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RISK MANAGEMENT IN GRANITE QUARRYING: A BRAZILIAN CASE STUDY

Dissertation to obtain a Master's Degree in Law, in the specialty of Law and Security

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Anti-Plagiarism Statement

I hereby declare that the work I present is my own work and that all my citations are correctly acknowledged.

I am aware that the use of unacknowledged extraneous materials and sources, constitues a serious ethical and disciplinary offence.

Hannah de Medeiros Chaia
September 15, 2024

DEDICATION

To my parents, Álvaro and Viviane, for teaching me the power of education, supporting me unconditionally, and inspiring me with integrity and the drive to be better each day.

To my loving husband, Rodrigo de Vasconcelos Esteves, for the countless brainstorming sessions, unwavering support, comforting me through the challenges of writing (and life), and believing in me when I doubted myself.

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To my dear grandmother, *vovó* Sandra, my biggest fan and the love of my life, whom I lost without a final goodbye after embarking on this path as an immigrant in Portugal.

And to Kimi, Mika, and Balu.

Quote and Other Conventions

The citation and reference format used in this dissertation follows the NP 405 guidelines. This standard has been adhered to throughout the document to ensure consistency and accuracy in the presentation of sources.

The language adopted for this dissertation is Canadian English. All text, including citations and references, is presented in accordance with the conventions and spelling of Canadian English. However, the *resumo* is written in Portuguese from Portugal, aligning with the specific linguistic norms of that variety.

Declaration of Character Count Compliance

I hereby declare that the body of this dissertation contains a total of 186.732 characters, including spaces and footnotes. I also declare that the abstract comprises 1.701 characters and the *resumo* comprises 1.889 characters, including spaces in both.

LIST OF ABBREVIATIONS

ABIROCHAS – Brazilian Association of the Ornamental Stone Industry

ABNT – Brazilian Association of Technical Standards

ANM – National Mining Agency

ANTT – National Land Transport Agency

BCM – Business continuity management

BS – British Standard

CEDEC – Civil Defense Centre

CREA-ES – Regional Council of Engineering and Agronomy of Espírito Santo

CONAMA – National Environmental Council

COSO – Committee of Sponsoring Organizations of the Treadway Commission

CRFB – Constitution of the Federative Republic of Brazil

DER-ES – Department of Buildings and Highways of the State of Espírito Santo

ERM – Enterprise risk management

FINDES – Federation of Industries of Espírito Santo

GDP – Gross domestic product

HR – Human Resources

IBAMA – Brazilian Institute of Environment and Renewable Natural Resources

ICMBio – Chico Mendes Institute for Biodiversity Conservation

IDAF – Institute of Agricultural and Forestry Defense of Espírito Santo

IEC – International Electrotechnical Commission

IEMA – State Institute of Environment and Water Resources

IGC-USP – Geosciences Institute of the University of São Paulo

ILO – International Labour Organization

IPHAN – National Institute of Historical and Artistic Heritage

ISO – International Organization for Standardization

KFRI – Kerala Forest Research Institute

KonTraG – Control and Transparency Act (Germany)

LI – Installation License

LO – Operation License

LP – Preliminary License

MMA – Ministry of Environment

MME – Ministry of Mines and Energy

MTE – Ministry of Labour and Employment

MTP – Ministry of Labour and Social Security

NBR – Brazilian Norm

NR – Regulatory Norm

ORM – Operational risk management

PAE – Economic Exploitation Plan

PPE – Personal protective equipment

PRAD – Project for the Recovery of Degraded Areas

PSL – Simplified Mining Plan

RASP – Risk architecture, strategy and protocols

SCRM – Supply chain risk management

SEAMA – State Secretariat for the Environment and Water Resources

SESMT – Specialized Services in Safety Engineering and Occupational Medicine

SINDIMARMORE – Union of Marble and Granite Workers of Espírito Santo

SINDIROCHAS – Ornamental Stone, Lime and Limestone Industry Union of Espírito Santo

SL – Support level

STF – Supreme Federal Court

STJ – Superior Court of Justice

TAH – Annual Rate per Hectare

TS – Technical Specifications

UN – United Nations

WHO – World Health Organization

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ABSTRACT

Granite quarrying is a significant industrial activity that drives economic growth while presenting a range of complex challenges. This dissertation, titled "Risk Management in Granite Quarrying: A Brazilian Case Study", delves into the complexities of managing risks within granite quarrying industry in Brazil. The core issue explored is the fragmented nature of current risk management practices in the industry, where risks are often addressed in isolation, resulting in incomplete solutions and unresolved critical vulnerabilities. The study offers a comprehensive overview of granite quarrying operations, including its socioeconomic benefits, environmental and human security challenges, and the historical and technical aspects of quarrying processes in Brazil. It also contextualizes the legal and regulatory frameworks and the systematic issues in law enforcement. Despite this broad context, the primary focus is on risk management strategies and the main challenges faced by granite quarrying companies. Through a detailed case study of a quarry located in Espírito Santo, the research underscores the limitations of fragmented risk management approaches and advocates for a holistic strategy. This integrated approach improves risk management by addressing business, legal, financial, operational, and safety aspects collectively. The findings emphasize the need for an integrated, continuous, proactive risk assessment process supported by a dedicated risk management framework to bolster organizational resilience and effectively manage the multifaceted risks inherent in granite quarrying.

Keywords: Granite quarrying, risk management, risk mitigation strategies, operational resilience

RESUMO

A extração de granitos é uma atividade industrial significativa que impulsiona o crescimento económico, ao mesmo tempo que apresenta uma série de desafios complexos. Esta dissertação, intitulada "Gestão de Riscos na Extração de Granitos: Um Estudo de Caso Brasileiro", explora as complexidades associadas à gestão de riscos na indústria de extração de granitos no Brasil. A questão central abordada é a natureza fragmentada das práticas atuais de gestão de riscos no setor, onde os riscos são frequentemente tratados de forma isolada, resultando em soluções incompletas e vulnerabilidades críticas não resolvidas. O estudo oferece uma visão abrangente das operações de lavra de granito, incluindo os benefícios socioeconómicos, os desafios ambientais e de segurança humana, e os aspetos históricos e técnicos da extração no Brasil. Também contextualiza os quadros legais e regulatórios e os problemas sistemáticos na aplicação da lei. Apesar deste contexto abrangente, o foco principal está nas estratégias de gestão de riscos e nos principais desafios enfrentados pelas empresas de lavra de granito. Através de um estudo de caso detalhado de uma empresa especializada na lavra de granito localizada no Espírito Santo, a pesquisa destaca as limitações das abordagens fragmentadas de gestão de riscos e defende uma estratégia holística. Esta abordagem integrada melhora a gestão de riscos ao abordar conjuntamente os aspetos empresariais, legais, financeiros, operacionais e de segurança. Os resultados enfatizam a necessidade de um processo integrado, contínuo e proativo de avaliação de riscos, apoiado por uma estrutura dedicada à gestão de riscos, para reforçar a resiliência organizacional e gerir de forma eficaz os riscos multifacetados inerentes à extração de granito.

Palavras-chave: Extração de granito, gestão de riscos, estratégias de mitigação de riscos, resiliência operacional

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INTRODUCTION

In an era of rapid industrialization and infrastructure expansion, granite quarrying has emerged as a major driver of economic growth, particularly in resource-rich regions. In Brazil, this industry plays a crucial role in both local and national economies, generating employment and contributing significantly to development. However, the operational complexities of granite quarrying introduce a wide range of multifaceted risks that extend beyond the industry itself, impacting human safety, environmental sustainability, legal and financial stability, and overall operational continuity. These challenges highlight the need for effective risk management to ensure the industry's long-term sustainability and mitigate its broader impacts.

This study investigates the risks associated with granite quarrying, with a particular focus on Espírito Santo, a Brazilian state known for its extensive granite production. The problem at the heart of this research is the fragmented nature of current risk management practices in that industry. Often, risks are addressed in isolation, leading to incomplete solutions and leaving critical vulnerabilities unaddressed. This highlights the need for a holistic, integrated approach to risk management that aligns operational, financial, legal, and safety concerns.

The methodology of this study is based on a case study design, utilizing interviews, surveys, and document analysis to gather data. The sample includes a range of key stakeholders from the Espírito Santo granite quarrying industry, such as workers, managers, and technicians. Both qualitative and quantitative data analysis were applied to provide a well-rounded understanding of the risks involved. Ethical considerations were carefully managed, with all participants providing informed consent and confidentiality being strictly upheld throughout the research process.

Intending to underline this object, the first chapter provides an overview of granite quarrying operations, exploring the socioeconomic advantages and the security challenges. The second chapter covers the fundamentals of risk management, outlining key concepts and strategies. The third chapter focuses on the legal and regulatory framework governing risk management and granite quarrying in Brazil, setting the stage for the fourth chapter. The final chapter presents a detailed case study from Espírito Santo, offering practical insights into risk identification, assessment, and mitigation in granite quarrying operations.

