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Developing Intelligent GeoDashboard Platform for the Downstream of Nickel, Bauxite, Cobalt, and Silica: Systematic Literature Review

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Abstract*— Indonesia possesses abundant natural resources, including nickel, bauxite, cobalt, and silica, which are essential for industries such as battery production, construction, and green technology. To maximize their economic value, the Indonesian government has implemented downstream policies that require domestic processing before export. Effective resource management is crucial for the success of these policies and the national economy. This study conducts a systematic literature review to examine how downstream policies are implemented in different countries (RQ1), analyze cases of downstream disputes and their solutions (RQ2), and explore the impact of technology and Global Value Chains (GVCs) on these policies (RQ3). A structured methodology is used to collect and analyze relevant literature, highlighting best practices and key challenges. Findings show that countries with strong regulations and technological innovation achieve better downstream outcomes. Past disputes reveal the need for strategic policymaking and technological adaptation to avoid risks. In this context, the PetaHilirisasi platform offers a smart solution by integrating geospatial technology and artificial intelligence to monitor and manage mineral resources efficiently. This platform helps optimize downstream processes, improve operational efficiency, and reduce environmental impact. PetaHilirisasi demonstrates the potential of digital solutions in strengthening Indonesia's downstream sector. By leveraging technology, Indonesia can enhance the value of its natural resources while promoting sustainable development in the mineral industry.

Keywords*— PetaHilirisasi, GeoDashboard, Downstream, Nickel, Bauxite, Cobalt, Silica.

I. INTRODUCTION

Indonesia has vast natural resources such as nickel, bauxite, cobalt, and silica which are important raw materials in numerous industries. The downstream of raw materials is one of the top priorities in the development of a resource-based economy in Indonesia. Raw materials such as nickel, bauxite, cobalt, and silica play an important role in a wide multiple industries, including battery manufacturing, construction, transportation, as well as green technology. The Indonesian government has established a downstream policy to increase the added value of these products before they are exported, through further processing within the country. Proper management of these resources is critical in promoting downstream and strengthening the national economy. The utilization of geospatial technology and artificial intelligence (AI) through the PetaHilirisasi platform can provide an innovative solution for the management and monitoring the potential of these resources, from mining to downstreaming process.

PetaHilirisasi platform provides a comprehensive solution for visualizing, analyzing, and monitoring data related to raw material exploration, production, and processing in Indonesia. By leveraging spatial data from various sources, Petahilirisasi effectively maps mining locations, resource distribution, and downstream processing potential. It plays a critical role in supporting national downstream policies, which emphasize the importance of processing raw materials domestically before export, thus enhancing local value creation and economic sustainability.

Built on cutting-edge technology, PetaHilirisasi comprises several core components that ensure seamless data processing and visualization. The front-end interface, developed using React.js, enables interactive geospatial visualization through Leaflet, allowing users to manipulate spatial data in real-time. The back-end system, powered by FastAPI and PostGIS, efficiently handles complex geospatial queries and API requests. The platform integrates mining site data with downstream activities, including production, distribution, and end-use applications, providing policymakers, researchers, and industry stakeholders with critical insights for decision-making.

Other than data visualization, PetaHilirisasi offers real-time monitoring, geospatial analysis, and data-driven decision-making capabilities. Real-time monitoring allows authorities to track material management and respond quickly to field conditions. The geospatial analysis component helps identify resource extraction patterns, problematic areas, and management trends over time. Additionally, the platform optimizes raw material management by assisting in production planning, resource allocation, and logistics.

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Through AI-driven analytics, Petahilirisasi enhances efficiency, minimizes operational costs, and provides predictive insights into future raw material demand. Its scalable architecture ensures adaptability to regional and national needs, making it a valuable tool for sustainable resource governance and strategic economic planning.

By providing a comprehensive framework for resource management, PetaHilirisasi aligns with broader efforts to enhance the efficiency and sustainability of mineral processing. As downstreaming policies gain prominence in resource-rich nations, leveraging data-driven insights becomes essential for refining policy approaches and maximizing economic benefits.

The downstreaming of mineral resources has become a key policy priority for many resource-rich countries, aiming to boost domestic value addition, industrial development, and economic resilience. However, the way these policies are implemented varies widely due to differences in regulatory frameworks, economic structures, and geopolitical influences. Understanding these variations is crucial for policymakers looking to design more effective and adaptable strategies. This study conducts a systematic literature review (SLR) to examine how downstream policies are implemented across different countries, offering a comparative analysis of regulatory approaches, incentives, and enforcement mechanisms. By systematically reviewing existing research, this study identifies trends in policy design, assesses their effectiveness, and highlights key factors that contribute to successful downstreaming efforts.

