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Optimization Model Applying Lean Six Sigma for the Reduction of Time in the Granting of Authorization Titles for Mining Projects

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Abstract

According to the Ministry of Energy and Mines (2024), in 2023, the mining sub-sector represented 10.4% of Peru's Gross Domestic Product (GDP), while in 2024, exports of key metals (silver, copper, lead, zinc) reached US$3,104 million. In January 2024, mining investment amounted to US$441,703,467, 61.9% higher than the figure recorded in the same month of the previous year. These indicators confirm that mining is essential for the Peruvian economy, representing one of the main sources of income and generating direct and indirect employment. As a world leader in the production of copper, gold, and silver, Peru occupies a strategic role in international markets. However, the long times in granting authorization titles for mining projects affect the competitiveness of the sector and the attraction of investments. This research addresses this problem by applying Lean Six Sigma tools to optimize administrative processes, reduce operating costs, and accelerate project execution. Improving efficiency in the Mining Concessions Department will strengthen Peru's position as an attractive destination for mining investment, especially in a context of growing global demand for minerals. Therefore, the results of this study contribute to the sustainability and competitiveness of a crucial sector for the national economy.

Keywords
Mining, digitalization, administrative processes, lean six sigma, and development times.

1. Introduction
The development of mining in Peru is essential to the economy. According to the Mining Statistical Bulletin (2024), between 2015 and 2024, the sector contributed more than S/55,855 million in royalties, fees, and expiry fees. According to García (2023), approximately 60% to 63.9% of Peruvian exports come from mining, which is a key source of foreign currency that facilitates the import of goods and technologies for the country's development. This activity positions Peru as a world leader in the production of minerals such as copper, gold, and silver, essential for

international markets. However, the process of granting mining permits faces serious inefficiencies, with deadlines that can exceed a year.

The institution studied, attached to the Ministry of Energy and Mines, is responsible for managing mining concessions, guaranteeing rights to mineral resources (Geological, Mining and Metallurgical Institute 2025). Currently, the compliance rate is 6%, significantly lower than the 41% achieved by the entity in charge of managing electricity concessions. These delays affect the sector's competitiveness, limiting the attraction of foreign investment and undermining Peru's perception as a mining destination. Worldwide, several countries have more efficient systems. For example, Ireland occupies a privileged position with a regulatory environment that encourages mining investment. It is worth remembering that if the processing of procedures is indefinitely extended or lacks transparency, trust diminishes, costs are generated, and this can cause investors to prefer to invest elsewhere (Montoya 2020). This underscores the urgent need to modernize administrative processes in Peru, strengthening its position in the competitive international mining market and fostering a more dynamic and sustainable economy.

Given this context, it is essential to highlight the mining projects in Peru in the pre-feasibility stage registered to date through 2025. First, First Quantum, in collaboration with Rio Tinto, has invested approximately US$2.4 billion in the pre-feasibility studies for "La Granja," a major copper project located in the Querocoto district, in the northern region of Cajamarca. This is estimated to be one of the largest copper deposits in the world, with a published inferred mineral resource of 4.32 billion tons and a copper grade of 0.51%. Likewise, First Quantum has fully acquired the "Haquira" copper mining project, which is also in the pre-feasibility stage. This deposit is projected to reach an annual production of 200,000 tons of copper (Energiminas 2025).

On the other hand, mining companies currently operating in Peru continue to invest in expansion projects to increase their production. A notable case in point is the Tía María project, developed by Southern Copper Corporation in the department of Arequipa. With an investment of US$1.802 billion, it is expected to achieve an annual production of 120,000 tons of copper. Similarly, the Inmaculada mining project, managed by Hochschild Mining, represents another significant investment in the sector. With a budget of US$1.319 billion, this underground gold and silver mine will be located in the department of Ayacucho, covering 20,000 hectares and comprising a total of 40 mining concessions (Poncec 2025).