1 GRANITE QUARRY OPERATIONS: AN OVERVIEW

Granite quarrying has a history deeply intertwined with the evolution of human civilization. The use of ornamental stones dates back to prehistoric times, notably the Stone Age, when early humans crafted tools, covered their deceased with stones, and constructed burial domes from these materials. From ancient monuments to modern architectural wonders, granite has been a prized material for construction and artistic expression due to its durability, beauty, strength, and versatility.

According to the Geosciences Institute of the University of São Paulo (IGC-USP)[1], granite is an igneous rock formed through the slow cooling and solidification of molten magma beneath the earth's surface, composed mainly of quartz, feldspar, and mica.

This durable, majestic, and visually striking stone has captivated civilizations for centuries. Historical records indicate that granite was already used as a building material and decoration in ancient Egypt, found in obelisks, columns, monuments, and burial chambers. Likewise, the Romans and the Greeks also used granite for paving and building, and iconic historical monuments like the Great Pyramid of Giza, the Temple of Luxor, the Parthenon, and the Pantheon, not to mention the castles and cathedrals of Medieval Europe, have granite in their structure.[2]

In the Modern Age, with the development of quarrying and processing techniques, granite was used to build palaces, churches, ornaments, and sculptures. It also became an interior design trend for flooring, tiling, countertops, luxurious baths, pools, and accent features.

Granite's unique combination of hardness, durability, and a diverse range of captivating colours and patterns is a sought-after material across multiple sectors. Consequently, granite quarrying plays an essential role in the socioeconomic development of numerous countries globally, a tradition that traces back to ancient Egypt.

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[1] IGC USP. – **Granito**. São Paulo: Instituto de Geociências da Universidade de São Paulo, [n.d.]. [Accessed 12 January 2024]. Available at: https://didatico.igc.usp.br/rochas/igneas/granito/.

[2] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.

Nowadays, granite is quarried in various locations and regions around the world. Some notable granite-producing nations include India, Brazil, China, Iran, Turkey, Spain, Italy, Norway, Finland, South Africa, and the United States, to name a few, being responsible for employment creation and revenue generation in all these countries.

The granite industry encompasses a series of processes, including extraction, cutting, polishing, and the production of final goods delivered to end consumers. This study, however, will concentrate exclusively on the quarrying of granite.

Despite contributing to the socioeconomic development of various regions and societies, granite quarrying has significant downsides. The work in a granite quarry is risky, involving heavy and dangerous machinery, explosives, cutting tools, and other inherent hazards. These conditions pose serious threats to the health and lives of workers. Additionally, the environmental impacts of extractive activities can lead to catastrophic and irreversible consequences.

1.1 Unveiling Socioeconomic Prospects and Security Complexities of Granite Quarry Operations

The granite quarry industry plays a pivotal role in driving economic development across various regions worldwide, providing various socioeconomic benefits alongside presenting complex security challenges. Through a multidimensional lens, this subchapter delves into the intricate balance between the advantageous aspects that contribute to economic growth, employment generation, and infrastructure development, probing the industry's role in fostering local economies and livelihoods while also addressing the potential drawbacks associated with environmental impact and human-centred risks that require responsible management within the industry.

By examining these dynamics, this analysis highlights key factors shaping both prosperity and security in granite quarrying, laying the theoretical groundwork for understanding the risks and opportunities examined in the Brazilian case study presented in Chapter 4. By addressing how these global issues play out locally, it offers practical insights into applying risk management strategies for sustainable industry practices.

1.1.1 Brief analysis of the socioeconomic advantages of granite quarrying

The mining industry holds considerable economic importance and brings forth a myriad of socioeconomic advantages vital for the development of regions engaged in this sector. Its crucial role in bolstering the gross domestic product (GDP) and generating government revenue through mining companies is further enhanced by its significant contribution to employment generation and its positive impact on local industries.

Among the benefits of granite quarrying is the substantial economic growth facilitated by creating employment opportunities directly within the quarries and indirectly through associated industries, as well as by enhancing local businesses, supporting related sectors, and fostering community development.

A single granite quarry company requires different suppliers for a wide variety of goods and services, such as machinery, parts, diesel oil, diamond cutting wire, maintenance, trucks and other automobiles, other oils and greases, uniforms, logistics, electronic equipment, personal protective equipment, not to mention every material resource necessary to operate any company, such as energy and water resources, office supplies, facilities, technological resources, human resources, and so on.

Each of these goods and services generates or precedes an entire supply chain. The economic impact of the granite quarry industry reverberates throughout the supply chain, showcasing its intricate network of interdependencies.

At the forefront of this supply chain are the quarry operations themselves, which rely on numerous suppliers to enable the extraction process. For instance, a quarry needs machinery suppliers to provide the necessary equipment. These machinery suppliers, in turn, rely on parts suppliers to furnish the components needed for manufacturing. The parts suppliers further extend the chain by sourcing materials from screws and tools suppliers, who, in turn, depend on iron or steel suppliers for their production.

This chain continues to unfold, encompassing various suppliers and sub-suppliers, each playing a vital role in ensuring the viability of granite extraction operations. Additionally, the administrative structure supporting the company, spanning financial, legal, commercial, administrative, logistics, and human resources sectors, is integral to the supply chain's functionality, further amplifying the economic impact across different sectors.

Moreover, the granite quarry industry serves as the foundational link in a vast supply chain that culminates in the provision of final products to end consumers. At the onset of this chain, granite is extracted from quarries by specialized mining companies equipped to handle the rigorous quarrying process. Once quarried, the granite blocks are then purchased by granite processing companies specialized in cutting the blocks into slabs, initiating the second phase of the production process. These companies utilize advanced cutting techniques and machines to transform raw granite blocks into more manageable forms that can be further refined into various final products.

In the subsequent stage, the slabs are meticulously crafted into an array of final products, ranging from floors and sinks to skirting boards, furniture, and decorative pieces. These refined products are then acquired by traders who act as intermediaries in the distribution process, purchasing them from manufacturers and wholesalers. Finally, these traders resell the final products to end customers through stores, completing the chain and delivering granite-based solutions to individuals seeking quality and aesthetics for their homes or businesses.

Thus, the economic impact of the granite quarrying industry extends far beyond the quarry sites, also affecting the network of interconnected businesses and services essential to its operation.

In this context, granite quarries often serve as essential sources of employment for local communities, generating numerous jobs both directly and indirectly through related industries. Additionally, these quarries provide opportunities for individuals with limited formal education, as a significant proportion of the tasks involved are manual and can be undertaken by unskilled labour with proper training. This not only contributes to the overall socioeconomic development of the region but also helps reduce local social inequality.

Furthermore, the mining industry contributes to infrastructure development and capital formation within developing countries. Some companies even actively engage in community support through their social programs.

The mere presence of a granite quarry can act as a catalyst for socioeconomic development[3], often leading to the formation of significant commercial activity centres and even entire communities around quarry sites, highlighting the potential sociocultural benefits of granite quarrying.

Moreover, granite is indispensable in construction, making substantial contributions to infrastructure development, such as buildings, roads, and bridges. This enhances the overall infrastructure quality and stimulates economic activities by generating employment, attracting investments, and fostering business growth in related sectors. Due to its durability and aesthetic appeal, granite is highly sought after in the construction and interior design industries. Its capacity to provide structures with longevity and visual appeal further elevates property values and attracts economic activity to surrounding areas.

Nations endowed with abundant granite resources frequently export granite blocks, slabs, and finished products, fostering economic relationships and contributing significantly to international trade. This trade in granite acts as a catalyst for economic growth, strengthening collaborations and partnerships between nations involved in production and importation alike.

As a result of these factors, the socioeconomic impact of the granite quarry industry is profound, leading many countries to deem it an activity of social interest and public utility.

The socioeconomic advantages of granite quarrying underscore its pivotal role in driving prosperity, with significant impacts both locally and globally. Its contributions to economic growth, job creation, and infrastructure development highlight the industry's positive influence. However, these benefits must be balanced against the security challenges inherent in quarrying operations. In the following sections, the environmental and human challenges associated with the industry will be explored, offering a more comprehensive understanding of its dual nature. This analysis will provide the necessary context for the case study in

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[3] CHIGONDA, Tanyaradzwa – **An assessment of the benefits and costs of black granite quarrying in Mutoko District, Zimbabwe: A socio-cultural, biophysical and economic approach**. Journal of Sustainable Development in Africa, v. 12, nº 3. Clarion: Clarion University of Pennsylvania, 2010. [Accessed 12 January 2024]. Available at: https://www.researchgate.net/publication/328048567_AN_ASSESSMENT_OF_THE_BENEFITS_AND_COSTS_OF_BLACK_GRANITE_QUARRYING_IN_MUTOKO_DISTRICT_ZIMBABWE_A_SOCIO-CULTURAL_BIOPHYSICAL_AND_ECONOMIC_APPROACH. ISSN: 1520-5509.

Chapter 4, where these issues will be considered in the context of a real-world quarrying operation.

1.1.2 Security challenges in granite quarrying: an environmental approach

While contributing significantly to the socioeconomic landscape, granite quarrying is not without environmental consequences. The adverse impacts on nature resulting from granite quarry operations are severe and often irreversible. Although efforts can be made to mitigate these impacts, the intrinsic nature of mining activities inevitably leads to environmental degradation.