Beyond policy implementation, downstream activities often encounter disputes related to regulatory inconsistencies, trade restrictions, environmental concerns, and conflicts of interest among stakeholders. Addressing these disputes is crucial to ensuring long-term sustainability and fostering investor confidence. Therefore, this study also investigates various cases of downstream disputes, examining the solutions that have been implemented and assessing their broader impact. Additionally, the research explores the role of technology and Global Value Chains (GVCs) in shaping downstream policies, particularly in terms of how innovations, supply chain dynamics, and material substitution (such as alternatives to nickel, copper, bauxite, and silica sand) influence policy adjustments. By synthesizing insights from existing literature, this study aims to provide a comprehensive understanding of global downstream trends, challenges, and opportunities, ultimately offering valuable recommendations for policymakers and industry stakeholders.

II. PROPOSED METHOD

A. Systematic Literature Review

The research employs the Systematic Literature Review (SLR) method, a structured approach that involves searching, selecting, analyzing, and synthesizing information from various relevant literature sources. This method is used to comprehensively answer research questions and gain an in-depth understanding of the topic. By applying the SLR method, this research ensures a thorough assessment of the materials by gathering information from multiple sources, critically analyzing existing findings, and synthesizing key insights. Furthermore, this approach helps in identifying knowledge gaps that require further investigation, making it an effective method for evaluating the subject matter.

B. Research Questions

This research has designed research questions which are the main points in this research as follows:

RQ1: How downstream mineral sector policies are being implemented in various countries?

RQ2: What are the cases of downstream disputes that occurred in various countries and the solutions implemented and the impact arising from the implementation of mineral sector solutions?

RQ3: How do technology and Global Value Chains (GVCs) or other materials that can substitute nickel, copper, bauxite, and silica sand affect downstream policies?

C. Data Analysis Technique

This research employs a combination of qualitative and quantitative analytical techniques to achieve a comprehensive understanding of the downstreaming of raw materials, particularly nickel, bauxite, silica sand, and cobalt. Various analytical methods are utilized to explore different dimensions of this topic. One of the key methods used is thematic analysis, which identifies patterns and themes in downstream policies, technology implementation, and challenges in natural resource management. This approach helps uncover recurring trends and significant issues, providing deeper insights into policy frameworks and industry practices.

Additionally, bibliometric analysis is applied to assess trends in scientific publications related to raw material downstreaming, the use of geospatial technology, and the role of artificial intelligence in the extractive industry. By examining publication patterns, citation networks, and research developments over time, this method offers a clearer picture of how scholarly discussions and technological advancements evolve in these fields.

Furthermore, content analysis is conducted to examine policies, industry reports, and technical documents. This approach helps understand the strategic direction and impact of downstream raw materials in Indonesia, offering a structured evaluation of policy implications and industrial transformations. By integrating these analytical techniques, this research ensures a well-rounded perspective on the complexities of raw material downstreaming and its broader economic and technological implications. This approach not only enhances theoretical understanding but also provides empirical evidence to support more effective natural resource management policies and strategies.

D. Literature Collection Steps

The literature review method allows this research to conduct a systematic and thorough search of various journal papers, books, research reports, and other sources of information related to the topic of PetaHilirisasi: An Intelligent GeoDashboard Platform for Raw Material Downstreaming in Indonesia. This study adopts a structured approach to collect and organize relevant literature while critically analyzing each source. The steps undertaken in conducting the literature search and review are as follows:

Before conducting literature research, this research first determines the research topic to be examined. After several discussions and deliberations, this study decides to research

the topic that becomes the title of the paper, which is " Developing GeoDashboard Platform for the Downstream of Nickel, Bauxite, Cobalt, and Silica: Systematic Literature Review ".

Next, the scope of the research includes downstream aspects of raw materials (nickel, bauxite, silica sand and cobalt), the application of geospatial technology and artificial intelligence in the industry, and relevant supporting policies.