With all this said, it can be said that mining is the strongest pillar of the Peruvian economy, surpassing other sectors in terms of contribution to GDP, attraction of foreign investment, and generation of foreign currency. While other sectors such as manufacturing, agriculture, and tourism are relevant, none achieve the level of economic impact that mining activity has. The execution of the aforementioned prefeasibility and expansion projects reflects confidence in the country's mining potential and its ability to continue increasing growth. This research seeks to implement Lean Six Sigma tools to identify and resolve the main obstacles in the process, with the goal of reducing the average time to seven months. The proposed solutions include process digitization, staff training, and standardization of procedures.

Delays in the granting of mining permits are a persistent issue that affects the efficiency of the sector. There are several fundamental causes contributing to these delays, with the structure of the process being one of the most significant factors. The granting of authorization permits in mining follows a series of sequential steps, which means that if one of the stages is delayed, it interrupts the entire sequence and delays the final authorization. This sequential approach can create a bottleneck, affecting the overall speed of the process. Another critical factor contributing to the delays is the lack of digitalization of the procedures. Currently, most of the paperwork related to the granting of permits is still done manually, which not only makes the processes tedious but also much slower and more prone to errors. Although technological alternatives have been proposed to streamline the procedures, such as the implementation of digital platforms, the adoption of these solutions has been limited and has not been generalized nationwide. This lack of progress in digitalization adds an additional layer of complexity to the process, prolonging waiting times and hindering efficiency in the processing. As a response to this problem, the development of a mobile application has been proposed to simplify the process, reduce bureaucracy, and optimize response times (IIMP 2023).

Delays in obtaining mining permits not only affect operational efficiency but also have a direct impact on the competitiveness of the sector. First, high operational costs are one of the most evident effects. Each delay in granting permits generates additional costs for companies, which must deal with periods of inactivity or the need to maintain

idle resources while awaiting the necessary authorization. These unforeseen costs directly affect the profitability of companies, limiting their ability to compete in an increasingly demanding global market.

In addition to the additional costs, uncertainty in the planning of mining projects becomes another important challenge. The unpredictability of permit approval timelines makes it difficult for companies to make informed strategic decisions. Without knowing for certain when the necessary authorizations will be obtained, companies cannot properly plan their resources, schedules, and investments, reducing their ability to execute projects efficiently. This uncertainty also increases the risk associated with mining projects, creating greater insecurity among investors. Finally, bureaucracy and delays in granting mining permits can generate disinterest from potential investors. The lack of an agile and efficient permit processing system can discourage investors from committing capital to the sector, thus limiting the flow of investments needed for the development of new projects. This disinterest negatively impacts the sector's ability to grow and develop, directly affecting its competitiveness both nationally and internationally (IIMP, 2023).

1.1 Objectives

The main objective of this project is to propose a model to improve management processes in the area of Mining Concession Management.

The specific objectives are as follows:
Diagnose the causes that slow down the process of granting authorization titles for projects in the mining sector.
Identify the causes that slow down the process of granting authorization titles for projects in the mining sector.
Propose alternatives for improvement in the process of granting authorization titles for mining projects
Validate the results of the application of the proposals for improvement in the process of granting authorization titles for mining projects

2. Literature Review

2.1 Public management

A study on the acquisition process of goods and services in a public entity is detailed regarding public management. To achieve this, interviews were conducted with the individuals involved, and documentation related to legal and financial aspects was evaluated. This analysis is valuable as it contextualizes how a Peruvian public entity operates and provides a basis for studying the process (Agama et al. 2020). On the other hand, an article examines the governance and management of a public organization in Iraq. According to Worya et al. (2022), to conduct research in a post-conflict country, an exhaustive study was carried out, and partial least squares equations were modeled using a sample from the local municipality, focusing on sustainable development.

2.2 Mining

According to Dammert (2020), Peru has a strong presence in the mining sector, excelling in silver, copper, and gold production. Additionally, the demand for these minerals is directly linked to internationalization, which has accelerated over time, leading to increased demand. This growth is a key variable to consider when studying the process of granting authorization titles, as the rise in requests requires the administrative system to be prepared to handle the situation. Otherwise, it results in an inefficient process (Kang et al. 2023).