Quarries are sites where rock, sand, gravel, dimension stone, and construction aggregates are excavated from the ground. To access high-quality quarry products, the layer of soil or rock known as "overburden" or "sterile"[4] must be removed to reach the fresh rock beneath.[5] This process generates considerable waste, which, if not properly managed, can exacerbate soil erosion and lead to significant environmental degradation.

Waste generation poses a significant challenge for the granite quarry industry. Overburden, waste rock, debris, and other materials moved during mining activities often lack economically viable concentrations of target materials and are, therefore, left unprocessed. These materials are typically stored in piles or dumps on mine sites,[6] serving as repositories for the by-products and unusable materials of the quarrying process. Due to the potential environmental impact of these sterile piles, quarrying companies often undergo an environmental licensing process to ensure proper disposal of the waste.

Besides the removal of extensive vegetation cover, the process of granite quarrying also involves the alteration of landscapes, leading to the destruction of ecosystems and the displacement of local flora and fauna. This habitat loss can trigger cascading effects on biodiversity and disrupt ecological balances.

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[4] *Sterile* is the term used in economic geology for mineral substances that have no economic value.

[5] HARYATI, A. [et al.] – **Overburden determination for quarry prospecting using seismic refraction: a case study**. IOP Conference Series: Earth and Environmental Science 244 012033. Kuantan: IOP Science Publishing, 2019. [Accessed 15 July 2024]. Available at: https://iopscience.iop.org/article/10.1088/1755-1315/244/1/012033/pdf.

[6] GOVERNMENT OF BRITISH COLUMBIA – **Tailings Management**. [s.l.]: BC Mining Information, [s.d.]. [Accessed 15 July 2024]. Available at: https://mines.nrs.gov.bc.ca/tailings-management.

The removal of vegetation not only diminishes the aesthetic and ecological value of the area but also displaces wildlife that relies on these habitats for shelter, nesting, and foraging. The consequences extend beyond the immediate quarry site. The displaced wildlife, often struggling to find alternative habitats, may face increased resource competition, predation risks, and altered migration patterns. This disruption may have long-term consequences on biodiversity, potentially leading to the decline or even extinction of particular plant and animal species in the affected areas.

Granite quarrying activities impart yet another significant impact on animal life, stemming from the audible effects of blasting and the operation of heavy machinery. The resultant noise and vibrations from quarrying operations can disrupt nearby wildlife's behaviour and communication patterns, interfering with essential activities such as mating rituals and inducing stress. Additionally, the noise pollution attributed to blasting has been associated with adverse outcomes, including the premature onset of labour in pregnant animals.

Given these factors, in Brazil, where the case study is situated, granite quarrying is typically prohibited in fully protected areas, such as national parks and biological reserves.

Moreover, the various stages of granite quarrying, including drilling, cutting, and crushing, generate airborne dust particles. This dust, not rare, is composed of crystalline silica, among other substances, and poses respiratory health risks to wildlife and nearby communities as inhalation of these particles can lead to respiratory ailments and compromise the well-being of organisms in the vicinity. It is incumbent upon granite quarrying companies to implement measures to mitigate these impacts, reflecting both their legal responsibilities and ethical commitments.

Besides, due to its nature, the quarrying of granite not only alters the physical landscape but also has profound implications for the aesthetics of the surrounding environment. As quarries expand and develop, they often transform once-pristine landscapes into industrial zones marked by massive excavation sites, overburden dumps, and altered topographies. This alteration can result in a degradation of the natural surroundings' visual appeal, impacting the region's scenic beauty.

When a quarry site is abandoned or undergoes mine closure without subsequent rehabilitation efforts, discernible and harmful alterations to the landscape become evident. The dispersion of sizable boulders, the exposure of excavated pits, and the accumulation of residual waste material are among the conspicuous features marking the aftermath. These transformations represent the physical scars of past quarrying activities and harbour the potential to induce adverse environmental effects.

In addition to the significant environmental risks and impacts already discussed, granite quarrying is an inherently finite process, underscoring the irreversible nature of resource depletion. Once the stone is quarried, it is gone forever. Without sustainable management, granite quarrying can accelerate the depletion of natural resources, leaving lasting impacts on the environment.

These potential outcomes highlight the severe environmental consequences associated with granite quarrying in the absence of proper planning and risk managing. In extreme cases, the impacts extend beyond resource depletion and environmental alterations, including the lowering of water tables, desiccation of marshes, and increased soil erosion due to soil destabilization. Collectively, these factors can lead to severe consequences such as slope instability, occurrences of rockfalls, and mudflows. These events may culminate in environmental disasters, posing tangible risks to surrounding ecosystems, nearby communities, and critical infrastructure.

In Brazil, where the case study company operates, granite quarrying is strictly regulated by a comprehensive environmental licensing process, and failure to adhere to these regulations constitutes a criminal offence. Given the significant environmental risks associated with granite quarrying, it is essential that all stakeholders – from industry leaders to local governments – commit to responsible and sustainable practices. Implementing effective risk mitigation strategies, conducting thorough environmental assessments, and maintaining rigorous ongoing monitoring are critical to minimizing adverse environmental impacts and ensuring that quarrying activities align with both legal requirements and ethical standards.

1.1.3 Security challenges in granite quarrying: a human approach

Moving beyond ecological concerns, it becomes evident that the health and well-being of workers and the communities situated near quarry sites are significantly affected by quarry operations. This section delves into the multifaceted dimensions of security concerns through a human lens, exploring the risks and implications for the health, safety, and overall quality of life of those directly and indirectly impacted by these operations.

Directly affected individuals include on-site workers who operate heavy machinery, blasters, and industrial equipment and are consequently exposed to dust, noise, and potentially harmful substances. Conversely, indirectly affected individuals encompass residents living near quarry sites and those who share roads and highways with quarry operations.

Worker health and safety represent the first and perhaps most challenging security concern in quarry operations. The nature of these activities – which involve the use of heavy machinery, blasting, working at height, and handling large stone blocks – makes them inherently dangerous. Without adequate safety measures, workers face a heightened risk of accidents, injuries, long-term health issues, and even fatalities.

The operation of heavy equipment, such as drilling rigs, loaders, excavators, and stone-cutting machinery is particularly hazardous. Improper handling or malfunctioning equipment can lead to crushing injuries, entanglement, and other severe mechanical accidents, ranging from minor injuries to the loss of a limb or even death.

Moreover, quarrying tasks often involve repetitive motions, heavy lifting, and awkward postures, which can contribute to musculoskeletal disorders. These ergonomic challenges can result in chronic pain and long-term health issues for workers.

Additionally, the use of explosives to break apart large rock formations introduces significant risks. When poorly executed, blasting can lead to uncontrolled rock fragmentation, debris release, or premature detonation, endangering not only workers but also nearby communities.

These factors necessitate the implementation of responsible occupational safety practices by granite quarrying companies. In Brazil, the setting for the case study in Chapter 4, regulations require companies with 50 or more employees in high-risk industries, like granite quarrying, to establish specialized safety services (SESMT) to meet strict safety standards.

Furthermore, the cutting, drilling, and crushing of granite generate substantial amounts of airborne dust, which poses a risk to the respiratory health of workers due to the presence of silica dust.

Silica is a major component of many types of rock, and granite can contain high levels of crystalline silica, making the presence of silica dust common in quarry sites. Inhaling airborne silica dust can lead to potential health hazards, particularly respiratory diseases like asthma, bronchitis, silicosis, chronic obstructive pulmonary disease and lung cancer.

According to the International Labour Organization (ILO)[7], "silicosis is an incurable lung disease caused by inhalation of dust that contains free crystalline silica" with the potential to cause "progressive and permanent physical disability", affecting and killing thousands of workers every year around the world. It results in inflammation and scarring of the lung tissue, impairing the affected individual's ability to breathe. Silicosis is characterized by symptoms such as persistent cough, shortness of breath, chest pain, and fatigue. In severe cases, it can lead to respiratory failure and death.

If a worker becomes permanently disabled or dies due to silicosis, the mining company may be legally obligated to pay a lifetime pension to the affected employee or their dependents. The duration of these payments is determined by the courts, based on local life expectancy estimates. As such, silica exposure not only represents a grave health risk to employees but also constitutes a significant legal and financial liability for the mining company.

However, the extent of silica exposure can vary based on factors such as the specific type of stone being quarried, the methods used in quarrying, the presence of effective dust control measures, and the use of personal protective equipment by workers. Some quarries may

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[7] INTERNATIONAL LABOUR ORGANIZATION – **Silicosis**. [s.l.]: Encyclopaedia of Occupational Health and Safety, 2011. [Accessed 24 January 2024]. Available at: https://www.iloencyclopaedia.org/part-i-47946/respiratory-system/item/418-silicosis.

implement measures to minimize silica dust, while others may have higher levels of exposure if preventive measures are not adequately enforced.

