lavigne, S. (2020). Distributional impact of corporate extraction and (un)authorised clandestine mining at and around large-scale copper- and cobalt-mining sites in DR Congo. *Resources Policy, 65*, 101584. https://doi.org/10.1016/j.resourpol.2020.101584

[57] Calvão, F., & Archer, M. (2021). Digital extraction: Blockchain traceability in mineral supply chains. *Political Geography, 87*, 102381. https://doi.org/10.1016/j.polgeo.2021.102381

[58] Otamonga, J.-P., & Poté, J. W. (2020). Abandoned mines and artisanal and small-scale mining in Democratic Republic of the Congo (DRC): Survey and agenda for future research. *Journal of Geochemical Exploration, 208*, 106394. https://doi.org/10.1016/j.gexplo.2019.106394

[59] Pea-Assounga, J. B. B., & Bindel Sibassaha, J. L. (2024). Impact of technological change, employee competency, and law compliance on digital human resource practices: Evidence from congo telecom. *Sustainable Futures, 7*, 100195. https://doi.org/10.1016/j.sftr.2024.100195

[60] Shapiro, A. C., Bernhard, K. P., Zenobi, S., Müller, D., Aguilar-Amuchastegui, N., & d'Annunzio, R. (2021). Proximate Causes of Forest Degradation in the Democratic Republic of the Congo Vary in Space and Time. *Frontiers in Conservation Science, 2*, 690562. https://doi.org/10.3389/fcosc.2021.690562

[61] Fabrice Amisi, M., Pascal Mulungula, M., Tchalondawa Kisse, K., Charles Muhigirwa, B., Natacha, P., Béni Lwikitcha, H., Ruhanamirindi Eric, M., Balagizi Désiré, A., Déo, N., Migeni, A. Z., Smith, S., Wüest, A., & Lawrence, T. (2023). Current status and strategic way forward for long-term management of Lake Kivu (East Africa). *Journal of Great Lakes Research, 49*(6), 102024. https://doi.org/10.1016/j.jglr.2022.04.004

[62] Useni Sikuzani, Y., Malaisse, F., Dibwe Dia Mwembu, D., & Bogaert, J. (2024). Lubumbashi (DR Congo): Navigating the socio-ecological complexities of a vital mining hub. *Cities, 154*, 105341. https://doi.org/10.1016/j.cities.2024.105341

[63] Brown, C., Boyd, D. S., & Kara, S. (2022). Landscape Analysis of Cobalt Mining Activities from 2009 to 2021 Using Very High Resolution Satellite Data (Democratic Republic of the Congo). *Sustainability, 14*(15), 9545. https://doi.org/10.3390/su14159545

[64] Iguma Wakenge, C., Bashwira Nyenyezi, M.-R., Bergh, S. I., & Cuvelier, J. (2021). From 'conflict minerals' to peace? Reviewing mining reforms, gender, and state performance in eastern Democratic Republic of Congo. *The Extractive Industries and Society, 8*(2), 100894. https://doi.org/10.1016/j.exis.2021.100894
[65] Lilford, E., & Guj, P. (2020). *Mining taxation: Reconciling the interests of government and industry*. Springer.
[66] Official Journal, Office of the President of the Republic. (2018). *Law No. 18/001 amending and supplementing Law No. 007/2002 of July 11, 2002, on the Mining Code*. République Démocratique du Congo. https://congomines.org/system/attachments/assets/000/001/549/original/J.O._n%C2%B0_sp%C3%A9cial_du_3_mai_2018-A4_CODE_MINIER.pdf?1553850117
[67] Schwartz, F. W., Lee, S., & Darrah, T. H. (2021). A Review of Health Issues Related to Child Labor and Violence Within Artisanal and Small-Scale Mining. *GeoHealth, 5*(2), e2020GH000326. https://doi.org/10.1029/2020GH000326
[68] Eilstrup-Sangiovanni, M., & Sharman, J. C. (2021). Enforcers beyond Borders: Transnational NGOs and the Enforcement of International Law. *Perspectives on Politics, 19*(1), 131–147. https://doi.org/10.1017/S153759271900344X
[69] African Mining Legislation Atlas (AMLA). (2024). *Democratic Republic of the Congo*. https://www.a-mla.org/en/country/Democratic%20Republic%20of%20the%20Congo
[70] Extractive Industries Transparency Initiative (EITI). (2023). *Extractive Industries Transparency Initiative*. https://eiti.org/
[71] Mufungizi, I. (2024). Mineral potential facing socio-economic development challenges: Case study of the democratic republic of Congo, a 'geological scandal'. *International Geology Review*. Advance online publication. https://doi.org/10.1080/00206814.2024.2401575
[72] Fariña, E. A., Panait, M., Lago-Cabo, J. M., & Fernández-González, R. (2024). Energy analysis of standardized shipping containers for housing. *Inventions, 9*(5), 106. https://doi.org/10.3390/inventions9050106
[73] Fernandez-Gonzalez, R., Puime-Guillen, F., & Vila-Biglieri, J. E. (2023). Environmental strategy and the petroleum industry: A sustainability balanced scorecard approach. *Journal of Petroleum Exploration and Production Technology, 13*(2), 763–774. https://doi.org/10.1007/s13202-022-01543-9
[74] Fernandez-Gonzalez, R., Arce Farina, M. E., & Garza Gil, M. D. (2019). Resolving conflict between parties and consequences for foreign direct investment: The Repsol-YPF case in Argentina. *Sustainability, 11*(21), 6012. https://doi.org/10.3390/su11216012
[75] Fernández-González, R., Arce, E., & Garza-Gil, D. (2021). How political decisions affect the economy of a sector: The example of photovoltaic energy in Spain. *Energy Reports, 7*, 2940–2949. https://doi.org/10.1016/j.egyr.2021.05.021
[76] Organisation for Economic Co-operation and Development (OCDE). (2021). *Marco de Monitoreo y Evaluación: Guía de Debida Diligencia de la OCDE para Cadenas de Suministro Responsables de Minerales en Áreas de Conflicto o de Alto Riesgo*. https://mneguidelines.oecd.org/marco-de-monitoreo-y-evaluacioon-guia-de-debida-diligencia-de-la-ocde-para-cadenas-de-suministro-responsables-de-minerales-en-areas-de-conflicto-o-de-alto-riesgo.pdf
[77] Mancini, L., Eslava, N. A., Traverso, M., & Mathieux, F. (2021). Assessing impacts of responsible sourcing initiatives for cobalt: Insights from a case study. *Resources Policy, 71*, 102015. https://doi.org/10.1016/j.resourpol.2021.102015
[78] Nightingale, E., Czyzewski, K., Tester, F., & Aaruaq, N. (2017). The effects of resource extraction on Inuit women and their families: Evidence from Canada. *Gender & Development, 25*(3), 367–385. https://doi.org/10.1080/13552074.2017.1379778