Furthermore, Torres (2021) outlines the necessary conditions for executing a mining project in a study. This includes a series of steps to follow, discussions, and stipulations in legal agreements. This information is essential as it is considered during the legal analysis of the process. Additionally, Feruque (2021) presents a complex scenario in an Asian country, highlighting the institutional impact by studying the resource extraction process at a macro level and the role of foreign investment in this sector.

2.3 Granting of Authorization Titles for Projects

An influential factor that slows down the process of granting authorization titles for mining projects is the presence of incomplete data and complex variables involved. The accelerated process of internationalization of mining companies in various countries has led to an increase in investment demand for projects, generating an oversaturation of information (Kang et al. 2023).

Furthermore, according to Maldonado-Matute (2019), the lack of technological innovation is another factor that must be considered. Innovation and entrepreneurship are not only about materializing ideas that lead to the creation of new products or services but also about improving or reinventing existing processes or products within an organization.

On the other hand, public perception of the mining development process is closely linked to trust in the government, as it is expected to act in accordance with the principles established in related institutions. In the case of mining, when governments demonstrate competence and transparency in sector management, they foster positive attitudes toward mining development (Poelzer 2023).

3. Methods

A macro design based on Lean Six Sigma is proposed to optimize the process of granting mining authorization titles in Peru, reducing processing times from 12 months to 6.4 months. To achieve this, three key components are implemented:

- Digitization of application submissions through an app with Poka Yoke to eliminate errors and reprocessing.
- Optimization of technical analysis and mining registry using DMAIC and staff training.
- Standardization of the process through digital manuals.

Validation through simulation in Arena shows improvements in key indicators, such as a reduction in reprocessed applications (from 50% to 18%), an increase in productivity (from 0.0481 to 0.051), and higher compliance (from 6% to 19.66%). These changes strengthen the competitiveness of the Peruvian mining sector, expedite investment, and promote the country's economic growth.