Furthermore, quarrying activities and blast warning sirens significantly contribute to elevated noise levels in quarry environments. Workers directly involved in these operations face health risks from prolonged exposure to high noise levels, including hearing impairment and loss. Therefore, implementing robust occupational safety measures, such as providing personal protective equipment and employing noise reduction strategies, is crucial to protect workers' hearing health.

Communities located near quarry sites may also experience disturbances from continuous noise, which can lead to heightened stress levels and a diminished quality of life for residents. The impact of quarrying on these communities varies between rural and urban settings. In rural areas, the impact is generally minimal due to the greater distance between residential areas and the quarry, which reduces direct exposure to noise and other disturbances.

In contrast, urban quarry sites are more prone to issues such as noise pollution, suspended dust, and debris, which can damage nearby structures and, in rarer cases, pose safety risks to the residents. Consequently, urban quarries often lead to greater conflicts with local communities.

Traffic and transportation also present significant concerns related to quarry operations. The movement of heavy machinery, trucks, and other vehicles for transporting materials, sterile, large stone blocks, processed stone, and equipment to and from the quarry sites increases vehicular traffic on local roads and highways. This can lead to congestion, noise and air pollution, and dirt accumulation on roads. Additionally, the risk of accidents rises, particularly on roads not designed for heavy industrial traffic.

Granite quarrying companies are generally held objectively or indirectly liable for any road accidents involving the transportation of blocks quarried from their mines. This liability implies that in the event of a fatal or serious accident, the company will face a range of consequences, including legal repercussions, financial losses, commercial setbacks, and damage to its reputation. These multifaceted impacts underscore the importance of stringent safety measures and robust risk management strategies to mitigate potential liabilities associated with the transportation of quarry products.

Moreover, quarrying often triggers land use conflicts, as mining companies lease land from surface owners, offering payments and royalties, but disagreements over terms and competition with other land uses, like agriculture or residential development, can create community tension. Such disputes, along with debates about the benefits and drawbacks of quarrying, can deepen divisions within the community. In rare instances, quarrying may require the relocation of local populations, further aggravating this scenario.

Additionally, granite quarrying drastically alter the aesthetic and cultural character of an area by destroying natural features and introducing industrial elements that clash with the values of local communities. This visual disruption – especially when it affects landscape visible from cultural or historical sites, residential areas, or tourist destinations – can diminish the scenic beauty and tranquillity of the region, leading to lower property values and reduced tourism potential.

The extensive impacts on both human well-being and the environment highlighted thus far emphasize the interconnection of security challenges in quarrying. When these challenges are neglected, the consequences can be catastrophic. For instance, in Kerala, India, the overlap of illegal granite quarries with ecologically sensitive zones has led to devastating outcomes.

According to the Kerala Forest Research Institute (KFRI)[8], Kerala has a total of 5.924 functioning granite quarries, of which only 750 operate with the mandatory permission from the Department of Mining and Geology, meaning over 87% are operating illegally. In the Kavalappara region, where a massive landslide in 2019 tragically claimed 59 lives, research indicates that unregulated quarrying significantly contributed to the disaster by causing geological instability in the area.[9]

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[8] C.J., Alex; SAJEEV, T. V. – **Mapping of Granite Quarries in Kerala, India: A critical mapping initiative**. Thrissur: Kerala Forest Research Institute, 2017. [Accessed 15 July 2024]. Available at: https://www.researchgate.net/publication/321491359_Mapping_of_Granite_Quarries_in_Kerala_India_A_critical_mapping_initiative.

[9] SHAJI, K. A. – **Quarrying in Kerala needs more monitoring, indicates environmental panel**. [s.l.]: Mongabay-India, 2020. [Accessed 15 July 2024]. Available at: https://india.mongabay.com/2020/11/quarrying-in-kerala-needs-more-monitoring-indicates-environmental-panel/.

Illegal granite quarry operations often prioritize maximizing profits at the expense of essential environmental, health, and safety standards, disregarding both the future environmental impact and the significant human costs involved. However, the risks extend beyond unregulated activities. Quarrying operations that lack proper environmental licensing, fail to adhere to mining and environmental regulations, and neglect health and occupational safety standards also pose severe threats. Without compliance and investment in adequate infrastructure and personal protective equipment, both human lives and local ecosystems, including fauna and flora, are put at significant risk.

Neglecting environmental and human security risks endangers lives and exposes mining companies to significant legal and financial liabilities. Thus, sustainable practices and responsible risk management are crucial not only for the preservation of the environment and human well-being but also for the long-term viability of the quarrying business itself.

Every action taken by an organization carries a degree of responsibility, and neglecting this responsibility can jeopardize its future. As V. Sajeev,[10] head of the forest health division at KFRI, noted, while mining is essential for construction and the economy, it should not come at the cost of the environment, human life, or safety.

The risks associated with granite quarrying are not only human and environmental but also financial and legal, with significant corporate and reputational implications. Although granite quarrying companies often address these risks in isolation – focusing separately on geological, environmental, health and safety, financial, and legal aspects – it is increasingly clear that an integrated approach is essential for effective risk management. This highlights the urgent need for comprehensive risk management practices within the granite mining industry to safeguard both its operations and its future.

To thoroughly address the safety challenges of granite quarrying, it is essential to consider the level of local development, as it greatly impacts operational standards and practices. Hence, this study must narrow its focus to a specific context. This approach will allow for a more realistic and detailed examination of the security issues in granite quarrying, rather than

[10] SHAJI, K. A. – **Quarrying in Kerala needs more monitoring, indicates environmental panel**. [s.l.]: Mongabay-India, 2020. [Accessed 15 July 2024]. Available at: https://india.mongabay.com/2020/11/quarrying-in-kerala-needs-more-monitoring-indicates-environmental-panel/.

offering a broad, generalized overview. In this context, the following section will explore the specifics of granite quarrying in Brazil, providing a detailed analysis that will set the stage for the case study in Espírito Santo, Brazil, presented in Chapter 4.

1.2 Granite Quarrying in Brazil: History, Relevance, and Challenges

Brazil stands as one of the world's leading producers of granite, renowned for its diverse and high-quality stone deposits. The country's rich geological formations and favourable economic conditions have fostered a thriving granite quarrying industry, particularly concentrated in Espírito Santo. This subchapter provides an overview of the granite quarry operation scenario in Brazil, examining the historical development, economic significance, and current landscape of the industry. By understanding the attributes and challenges Brazilian granite quarries face, the specific case study presented in Chapter 4 is better contextualized, highlighting the balance between economic opportunities, local development, and risk management within this key sector.

During the 18th century, amidst Portuguese rule in Brazil and the peak of gold exploration in Minas Gerais, stone emerged as a preferred building material, supplanting traditional wattle and daub construction methods. Stone quarrying during this era relied on rudimentary manual techniques involving stone drilling and wedge installation, with transportation and handling demanding substantial labour.[11]

Through the 20th century, ornamental stone quarrying persisted in small, primitive quarries across Brazil. It was the exploitation of this natural resource in Espírito Santo in the late 60s that catalyzed the nation's ornamental stone industry, with the city of Cachoeiro de Itapemirim becoming a pivotal hub for processing, initially focusing on marble and later expanding to granite.

From the 1980s onward, global demand for granite increased, prompting increased production activities in Espírito Santo. This growth accelerated notably in the 1990s, mirroring global trends and aided by the introduction of diamond wire cutting in quarries.

[11] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.

The modernization of mining, processing, and finishing technologies marked the 21st century.[12]

The transition from exporting raw blocks to exporting polished slabs marked Brazil's evolution at the turn of the century, enhancing the value chain. This heightened international demand for Brazilian granite spurred further development and expansion of processing facilities in southern Espírito Santo, necessitating a corresponding growth in suppliers of equipment, materials, and services to support the burgeoning industrial complex.

Thus, while granite quarrying in Brazil has a historical presence dating back to the 18th century in various regions, its technological advancement gained momentum from the 1960s onward, with significant prominence emerging only in the late 1980s as a distinct mining activity.

Today, the sector not only holds a prominent position in Brazil's export agenda but also on the national level, with Espírito Santo being particularly distinguished for its contribution to the industry.

According to the Brazilian Association of the Ornamental Stone Industry (ABIROCHAS)[13], Brazil's ornamental stone sector is of significant economic importance, with approximately 1.100 active quarries and 12.000 companies operating within the production chain. This industry generates 150.000 direct jobs and over 360.000 indirect jobs, with commercial transactions in domestic and international markets exceeding US$ 6 billion, highlighting its crucial role in the national economy.

In the context of the domestic market and the consumption of ornamental stones, granite constituted 44% of the total ornamental stone consumption in 2023,[14] underscoring the material's prominence.

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[12] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.

[13] ABIROCHAS – **Balanço do setor brasileiro de rochas ornamentais e de revestimento em 2023**. Informe 01/2024. Brasília: Associação Brasileira da Indústria de Rochas Ornamentais, 2024. [Accessed 17 July 2024]. Available at: https://abirochas.com.br/wp-content/uploads/2024/03/Informe-01_2024-Balanco-2023.pdf.

[14] Ibidem.