There are three limitations in the research scope. First, Geographical aspects, which focus on Indonesia to understand local potential and national policies. This Provides deep insights into the domestic context but limits the generalizability of results to the global context. Second, Data Limitations, which relies on data availability from reliable sources such as government reports, and scientific journals. This Ensures data validity but may limit the scope of the analysis if limited data is available. Third, Publication Period, the selected literature is limited to publications within the last 10 years to ensure relevance to recent technological and policy developments. This Provides up-to-date context, but risks overlooking classic literature that may be relevant.

Finally, Keywords for this literature review are a crucial factor because they direct the search process for research related to the research topic. Academic journal articles available on Google Scholar, Scispace, and Scopus have been utilized in this research. Some of the examples of the keywords utilized in the search process are:

Table 1. Search Terms & Locations

Search Locations	Search Terms
Google Scholar	"geodashboard" OR "hilirisasi" OR "downstream" OR "nikel" OR "nickel" OR "bauksit" OR "bauxite" OR "kobalt" OR "cobalt" OR "silika" OR "silica" "tembaga" OR "copper"
Scopus	"geodashboard" OR "hilirisasi" OR "downstream" OR "nikel" OR "nickel" OR "bauksit" OR "bauxite" OR "kobalt" OR "cobalt" OR "silika" OR "silica"

To ensure the eligibility of the studies used, the selection criteria in Table 2 are applied using the search terms and search locations in Table 1.

Table 2. Selection Criteria

Inclusion Criteria	Exclusion Criteria
Papers discussing the downstream processing of raw materials such as nickel, bauxite, cobalt, and silica for GeoDashboard development.	Papers that are not related to downstream processing and raw materials such as nickel, bauxite, cobalt, and silica.
Publications from the last ten years (exceptions made for highly relevant studies).	Publications date is published before 2015.
Papers addressing the relationship between nickel and downstream processing.	Papers that do not discuss the relationship between nickel and downstream processing.
Papers addressing the relationship between bauxite and downstream processing.	Papers that do not discuss the relationship between bauxite and downstream processing.
Papers addressing the relationship between cobalt and downstream processing.	Papers that do not discuss the relationship between cobalt and downstream processing.
Papers addressing the relationship between silica and downstream processing.	Papers that do not discuss the relationship between silica and downstream processing.

Example: Papers discussing the downstream processing of nickel, bauxite, cobalt, silica, or GeoDashboard that were published more than five years ago will be excluded as they exceed the publication year criteria. However, if a paper has a very high level of relevance to the downstream processing of nickel, bauxite, silica, and cobalt in Indonesia, it will still be included even if it exceeds the publication year criteria.

a. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) Flow Chart

The collection, selection, and analysis of data in this study use the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) method. The selection process is divided into four parts (filters): Identification, Screening, Eligibility, and Included. The data collection using the PRISMA method is divided into four stages (see Figure 1).

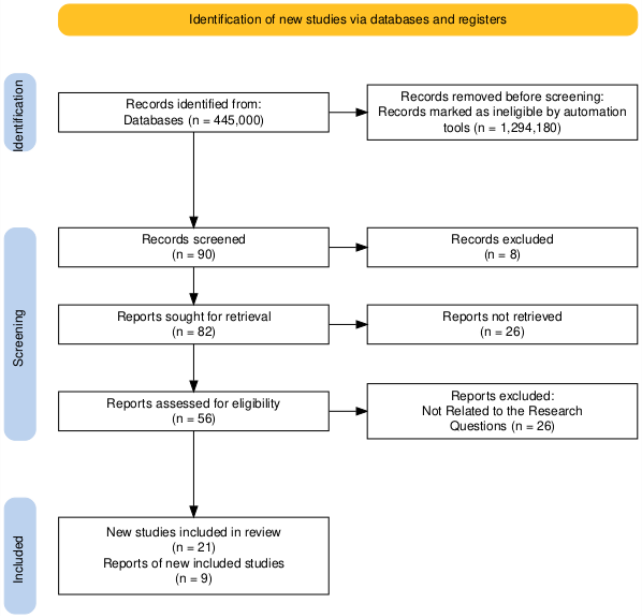

Figure 1. Systematic Review Process

b. Study Limitations

There are certain limitations in conducting this study. Some relevant papers are behind paywalls, and certain journal websites are not affiliated with Bina Nusantara University. Another external limitation is that we are not fully involved in the development process of the PetaHilirisasi.