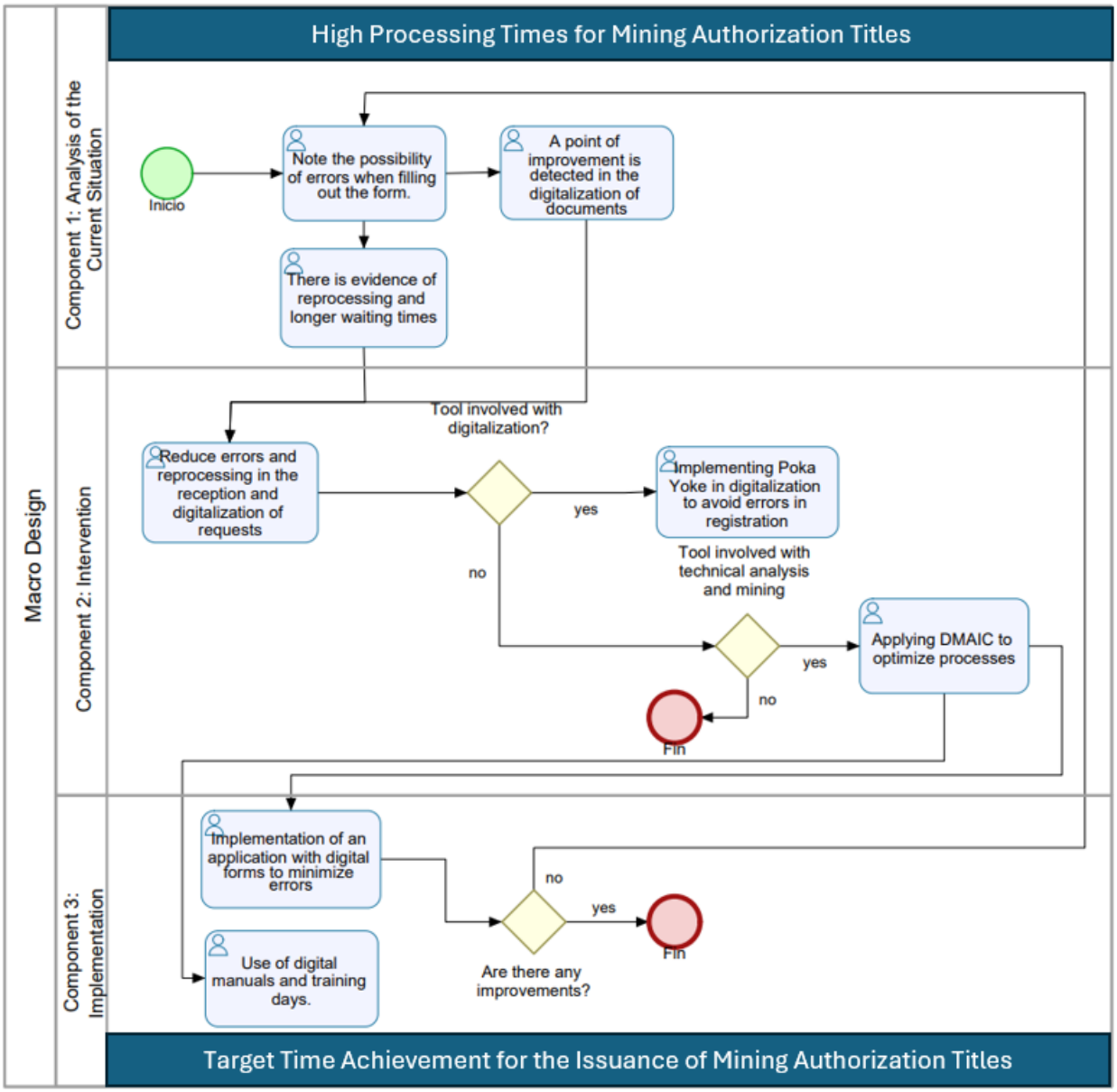

Figure 1. Macro Design

As a first step in the analysis, an evaluation was conducted to identify the root causes of this issue, with the goal of explicitly understanding the factors contributing to the main problem. The first identified cause was errors in the procedure due to the presence of inaccurate or false data. This issue was detected in the first stage, related to the application submission process. In this stage, the applicant arrives at the organization and is asked to complete a form where they must provide various details such as the name of the request, substance type (metallic or non-metallic), the geographical location of the project, petitioner details, etc. It is important to highlight that this application is currently filled out manually on a physical sheet of paper.

The second identified cause was complaints and legal claims from local communities, which result in delays due to observed case files. This issue arises in the legal study phase, where attorneys analyze each application in detail to ensure compliance with established regulations and agreed-upon filters. The goal is to prevent cases of environmental contamination in surrounding areas and to limit the number of individuals exposed to toxic emissions during the mineral extraction process.

Regarding the third cause, it was determined that limited human resource capacity stems from inadequate staff training. As a result, execution times are prolonged in two key stages: mining registry and technical analysis. Once data registration is complete, it is necessary to verify whether the requested area is an unclaimed mining zone. Afterward, the technical aspects of the application are reviewed. However, the lack of adequate training or specialized knowledge among staff significantly slows down the process.

The fourth identified cause was the excessive accumulation of applications. This issue is closely linked to limited human resource management capacity and was identified throughout nearly the entire process, but mainly during the documentation phase. Once an application is submitted, it must be officially recorded. However, the documentation process is time-consuming, and applications continue to arrive regardless of whether the staff has completed the previous records. As a result, there is an accumulation of pending applications that further delays the authorization process.