On the global stage, Brazil ranked as the fourth largest producer of ornamental stones in 2023, following China, India, and Turkey. The primary export destinations for Brazilian ornamental stones included the United States, China, Italy, Mexico, the United Kingdom, Spain, Canada, Argentina, Australia, and Germany. Notably, Brazil is the leading supplier of these materials to the US market.[15]

A significant portion of Brazilian ornamental stone exports is concentrated in Espírito Santo, which accounts for 82% of the country's total export volume in this sector. In 2023, Espírito Santo's exports reached US$ 914.7 million, representing 82.2% of the country's total.[16] From January to June 2024, the state earned US$ 498.618.382 from ornamental stone exports, constituting approximately 82.86% of Brazil's revenue from these exports.[17]

This small state's dominance is particularly striking when compared to other exporting states. For instance, Minas Gerais, the second-largest exporter, generated US$ 112.3 million in 2023, highlighting a substantial disparity when contrasted with Espírito Santo's US$ 914.7 million. In June 2024 alone, Espírito Santo earned US$ 75.708.407 from ornamental stone exports, far surpassing Minas Gerais at US$ 9.914.077 and Ceará at US$ 5.938.316.[18]

The Brazilian ornamental stone industry is currently navigating several sectoral transformation agents. According to ABIROCHAS[19], key factors include the consolidation of diamond wire technology, domestic and international market demand fluctuations, the high cost and scarcity of specialized labour, and expanding environmental and mining licensing requirements, alongside legislative conflicts.

While the diamond wire technology consolidation has enhanced productivity in quarries and slab cutting, other transformation agents present significant challenges and uncertainties.

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[15] ABIROCHAS – **Balanço do setor brasileiro de rochas ornamentais e de revestimento em 2023**. Informe 01/2024. Brasília: Associação Brasileira da Indústria de Rochas Ornamentais, 2024. [Accessed 17 July 2024]. Available at: https://abirochas.com.br/wp-content/uploads/2024/03/Informe-01_2024-Balanco-2023.pdf.
[16] Ibidem.
[17] SINDIROCHAS – **Exportações de rochas**. Informativo mensal 06/2024. [s.l.]: Sindicato da Indústria de Rochas Ornamentais, Cal e Calcários do Espírito Santo, 2024. [Accessed 17 July 2024]. Available at: https://www.sindirochas.com/downloads/relatorios/exportacoes-de-rochas-junho-2024.pdf.
[18] Ibidem.
[19] CHIODI FILHO, Cid – Agentes de transformação setorial. In ABIROCHAS – **O Setor Brasileiro de Rochas Ornamentais**. Informe 05/2018. Brasília: Associação Brasileira da Indústria de Rochas Ornamentais, 2018. [Accessed 17 July 2024]. Available at: https://abirochas.com.br/wp-content/uploads/2022/01/Agentes-Transformacao-Setorial-2021.pdf.

Fluctuations in domestic and international markets have created variability in the demand for slabs and finished products, posing concerns for processing companies. Additionally, the high cost and scarcity of specialized labour, a current challenge across Brazil's industrial sector, affects both mining and processing companies. In response, leading companies are increasingly investing in automation and transitioning part of their industrial workforce into service providers to mitigate these economic pressures.

Moreover, the expansion of environmental and mining licensing requirements, coupled with frequent legislative changes and jurisdictional conflicts, adds legal uncertainty and risks to the entire ornamental stone sector.

As one of the world's leading producers of granite, Brazil navigates a complex terrain of environmental regulations, socioeconomic impacts, and operational complexities. These dynamics underscore the necessity for effective risk management strategies tailored to local conditions and practices. To ensure long-term viability in the Brazilian granite sector, mining companies must proactively address these challenges by prioritizing sustainable operations, environmental stewardship, and community well-being.

The following section will explore the practical stages of the quarrying process, demonstrating how historical and socio-economic factors – such as advancements in quarrying technology and socio-economic development – impact daily operations and decision-making in the granite quarrying industry.

1.3 The Quarrying Process: A Symphony of Precision and Expertise

To begin, it is essential to clarify that this analysis does not delve into the technical aspects of Geology and Engineering. Instead, the focus here is to offer a practical perspective on the granite quarrying process, enabling a clearer understanding of the inherent risks associated with this activity. By examining the steps and methods employed in granite quarrying, a better comprehension of the potential hazards and challenges involved can be achieved.

Granite quarrying is a complex and meticulous process that demands precision, expertise, and a deep understanding of geological formations. The process begins long before the first cut is made into the earth, encompassing a range of preparatory activities that ensure the viability and sustainability of the quarry.

Once the groundwork is laid, the quarrying phase unfolds as a carefully orchestrated series of steps, from the initial removal of overburden to the precise cutting and handling of the granite blocks. Each phase requires specialized equipment and skilled labour to ensure efficiency and safety.

However, the responsibilities of quarry operations extend far beyond mere quarrying. Effective waste management and handling of overburden, as well as the strategic closure of quarries, are critical components that safeguard environmental integrity and ensure the longevity of quarry sites.

The granite quarrying process encompasses three critical phases: prospecting and mineral research, mining, and recovery.

1.3.1 Phase 1 – Foundations of quarrying: strategic planning and site selection

As the name implies, the prospecting and mineral research phase is divided into two distinct steps. The prospecting step focuses on identifying and locating ornamental stone deposits, which forms the basis for subsequent exploration. This is followed by mineral research, where detailed evaluations assess the deposit's potential and gather essential data to inform precise mining planning.

This phase encompasses a series of stages and analysis to ensure the exploration's economic and technical viability. The detailed geological research analyses aspects of the deposit and stone that determine its suitability as an ornamental material for the proper planning of mining operations and the success of the mining enterprise.

These aspects can be categorized into two groups: geological and non-geological. The following table summarizes the key elements of each category, providing an overview of the main considerations relevant to granite quarrying operations.

Geological	Non-Geological
▪ Stone composition ▪ Colour ▪ Texture ▪ Homogeneity ▪ Hardness ▪ Quality ▪ Oxidation level ▪ Infrastructure ▪ Structure ▪ Mode of occurrence	▪ Climate ▪ Laws ▪ Economic factors ▪ Environmental aspects ▪ Transportation ▪ Logistics ▪ Political scenario ▪ Commercial reality ▪ Infrastructure context ▪ Availability of services

Table 1 – Geological and non-geological aspects of geological research

Geological aspects, classified according to the specific properties of stones, are decisive for the market evaluation of granite and its suitability for ornamental use. Stone composition, colour, texture, and homogeneity determine the aesthetic appeal and market value of the granite, while hardness and quality influence its durability and practical applications. Factors such infrastructure, structure, and mode of occurrence affect both the accessibility to the quarry and the geological conditions of the deposit, impacting the economic feasibility of exploration. Additionally, features like fractures, faults, veins, facies variations, pegmatitic masses, and oxidation nodules can alter the aesthetic pattern and marketability of the granite, potentially rendering the material unfeasible and even leading to the abandonment of a quarry. These geological variables are controlled by geology and must be evaluated in studies to ensure the quality and value of the material.[20]

Thus, to understand the potential of a region for ornamental stones, it is essential to obtain thorough information through a detailed geological study, which will provide a “radiograph” of the deposit, enabling more effective operational planning and appropriate selection of methods and equipment. The lack of geological research and knowledge can lead to failures, predatory mining, increased waste, low block recovery, decreased profitability, financial losses, environmental harm, and frustration within local communities.

[20] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.

Geological research involves several steps: reconnaissance and geological mapping, material sampling and analysis, petrographic analysis, technical characterization, commercial evaluation, industrial-scale sampling, and the preparation of a comprehensive research report.[21]

Initially, geological, topographic, and structural surveys of the area are conducted to identify promising quarry sites and minimize environmental impacts. Samples are collected during mapping for analysis to determine reserve volumes and obtain structural and aesthetic parameters.

Subsequent analysis focus on the material's geological and technical aspects to evaluate its usability and application. Market research follows, assessing the economic feasibility of the investment by comparing the material with existing products to set prices and assess profitability. The research concludes with a simulation of industrial-scale operations to evaluate the material's performance under real production conditions and calculate operational costs. The final report compiles all data, including reserve estimates, quarry life projections, and a detailed exploration and financial viability plan.

The non-geological aspects encompass factors that can facilitate, hinder, or prevent the development of an ornamental stone enterprise. The most relevant non-geological aspects include economic, climatic, environmental, and legal factors.[22]

Economic considerations are integral to every stage of the granite quarrying process and are crucial for the viability of each phase – without adequate funding, even basic prospecting is impossible. Mining enterprises require substantial investment, and many projects, research initiatives, and operations are halted due to financial constraints. This underscores the fact that the feasibility and success of any mining venture are directly dependent on economic factors.