III. EXPERIMENTAL RESULT

The results of this paper are the answers to the research questions mentioned earlier. The answers are based on a literature study that involved searching through various academic sources such as Google Scholar, Scopus, and others. From this search, a total of (jumlah referemsi) relevant papers.

RQ1: How downstream mineral sector policies are being implemented in various countries?

Based on the results of this research, it shows that mineral downstreaming policies vary across countries, depending on their economic priorities, resource endowments, and industrial strategies. Some countries implement strict export bans to force domestic processing, while others rely on incentives and partnerships to attract investment in value-added industries.

Indonesia, for example, has implemented an export ban on raw nickel and other minerals to develop its domestic smelting and battery industry. This policy aims to increase national revenue, create jobs, and establish Indonesia as a key player in the electric vehicle (EV) supply chain [9]-[12], [14]. Furthermore, Indonesia's downstream policy has been significantly influenced by its cooperation with China, particularly in the nickel processing sector. Studies highlight that Chinese investments in Indonesia's nickel industry have accelerated industrial development, particularly in the smelting sector, while also raising concerns over environmental sustainability and resource dependency [25]. Neilson et al. [26] further elaborate on how resource-based industrial policies shape Indonesia's position in global production networks, while Wau et al. [27] analyze the economic impacts of Indonesia's downstreaming policies, providing crucial insights into their effectiveness and broader economic implications.

Australia, in contrast, focuses on providing fiscal incentives and regulatory support to encourage value-added mineral processing without imposing export restrictions [4]. China has adopted a mix of export quotas, local content requirements, and state subsidies to maintain its dominance in rare earth minerals and other strategic resources. This policy ensures that most processing activities remain within China, strengthening its control over global supply chains [13]. Wang and Wang [28] discuss how China has extended its industrial upstream-downstream model to Africa, offering a comparative perspective on its downstreaming strategy relative to other nations.

Meanwhile, Botswana has successfully implemented a model of resource beneficiation by mandating local processing of diamonds through partnerships with global mining companies [1]. Zimbabwe has imposed domestic refining requirements for platinum group metals (PGMs), though challenges such as inadequate infrastructure and high operational costs have hindered its success [1], [2]. In the United States, recent policies emphasize securing domestic supply chains for critical minerals by investing in local extraction and refining capabilities, partly as a response to geopolitical tensions [14].

RQ2: What are the cases of downstream disputes that occurred in various countries and the solutions implemented and the impact arising from the implementation of mineral sector solutions?

The downstreaming policies in the mineral sector have led to several international trade disputes, particularly concerning export restrictions and resource nationalism. For instance, Indonesia's ban on nickel ore exports to stimulate domestic processing was challenged by the European Union at the WTO, arguing that it violated free trade principles [12], [11]. Indonesia defended its policy as a strategy to enhance industrialization and economic sovereignty [10]. Research by Barizi and Triarda [29] further explores the role of resource nationalism in Indonesia's nickel downstreaming policies, analyzing its impact on global supply chains and the broader economic consequences. While such policies may contribute to industrial upgrading, they often fail to achieve environmental and social improvements [4].

A similar case occurred in China, where the government implemented export quotas and local content requirements on rare earth elements, tungsten, and molybdenum, leading to WTO disputes [13]. This restriction was designed to protect domestic industries but was ruled as a violation of trade agreements, forcing China to revise its policies. Such disputes highlight the tension between resource nationalism and international trade obligations [2]. In Zimbabwe, the government enforced domestic refining requirements to maximize the value of its Platinum Group Metals (PGM) industry. However, studies suggest that the lack of adequate infrastructure and investment made the policy difficult to implement effectively [1]. Meanwhile, Botswana's approach to resource beneficiation mandates has been more successful due to long-term planning and stable governance, serving as a potential model for other nations [1].

Furthermore, research by Mwesiga, Kaswamila, and Mwakipesile [30] examines how resource nationalism affects community benefits, providing insights into the social and economic implications of such policies in various countries. This underscores the broader impact of downstreaming policies beyond trade disputes, highlighting their effects on local communities and economic development.

The United States and Australia have pursued different strategies, relying on investment incentives and regulatory support to develop domestic supply chains [4], [14]. These policies align with global concerns over securing critical minerals for energy transitions [5]. Additionally, research suggests that energy availability is a crucial factor in determining the success of downstream processing, as seen in the copper industry, where energy costs heavily influence integration feasibility [6].