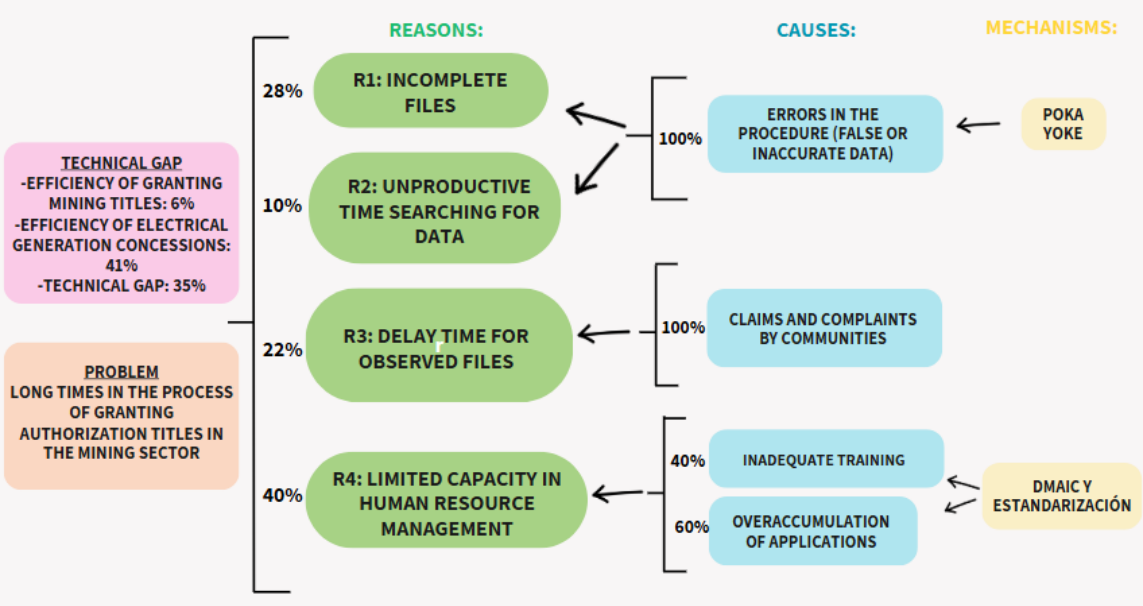

Figure 2. Problem Tree

3.1 Component 1: Application Submission

For this component, the Poka Yoke sequential tool will be implemented. This tool is designed to ensure order and proper sequence in a process, preventing any advancement to the next step unless the previous task has been correctly completed.

The implementation will involve the development of an application that enables structured form completion. This digital application will include mandatory fields, ensuring that all required information is provided before submission. This approach eliminates incomplete data entries and enhances the accuracy of the process.

Figure 3. Interface design.

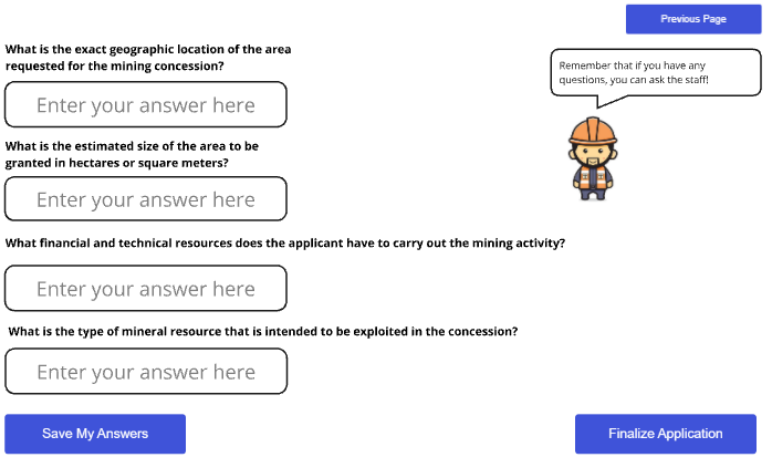

Figure 4. Application design.

3.2 Component 2: Mining Registry and Technical Analysis

For this component, the DMAIC methodology will be applied. This approach allows for mapping and optimizing the procedure through five phases: Define, Measure, Analyze, Improve, and Control.

The implementation will include training sessions and knowledge assessments, aiming to provide personnel with the necessary expertise to efficiently perform tasks related to mining registry and technical analysis. This proposal also ensures better information management among employees and collaborators. A brief, interactive group evaluation will be conducted to reinforce key aspects that require further clarification.

To facilitate these training sessions, the institution has designated a dedicated training space where the following topics will be covered: Detailed procedures for mining registry and technical analysis and main objectives, key performance indicators, and control measures. The primary objective of this tool is to enhance staff capabilities and ensure the proper execution of process

Figure 5. Space enabled for training sessions.