Climatic aspects can also significantly impact the economic and technical viability of a quarry project. Unfavourable weather conditions, such as rain, snow, or extreme drought, can

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[21] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.
[22] Ibidem.

disrupt productivity, leading to increased financial expenses and economic instability. Heavy rains and snow, particularly when concentrated in specific seasons, may force temporary halts in operations, while a lack of precipitation can create water supply challenges. In many quarries, activities are further restricted by snow and soil freezing, while heavy seasonal rains in tropical regions complicate work and access to deposits, damaging roads and equipment. Additionally, quarries located at high altitudes face reduced machinery production capacity, with an average loss of 10% per 1.000 meters above sea level, necessitating more effective systems to maintain productivity.[23]

Environmental aspects, detailed in subsection 1.1.2, relate to the impact caused by quarrying activities. Quarries can be located in different terrains: at the base of hills, on slopes, at the summit, or in plains. Quarries at the base of hills cause modest environmental impacts and tend to develop more horizontally than vertically. Quarries on slopes have a significant visual impact during their development, face difficulties with sterile management, and often exhibit low recovery rates. Quarries at the summit are less visible from a distance, but sterile released on slopes results in a considerable visual impact. On the other hand, quarries in plains offer easy access, facilitate equipment and block movement, have low visual impact, and have high recovery rates.[24]

Finally, regarding legal aspects, each country's legislation defines the specific criteria that must be observed for initiating a mining enterprise, including research, prospecting, extraction, and processing. These criteria cover documentation, regulations on mining concessions and permits, customs regulations for import and export, tax systems, monetary laws for foreign operators, and health, hygiene, and safety standards at the workplace, which are more stringent in industrially advanced countries.

To open a new quarry, obtaining an initial research license and an exploration license is necessary, a process that may take years. In some countries, licenses have minimal durations, requiring exploration, research, and testing to be completed quickly. In others, permits may be extended without immediate expiration. Each of these licenses involves costs,

[23] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.
[24] Ibidem.

bureaucratic procedures, obligations, and limitations that vary according to the mining regulations of each country.

The legal aspects of this activity in Brazil will be explored in detail in Chapter 3, providing a comprehensive understanding of the legal framework for mining activities.

Once the feasibility of quarrying in a specific area is confirmed, the following steps involve navigating the environmental and mining licensing processes dictated by the applicable jurisdiction. These processes outline the legal requirements and conditions that must be met. Upon securing the necessary permits and approvals, the mining phase can commence.

1.3.2 Phase 2 – The art and science of extraction: quarrying techniques and stages

The mining phase represents the core production activity, involving the application of specialized methodologies tailored to the material's characteristics and the geological formation of the quarry.

The extraction of ornamental stone has evolved significantly since its inception, reflecting advancements in technology and changes in mining practices. In earlier times, methods were primitive and based on rudimentary techniques. Granite blocks were quarried by inserting wooden wedges into the natural fissures of the stones, which, when moistened, caused the stones to expand and split. This ancient technique employed by the Romans, known as the "Roman cut", used metal hammers and chisels to create deep V-shaped cuts along the rock's seams.[25]

The blocks were then removed with wooden beams, iron levers, and, eventually, wooden wedges. The entire process was manual and involved a diverse team of labourers and tools, including wedges, chisels, hammers, mallets, shovels, and hoes. Mallets and wedges were used to open natural fractures or deliberately created breaks in the rock; hammers and chisels were used to make cuts or notches, isolating the blocks to be extracted in predetermined

[25] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.

sizes. Other ancient techniques included the use of wooden pieces soaked in water to widen the cracks due to the expansion caused by the freezing of the wet wood.[26]

Thus, early granite quarrying was conducted rudimentarily, utilizing manual tools such as levers, wedges, mallets, and techniques based on traditional mining methods, with low efficiency and high reliance on human labour.

The transition to more advanced methods began with industrialization in the late 19th and early 20th centuries when the introduction of explosives revolutionized granite quarrying. While explosives allowed for faster and more efficient extraction, they also presented significant risks, such as damage to the integrity of the stones, undesirable fragmentation, and dangers to workers.

Innovation continued with the introduction of diamond wire cutting techniques in the 1970s and 1980s, which provided more precise cuts and significantly reduced material waste. This method uses a metal wire coated with industrial diamond segments to cut the stone continuously and efficiently. Concurrently, modern drilling and cutting equipment, such as pneumatic and hydraulic drills, replaced manual tools and explosives. The introduction of diamond drills allowed for the creation of precise holes, facilitating the insertion of diamond wires or hydraulic wedges for controlled stone cutting. The high-pressure water jet cutting technique was also incorporated as an alternative, especially when preserving the stone's integrity is crucial.[27]

Since the 2000s, the granite mining industry has witnessed significant advancements in automation and sustainability. The automation of machinery and the use of remote-control technologies have improved the safety and efficiency of mining operations, allowing for the monitoring and control of cutting, drilling, and block handling processes with minimal direct human intervention. Sustainable practices, such as reusing water used in water jet cutting and proper waste management, have become integral to mining plans. Mining processes have also incorporated environmental and landscape restoration projects of mined areas.

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[26] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.
[27] Ibidem.

Currently, the use of explosives in mining is limited due to the advent of more precise and controlled techniques and is employed only in specific situations, usually during preliminary dismantling operations. To ensure the safety and efficacy of these methods, countries establish stringent regulations regarding the possession, storage, and use of explosives in quarries. Mining companies must adhere to strict safety standards to ensure the safe and responsible use of these resources through controlled fragmentation techniques and advanced detonation technologies.

The evolution of granite quarrying reflects a transition from manual and rudimentary methods to highly mechanized and technologically advanced techniques. This evolution has increased efficiency and productivity, improved worker safety, and reduced the environmental impacts associated with ornamental stone quarrying.

The quarrying of granite stone blocks can be performed either through open-pit mining or underground mining. The choice of method is determined by the characteristics of the mineral deposit, the type of mineral, and economic and environmental conditions.

Open-pit mining, the more common method, involves removing the material covering the mineral deposit to access the desired material and is subdivided into boulder mining and massif mining. Boulder mining involves the removal of large, rounded rock blocks displaced from the rock mass by erosive processes, while massif mining, more commonly undertaken, is performed directly on the stone massif, allowing for more controlled and efficient extraction.[28]

Although less common, underground mining is used for mineral deposits located at great depths or when required by legal regulations.[29]

The granite quarrying process, particularly open-pit mining, is structured into several stages to ensure the efficiency, safety, and quality of the quarried material. The main phases of this

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[28] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.

[29] JAZIDA – **Lavra na Mineração: Uma Abordagem sobre Métodos e Regulamentação**. [s.l.]: Jazida Blog, 2023. [Accessed 15 May 2024]. Available at: https://blog.jazida.com/lavra-na-mineracao-uma-abordagem-sobre-metodos-e-regulamentacao/.

process include prospecting and planning, terrain preparation, primary dismantling, secondary dismantling, transportation and storage, processing, and waste management.

Following geological prospecting and mining planning, where granite deposits are identified and evaluated, extraction areas and process stages are defined, and the terrain is prepared with the construction of access roads, storage areas, and drainage systems. Terrain preparation concludes with the removal of vegetation and superficial soil to expose the stone and the preparation of areas for waste and sterile deposit.

With the terrain prepared, primary dismantling begins, which is the initial phase of separating large granite blocks from the solid rock. Techniques used in this phase include drilling with specialized equipment, controlled use of explosives, and cutting with diamond wire. Holes are strategically positioned to allow for efficient cuts, and explosives are used in a controlled manner to avoid undesirable fragmentation. When introduced into the holes, diamond wire cuts the stone precisely, minimizing fissures and improving material utilization.

Primary dismantling results in large granite blocks, which are then prepared for the next stage, secondary dismantling. In this phase, larger blocks are subdivided into smaller, more manageable sizes suitable for commercialization or processing. Techniques such as additional cuts with diamond wire, hydraulic wedges, and diamond blade saws ensure precision and maximize material utilization.

After secondary dismantling, the cut blocks are removed from the mining front with the aid of cranes, shovel excavators, and other handling equipment and transported to storage or processing areas. The blocks are stored until they are sent for processing or directly to the market.

Not all companies engaged in quarrying also engage in processing – the case study company in Chapter 4 does not do so, for example. Those that do will have the blocks moved from storage to processing, where they are cut to size into slabs and polished to meet customer specifications. This step concludes the quarrying process, providing the necessary finish for commercial use.

Mining companies must address the aftermath once the granite quarrying cycle is complete. Waste management is a critical and concluding phase of the production process involving the management and treatment of waste generated during mining. This step is essential for minimizing environmental impact and ensuring the sustainability of operations.

In fact, effective waste management is essential for the ongoing viability of quarrying operations, as the generation of waste – particularly sterile materials – is an unavoidable byproduct of mining activities. The ability to manage and dispose of these sterile materials is a critical factor that influences the operational capacity of a quarry. Without an adequate and designated site for waste deposition, quarrying cannot proceed, as there would be no means to handle the substantial volumes of waste generated alongside the extraction of granite. Therefore, establishing and maintaining appropriate waste disposal facilities is not only a logistical necessity but also a fundamental prerequisite for the successful continuation of quarrying activities.