Despite these policies aiming to promote economic independence, studies indicate that downstream industrialization efforts often face challenges such as legal disputes, economic retaliation, and environmental concerns [9]. Moreover, the paradox of downstream policies is that while they seek to increase domestic value addition, they may also discourage foreign investment and create market inefficiencies if not carefully designed [3].

Thus, while downstreaming policies can contribute to economic development, their implementation requires careful balancing between national interests, trade commitments, and sustainable development goals.

RQ3: How do technology and Global Value Chains (GVCs) or other materials that can substitute nickel, copper, bauxite, and silica sand affect downstream policies?

The development of technology and the dynamics of Global Value Chains (GVCs) have a significant impact on downstream policies for mineral resources such as nickel, copper, bauxite, and silica sand [15]. Based on the World Investment Report (WIR) from 1991 to 2024, digital transformation has become a major factor in changing investment patterns and global supply chain management strategies. The WIR 2017 and WIR 2018 reports highlight the role of digitalization as a driver of foreign direct investment

(FDI), especially in technology-based sectors such as e-commerce, fintech, and cloud services. The integration of digital technology in the industrial sector enables downstream processes to be carried out more efficiently through the application of artificial intelligence (AI), Internet of Things (IoT), and blockchain technology in the refining and production of metal-based materials. This requires the government to improve digital infrastructure to support the competitiveness of the downstream industry, including encouraging FDI investment in the technology sector and adopting big data in the mineral supply chain to improve efficiency and transparency [16], [17].

In another example, technological innovation has also contributed to changes in investment in global value chains, as discussed in WIR 2013 and WIR 2020. The use of advanced technology in supply chains allows multinational companies to be more flexible in determining where to invest, so countries with lower production costs and attractive downstream policies have a greater chance of attracting investors. To remain competitive, Indonesia needs to develop industrial policies that encourage investment in downstreaming and build strategic partnerships with multinational companies to adopt more advanced materials processing technologies [18], [19].

Beyond digitization, downstream policies also face challenges from the emergence of substitute materials that can replace conventional minerals in various industrial applications. Some of the trends noted in the WIR show that material innovations such as sodium or hydrogen-based batteries can be an alternative to nickel in the electric vehicle industry, while composite materials or graphene have the potential to replace copper in various electrical applications [20], [21]. In addition, the increasing use of recycled materials in manufacturing industries based on the circular economy also contributes to reducing dependence on new raw materials. These changes require the government to anticipate the possible decline in demand for certain types of minerals by strengthening research and development (R&D) policies to create more value-added mining-based product innovations [22].

The COVID-19 pandemic has also impacted on the structure of global value chains, as identified in WIR 2020 [19], [23], [24]. The pandemic has pushed multinational companies to differentiate their supply chains and accelerate the adoption of digital technologies to reduce the risk of production disruptions. In the context of downstream, these changes require developing countries to strengthen digital infrastructure and encourage the implementation of AI and big data-based technologies in the mining sector to improve efficiency and competitiveness [23], [24].

Altogether, technology and global value chains play an increasingly crucial role in determining the direction of downstream policies. The integration of digitalization in industrial processes offers opportunities to improve efficiency, but also poses challenges in investment competition. Meanwhile, the emergence of substitutes demands diversification and innovation strategies to keep downstream industries relevant in the global market. Therefore, countries that are able to adopt new technologies, build digital-based industrial ecosystems, and develop adaptive downstream strategies will have a competitive advantage in facing global investment dynamics.

IV. CONCLUSION

PetaHilirisasi is a bright and innovative platform that can support the downstream of raw materials such as nickel, bauxite, cobalt and silica in Indonesia. By leveraging geospatial technology and artificial intelligence, the platform provides data-driven solutions to optimize the downstream process, improve operational efficiency and minimize environmental impact. The downstreaming of raw materials through PetaHilirisasi not only enhances the added value of Indonesia's natural resources but also supports sustainable development and green technology in the future.

AUTHOR'S CONTRIBUTION

The study was conceived and designed by Andrea Sutanto, Raditya Tamam and Alexander A S Gunawan. The systematic literature study is performed by Andrea Sutanto and Raditya Tamam. The writing is guided by Alexander A S Gunawan. All authors read and approved the manuscript.

AVAILABILITY DATA AND MATERIALS

This study utilized publicly available literature from Google Scholar and Scopus. These databases were specifically chosen to ensure comprehensive coverage of the relevant research.

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