3.3 Component 3: Mining Registry and Technical Analysis

For this component, the work standardization tool will be implemented. This tool is designed to develop a uniform work system that facilitates the effective execution of tasks by employees.

The implementation of this tool will be carried out through the creation of digital manuals, allowing institutional collaborators to efficiently perform activities related to the mining registry and technical analysis stages.

This phase involved the design and review of the content of the digital manuals, as well as the development of an access method and the distribution of the manuals to institutional users involved in the standardized process stages. Notably, access to the manuals will be provided through the SharePoint platform. This will allow all employees to log in using their corporate email accounts via a shared link distributed to all members of the institution.

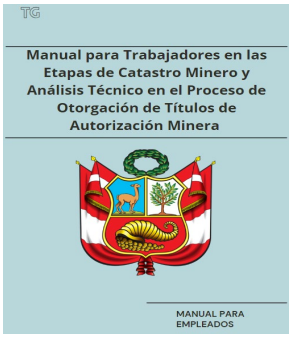

Figure 6. Manual covers.

4. Validation and Results

For the functional validation design, a process simulation was conducted using Arena software. A prior validation design was carried out, which will be described below.

In the first phase, the user or client visits the institution and proceeds to the reception desk to fill out the mining application form. This form must contain accurate, clear, and transparent information. All applicants complete the application at the reception desk, which takes a time uniformly distributed between 0.99 and 1.66 hours. In this stage, ten employees are involved. Generally, 50% of the applications are filled out correctly, while the remaining 50% require reprocessing due to errors, false, or inaccurate data, leading to incomplete applications and delays in processing times.

Once the first phase is completed, applications move to the second stage, which is the documentary area, where the information is digitized and stored in a database, forming a file. This phase is carried out by the same operators involved in filling out applications. 6% of the applications are processed immediately, while the remaining percentage requires reprocessing. This activity takes a time uniformly distributed between 32.5 and 45.5 minutes.

Once the file is created, it moves to the third station of the process, called "Mining Registry." In this phase, a review is conducted to determine whether the requested mining area is available, preventing complications such as applications overlapping with archaeological sites. This activity takes three months and involves 20 people. 85% of the applications proceed to the next stage, while the remaining 15% face claims or complaints, preventing further processing and terminating their application. Approved applications move on to the next phase, called "Mining Concession." This stage is divided into two sub-areas:

1. Technical Analysis – evaluates the technical feasibility of the application. This process takes two months and involves fifteen operators. 92% of the applications are approved for legal analysis, while 8% are rejected.
2. Legal Analysis – takes approximately three months. In this phase, 5% of the applications are definitively excluded from the process.

If everything is in order, the institution's director and president proceed to sign the file, which takes one day, thus concluding the process.

From the simulation results, a significant variation was observed in different indicators. The first is the total process time, which showed a notable improvement. In the initial model, the duration was 240 days (8 months), while in the improved model, it was reduced to 193 days (6.4 months). Additionally, progress was observed in other key indicators, such as the number of reprocessed applications, productivity, and compliance, reflecting a positive impact on process optimization.

Table 1. Comparison of Indicators Before and After Improvement

	As Is	To Be	Variation	Value Obtained in Pilot Test
Number of Reprocessed Requests	50%	15%	35%	18%
Productivity	0.0481	0.06	24.74%	0.051
Compliance	6%	20%	14%	19.66%

4.1 Percentage of Reprocessed Applications

The results achieved demonstrate significant progress toward the main objective of reducing processing times. Key indicators show a notable improvement: the number of reprocessed applications per month decreased from 50% to 18% in the pilot test, representing a considerable reduction in reprocessing cases.

To calculate this indicator, the number of reprocessed applications was divided by the total applications submitted, using data provided by the institution, obtaining an initial result of 50%. The target ("To-Be") is to reduce reprocessed applications to 15%. Based on the difference between the current state ("As-Is") and the desired goal, a variation of 35% was calculated. As a reference, a more ambitious objective was considered, supported by Mechato's study, which suggests that after process improvements, it is possible to reduce reprocessed applications to 5%. This indicator will help monitor errors in procedures caused by inaccurate or false data.