1.3.3 Phase 3 – Beyond quarrying: managing waste, sterile, and mine closure

Finally, the recovery phase addresses the rehabilitation of the areas affected by mining, aiming to restore the environment and mitigate any negative impacts. Mining is among the industrial sectors that generate the highest volume of waste, and the production of ornamental stones, due to its low utilization rates, significantly contributes to this indicator. This process generates various waste materials, such as rock fragments, sawdust, clay, and cutting sludge, which, if not properly managed, can have severe environmental impacts.

Effective waste management is therefore crucial for both environmental and economic sustainability. Improperly treated mining waste can lead to environmental degradation, pollution, and health hazards. Continuous monitoring of waste disposal sites, including sterile piles, is essential to ensure their stability and prevent further risks, such as landslides and soil erosion.

Moreover, materials with significant aesthetic inconsistencies, which cannot be commercially utilized, can still serve valuable purposes in public and private construction projects. These materials can be repurposed for the construction of dams, roads, and bridges, as well as for minor landslide mitigation. In this way, even non-commercialized materials can be utilized for public benefit, contributing to a more sustainable approach to mining waste.

Alternative methods for reusing and recycling mining waste have been successfully explored across various industries. For example, stone fragments and sawdust can be processed into aggregates for the construction sector, replacing natural materials and reducing the demand for new resource extraction. Additionally, cutting sludge and clay can be repurposed for the production of ceramic materials, such as bricks and tiles, as well as for flooring and coatings. Some waste materials are even utilized in the production of glass and vitreous products, taking advantage of their mineral composition to create new, valuable items.[30]

An innovative application of these materials is found in green infrastructure projects, where mining waste is used to create substrates for planting and soil conditioning. This approach is particularly beneficial for reforestation efforts and sustainable agriculture, as it not only reduces the volume of waste sent to sterile piles but also promotes environmental regeneration.

Beyond the environmental benefits, the reuse and recycling of mining waste open economic opportunities and stimulate technological innovation. Continuous advancements in technology and processes are enhancing the efficiency of waste management and uncovering new applications for these materials.

Such practices contribute to the conservation of natural resources and promote a circular economy, where waste is reimagined as a valuable resource. Integrating innovative and sustainable solutions is therefore essential for transforming environmental challenges into opportunities for the future of mining and civil construction.

Furthermore, the responsibility for managing environmental impacts extends beyond the operational phase of granite quarrying and continues through the mine closure process. Closing a mine involves a complex series of steps aimed at restoring the affected area to minimize adverse effects and promote ecological recovery.

[30] AZEVEDO, Hélio; CASTRO, Nuria; VIDAL, Francisco – **Tecnologia de rochas ornamentais: pesquisa, lavra e beneficiamento**. Rio de Janeiro: CETEM/MCTI, 2013. [Accessed 14 May 2024]. Available at: http://mineralis.cetem.gov.br/bitstream/cetem/1733/1/CCL00020014_CAPITULO_04_opt.pdf. ISBN 987-85-8261-005-3.

The initial phase of mine closure requires detailed planning, ideally initiated during the operational phase. This plan must address waste management, landscape and local ecosystems impacts, removal of obsolete equipment and structures, treatment and safe disposal of waste, and soil restoration. Effective planning ensures that these aspects are thoroughly managed to facilitate a smooth transition from active mining to closure.

Restoring the degraded area is essential for reestablishing the site's ecological functionality. This process often involves soil rehabilitation and revegetation with native plants to stabilize the soil and support biodiversity recovery.

The practices of waste reuse and recycle, alongside effective closure and restoration strategies, are essential for minimizing environmental impacts and ensuring a positive legacy. A commitment to sustainable practices must extend throughout the entire lifecycle of quarrying, including post-closure activities. By embracing environmentally sound techniques and prioritizing ecosystem health, the natural environment can be preserved and restored, ensuring the well-being of both current and future generations.

Despite its importance, the recovery phase in mine closure presents significant challenges. Restoring a quarry site to its pre-mining condition involves numerous uncertainties, and financial and logistical constraints can undermine the thoroughness of recovery efforts, potentially resulting in incomplete or ineffective restoration. These challenges highlight the need for robust risk management strategies that ensure recovery practices are comprehensive and resilient to unforeseen issues, thereby safeguarding both environmental and public health.

To bridge the operational and security complexities of granite quarrying with effective management practices, Chapter 2 will introduce key risk management theories that underpin effective strategies for addressing the challenges outlined. By connecting these theoretical frameworks to the practical issues identified in quarry operations, we can better understand how these concepts can be applied to mitigate risks in the quarrying industry.

2 THE FUNDAMENTALS OF RISK MANAGEMENT

Risk is an intrinsic part of human existence. From the dawn of humanity to the present day, individuals are continuously exposed to a wide array of risks, spanning from the moment they wake up until they retire for the night. In our personal lives, many of our responses to these risks are automatic and subconscious.

The practice of making effective decisions in the face of uncertainty and risk likely originated with the earliest humans. Evolution naturally favoured those individuals who could utilize their experiences and intellect to minimize uncertainties related to food, warmth, and protection. *Homo sapiens* survived by cultivating an instinctive and persistent drive to defend themselves against the inherent risks of existence.[31]

The development of tools, the mastery of the use of fire, and the techniques and equipment developed and used for hunting are examples of risk management by early civilizations long before risk management became a science. This "genetic expression" of survival instincts and intuition can, thus, be considered the nascent form of risk management, which has evolved into a formal discipline for navigating uncertainty.[32]

Over time, humans began attributing misfortune and fortune to divine beings, seeking to influence their outcomes through rituals and sacrifices. This reliance on gods led to the emergence of intermediaries such as priests and astrologers who attempted to predict future events. However, the advent of written language marked a significant shift, allowing for the preservation and transmission of knowledge. This development provided an alternative to divine explanations by enabling systematic analysis of uncertainties.

In the early 400s BC, Thucydides advanced a pioneering perspective that removed divine causation from historical events, emphasizing empirical observation. Often regarded as a precursor to modern risk management, Thucydides highlighted the gap between expectations and outcomes, laying the groundwork for a more analytical approach to risk.[33]

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31 KLOMAN, H. Felix – A Brief History of Risk Management. In FRASER, John; SIMKINS, Betty – **Enterprise Risk Management: Today's Leading Research and Best Practices for Tomorrow's Executives**. Hoboken: John Wiley & Sons Inc., 2010. [Accessed 23 July 2024]. Available at: https://www.researchgate.net/publication/230538385_A_Brief_History_of_Risk_Management.
32 Ibidem.
33 Ibidem.

The Renaissance and Enlightenment brought transformative changes to the understanding of risk and the future. The growing skepticism towards divine determinism was paired with advancements in numerical methods, and humanity witnessed the replacement of faith and luck with tools for evaluating probabilities, fundamentally changing the approach to risk management.

The 20th century began with optimism, marked by economic growth, peace, and industrial progress, but soon faced upheaval through global conflicts. The century's ideas, including those about individual dignity, societal organization, and human potential, profoundly impacted risk management. This era saw the development of risk management as a scientific discipline aimed at making informed decisions and optimizing resource use. The focus shifted to a systematic approach to uncertainties, allowing societies, businesses, and governments to navigate complex challenges more effectively and prudently.

2.1 Understanding Risk Management: Concepts, Purposes, Principles and Relevance

Deeply related to uncertainty, risk can have many concepts. Theoretical approaches relating risk and uncertainty argue that risk is "measurable uncertainty" or "uncertainty that matters".[34] Uncertainty manifests in various forms and influences predictions about future events and the comprehension of unknown factors.

Donald Rumsfeld argued that there are "known knowns", "known unknowns", and "unknown unknowns", a finding that shows that while some risks are identifiable and measurable, others remain elusive and unpredictable. Known knowns are aspects or information that are fully known, representing risks that are identified and well comprehended. Known unknowns refer to aspects or information recognized as unknown, representing risks acknowledged as potentially existing. In these cases, uncertainty can either be quantifiable, where the extent of ignorance can be measured, or non-quantifiable, where the lack of knowledge cannot be precisely measured. Unknown unknowns are entirely unforeseen and unexpected factors, representing risks that are never considered due to their unpredictability.

[34] HILLSON, David – **The risk management handbook: A practical guide to managing the multiple dimensions of risk**. 2nd edition. London: Kogan Page, 2023, p. 4-5. ISBN 978-1-3986-1061-3.

Uncertainty is a broader concept than risk, and although every risk contains uncertainty at some level, not every uncertainty is a risk. In the context of risk management, risk is defined as the "effect of uncertainty on objectives"[35], which can be positive or negative. This definition highlights that risk is not solely about potential losses but also encompasses opportunities that may arise from uncertain situations.

A risk that could negatively affect objectives if it occurs is called a threat. Conversely, a risk that could positively impact objectives if it happens is known as an opportunity. To determine whether a risk is a threat or an opportunity and to assess and prioritize risks, it is essential to analyze the likelihood of a particular event happening and the potential impact it would have on the organization if it happened.

In risk management, *likelihood* denotes the probability or chance that a specific event will occur. This concept is often referred to as "probability" in risk management literature. It measures how frequently or likely a particular risk will materialize over a given period.