4.2 Productivity

Regarding productivity, the indicator increased from 0.0481 to 0.051, equivalent to a 6.03% increase compared to the initial value, bringing it closer to the target value and reflecting a more efficient use of Man-Hours in the process. Productivity was calculated by dividing the number of concessions or titles issued by the total Man-Hours reported by the entity.

The proposed target is to raise this index to 0.06, representing a desired variation of 24.75% between the current state and the "To-Be" objective. A study by Raul and Torres supports that, after implementing improvements, productivity can increase up to 65.9%. This indicator will help identify the impact of inadequate staff training on productivity.

4.3 Compliance

On the other hand, the percentage of compliance in title issuance over the applications submitted increased from 6% to 19.66%, achieving a significant improvement that brings the process closer to the 20% target. This increase suggests an enhancement in the institution's capacity to manage and process applications. The calculation of this indicator was made by dividing the number of titles issued by the number of applications submitted, obtaining a current value of 6%.

The "To-Be" target is to increase the percentage of titles issued to 20%, reflecting a 14% variation between the current state and the goal. As a reference, Huallpa's study indicates that with process improvements, this indicator could increase by 10%.

These advancements in reducing processing times and improving key indicators have a positive impact. Streamlining these processes contributes to the development of mining projects, promotes job creation, and fosters investment in the country, indirectly strengthening the national economy.

4.4 Process Capability Index (Cp)

This is an indicator that evaluates the process capability, considering defined limits, assuming that the process is centered.

Table 2. CP after improvement

Indicators	Value (months)
Upper specification limit (USL)	7
Lower specification limit (LEL)	6
Standard deviation after improvement	0.50
CP Index	0.33

4.5 Adjusted Process Capability Index (Cpk)

This indicator evaluates the actual capability of the process, regardless of whether it is centered within the defined limits (Upper Specification Limit – USL and Lower Specification Limit – LSL).

Table 3. Cpk After Improvement

Indicators	Value (months)
Upper specification limit (LSE)	7
Media after improvement	6.4
Lower specification limit (LEL)	6
Desviación estándar después de la mejora	0.50
CPK Index	0.27

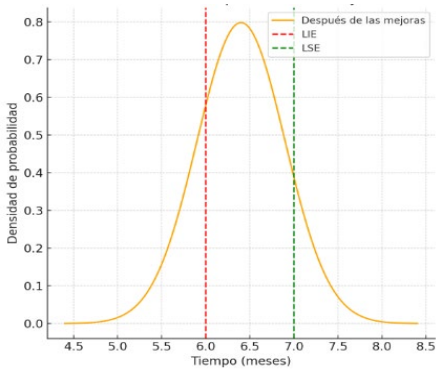

Figure 7. Distribution curve diagram after improvement

The average processing time has been reduced to 6.4 months, with lower dispersion (a standard deviation of 0.5 months). The entire distribution falls within the specified limits (USL = 7 months and LSL = 6 months), indicating improved process control.

However, despite a Cp value of 0.33, which suggests a reduction in variation, the specified limits became stricter, reducing the process's potential capability. The Cpk value was 0.27, meaning that although the mean is better centered, the actual capability remains limited due to the strict limits.Even though the average processing time improved after implementing Lean Six Sigma tools, the low Cp and Cpk values indicate that the improvements have not yet achieved adequate process control. A Cp below 1 and a Cpk significantly lower than 0.5 suggest that the process is still far from being "capable" in terms of quality.
The process can be classified as Level 1 (Initial) in Lean maturity, as initial tools and improvements have been applied to reduce processing times. However, the process is neither consistent nor robust, as it fails to meet the desired quality standards. This implies that the Lean implementation is still in its early stages and requires a greater focus on reducing variability and centering the process.

4.6 Economic or Financial Benefits

Faster Investment Execution: By granting mining project authorization titles more efficiently, mining companies can start operations sooner. This is beneficial as it boosts investments and stimulates the national economy.
Increased Competitiveness: Countries with faster and less complex authorization processes (such as in this case, for mining projects) become more attractive to potential investors.
Higher Employment Generation: By streamlining the authorization process, mining projects can begin operations sooner, fostering job creation.
Increased Tax Revenue: With mining projects in operation, companies start generating income, contributing to tax payments, royalties, and other financial contributions to the Peruvian government.

The faster approval of mining concessions due to process improvements could increase foreign investment, attracting between $2 billion to $5 billion, depending on the project's scale. With mining representing nearly 10% of the Gross Domestic Product (GDP), this increase could boost the economy by 0.5% to 1% annually, with projected profits of up to $1.5 billion. Additionally, the creation of 3,000 to 5,000 jobs (direct and indirect) could generate higher salaries, benefiting the national economy.

5. Discussion

The implementation of process improvement proposals to reduce the approval times of mining titles not only optimizes operational efficiency but also significantly improves response times for applicants. This advancement contributes to a more positive perception from users, promoting a more efficient and responsible management environment.

Firstly, a 32% reduction was achieved in the number of requests that had to be reprocessed due to incorrect data entry. This result was achieved through the development and implementation of an application with restrictions that prevent the input of erroneous or incomplete information. This improvement has been crucial as it has allowed the process to be streamlined, enabling requests to quickly enter the workflow and receive prompt responses. We identified that requests rejected due to this type of incident not only caused delays but also negatively impacted the economy of mining companies. The economic impact depends on several factors, such as the size of the mine (small, medium, or large), the type of investment, and the duration of the projects.

Additionally, the objective was to increase the productivity of the staff responsible for the management and issuance of mining concessions. During the pilot phase, the productivity of the staff increased from 0.0481 to 0.051, demonstrating the positive impact of specialized training programs. This result highlights the importance of having a better-trained team, as their efficiency in performing their tasks allows mining permits to be properly evaluated and quick responses to be provided to applicants. Aside from the economic impact of streamlining this process, it is also important to highlight other key aspects mentioned in the article, such as the generation of employment benefiting thousands of citizens (Ministry of Energy and Mines, 2021).

Finally, the projected increase in the compliance rate of issued mining titles was 14%, but the results of the pilot phase reached 19.66%, coming very close to the established goal. This result demonstrates that the instruction manuals for technical analysis and mining registry were essential tools in optimizing processes, contributing to improved efficiency in the issuance of permits (González, 2022).

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Biographies

Susana Silva Ordaya holds a Bachelor's degree in Industrial Engineering from the University of Lima, with a solid track record in logistics and commercial management. Her experience includes key roles in companies from various sectors, including Mediterranean Shipping Company, where she specialized in documentation, and Viettel, where she held roles in the commercial area. Currently, she is part of Sandvik's Parts and Services team, contributing to operational efficiency and strategic support in the mining sector. Passionate about mining logistics, Susana focuses on process optimization, efficient resource management and continuous improvement, providing innovative solutions in a highly dynamic and challenging environment.

Ivana Tejada Alarcón is an Industrial Engineering student at the University of Lima with experience in the commercial and financial sectors. Currently, she is an intern at Banco Falabella in the Active Financial Products team, where she has strengthened her analytical and strategic skills in financial product management. Her role has enhanced her competencies in data analysis, process optimization, and financial decision-making. With a results-driven approach and strong learning ability, she aims to further develop professionally in the financial and industrial sectors, contributing effectively to her field.

Richard Nicholas Meza-Ortiz is the Demand, Distribution and New Business Planning Lead of Ajeper, and additionally serves at the University of Lima as a Professor. Mr Meza is a qualified Industrial Engineer (University of Lima), and holds a Masters in Strategic Business Administration from Pontification Universidad Catolica Peru (PUCP). He has led multiple supply chain networks in multiple locations, both domestically and internationally for large bulk consumers, retailers, automotive industries and agricultural clients. He has been responsible for managing processes covering S&Op, Operations, Planning, Warehousing, Distribution planning, Procurement, Comex, Digital transformation and Reverse logistics