The term *impact* refers to the potential severity or consequences of the risk should it occur. This concept represents the risk's inherent or gross level before any mitigation strategies or controls are implemented. It indicates the potential damage that could result if the risk event happens.

In this context, risk management serves as a tool to reduce uncertainty by coordinating efforts to minimize, monitor, and control the likelihood and impact of adverse events while also maximizing the potential benefits from opportunities.

According to ISO 31000:2018, risk management refers to "coordinated activities to direct and control an organization with regard to risk". Similarly, the Institute of Risk Management defines it as the "process which aims to help organizations understand, evaluate, and take action on all their risks with a view to increasing the probability of success and reducing the likelihood of failure."[36]

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[35] ISO 31000:2018 – **Risk management – Guidelines**.
[36] Apud HOPKIN, Paul; THOMPSON, Clive – **Fundamentals of Risk Management: Understanding, Evaluating and Implementing Effective Enterprise Risk Management**. 6th edition. London: Kogan Page, 2022, p. 45. ISBN 978-1-3986-0286-1.

Risk management is therefore fundamentally about taking calculated risks. While some might think that risk management aims to eliminate all risks, it is essential to understand that complete risk elimination is neither feasible nor practical. Instead, effective risk management focuses on the balance between taking risks and acknowledging the possibility of failure, all in pursuit of organizational objectives. This approach is not about simply accepting risks, but about managing them strategically, with a clear understanding of their likelihood and potential impact.

Building on this, it is essential to distinguish between risk appetite and risk tolerance. *Risk appetite* refers to the amount and type of risk an organization is willing to take in order to achieve its strategic objectives. It reflects the organization's overall attitude towards risk and influences decision-making at the highest levels. On the other hand, *risk tolerance* defines the specific level of risk that an organization can handle within its operational framework. It represents the boundaries within which the organization is prepared to operate while still maintaining its stability and effectiveness.

When analyzing an organization's risk context, it is essential to consider not only risk tolerance and appetite but also the risk universe and risk capacity. The Institute of Risk Management[37] defines *risk universe* as the full range of risks which could positively or negatively impact the organization's ability to achieve its long-term objectives. *Risk capacity*, on the other hand, refers to the organization's capacity to take risks, which is inherently limited. This limitation arises from factors such as insufficient capital or resources, which restrict the capacity to manage additional risks, as well as external factors like industry regulations or constraints imposed by regulators.

Integrating risk appetite and risk tolerance within the broader context of risk universe and risk capacity is fundamental to effective risk management. These concepts ensure that risks are not just identified and assessed, but also strategically aligned with the organization's overall goals and its ability to manage uncertainties. Risk management, therefore, emerges as a decision-making tool, providing a structured framework that keeps decisions within acceptable risk levels and prevents exceeding the organization's capacity to handle potential impacts.

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[37] Apud HILLSON, David – **The risk management handbook: A practical guide to managing the multiple dimensions of risk**. 2nd edition. London: Kogan Page, 2023, p. 17. ISBN 978-1-3986-1061-3.

Risk management serves as a critical mechanism for achieving the best possible outcomes while minimizing volatility and uncertainty within an organization. By adopting a proactive approach rooted in thorough analysis and scenario planning, decision-makers can rely on data-driven insights rather than intuition, leading to better-informed decisions that align with the organization's strategic goals. As a result, the organization becomes more resilient, capable of adapting swiftly to changes, and better equipped to navigate uncertainties, ensuring long-term success.

A strong risk management framework offers numerous advantages that significantly boost organizational performance. It enables better planning and resource allocation by identifying potential challenges early, thus reducing the likelihood of unexpected disruptions. This proactive stance fosters sustainable growth, improves stakeholder communication by openly addressing risks, and strengthens reputation and consumer trust, ultimately providing a competitive edge. Moreover, effective risk management encourages innovation, allowing organizations to pursue new opportunities with confidence, knowing that potential risks are being effectively managed.

Risk management is guided by a set of core principles outlined by international standards, which ensure that practices are robust, comprehensive, and adaptable to the unique needs of different organizations.

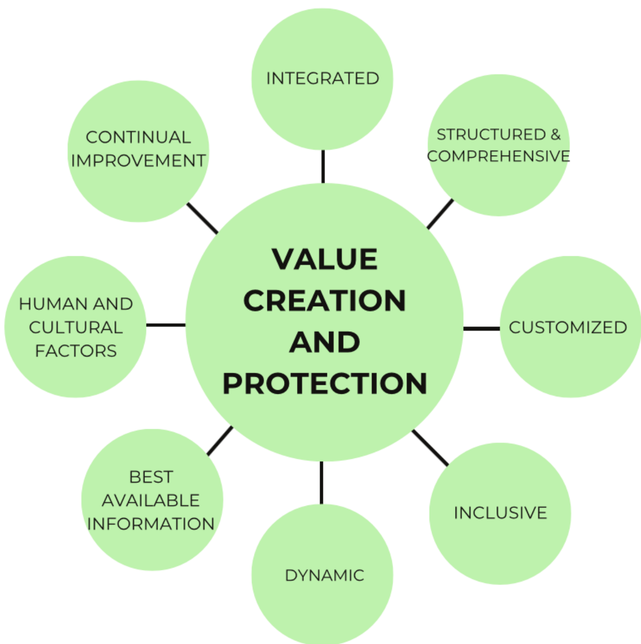

Figure 1 – Principles of risk management according to ISO 31000:2018

One of the foundational principles is the *integration* of risk management into all organizational activities. It should not be confined to a specific department but must be a collective responsibility across all levels, ensuring that risk management becomes an integral part of the organizational processes and decision-making framework.

Another key principle is the adoption of a *structured and comprehensive* approach to risk management. This involves developing clear, well-documented methods and routines that are accessible and actionable for all employees. A structured approach ensures consistent and comparable results, which are crucial for effective risk mitigation and management.

Customization of risk management processes is also essential and considered a principle. These processes should be tailored to fit the organization's specific needs, considering factors such as industry, size, and objectives. Generic templates are often insufficient for addressing the unique context of different organizations, making customization a critical aspect of effective risk management.

Stakeholder *involvement* is another crucial principle. Engaging stakeholders in the risk management process brings valuable insights and perspectives, helping to identify potential biases and blind spots.

Moreover, the *dynamic* nature of risk management requires that it be inherently adaptable and responsive to new and evolving risks, proactively anticipating, identifying, recognizing, and addressing changes as they occur. This dynamic approach helps organizations remain resilient in the face of unforeseen events.

Acknowledging the limitations of available information is also vital. Risk management relies on the *best available data* but must account for gaps and uncertainties. Decisions should be based on the most accurate and reliable information possible while also recognizing and addressing the inherent limitations.

Human and cultural factors significantly influence all aspects of risk management. Understanding how human behaviour and cultural contexts affect risk perception and management is essential. Recognizing the capabilities, perceptions, and intentions of both internal and external stakeholders is crucial for effective risk management.

Finally, *continuous improvement* is a cornerstone of effective risk management. The process should evolve based on experience and learning, with continual refinement of strategies to adapt to new challenges. This principle ensures that risk management practices remain relevant and effective over time, fostering a culture of ongoing enhancement and learning.

To summarize, effective risk management involves integrating risk considerations into all organizational activities, adopting a structured and tailored approach, involving stakeholders, and being responsive to changes. It relies on the best available information, recognizes the impact of human and cultural factors, and emphasizes continuous improvement.

In the following section, we will delve deeper into the practical application of these principles by exploring the different phases of the risk management process. This comprehensive overview will cover the essential steps from risk identification and analysis to assessment, monitoring, and control.

2.2 The Risk Management Process: From Identification to Monitoring

At its core, risk management is profoundly influenced by human behaviour. Cognitive biases can affect decision-making by causing systematic deviations from rational judgement. These biases arise because the human brain uses mental shortcuts to simplify the overwhelming amount of information it processes. While these shortcuts can facilitate quicker decisions, they often lead to perceptual distortions, inaccurate judgments, and misinterpretations.

As cognitive biases can cause individuals to prioritize feelings over objective analysis, emotions significantly influence decision-making. Psychological factors such as excessive optimism, overconfidence, confirmation bias, and aversion to a sure loss impact how risks are perceived and managed.

Excessive optimism can lead to overestimating the likelihood of favourable outcomes, causing decision-makers to overlook potential risks and inadequately prepare for adverse scenarios. Similarly, overconfidence often results in underestimating the probability of rare but significant events, leading to insufficient safeguards.

Confirmation bias is a cognitive phenomenon where individuals favour information that supports their preexisting beliefs while ignoring or undervaluing contradictory evidence. This bias distorts perceptions of reality, which can skew decision-making and risk assessment by reinforcing misconceptions and hindering objective analysis.

Aversion to a sure loss may drive people to engage in risk-seeking behaviour to avoid accepting a guaranteed loss. This often results in taking on greater risks, potentially leading to more significant negative outcomes.

In light of these considerations, international standards establish, in addition to a risk management process, a framework necessary to contextualize, implement, and support this process. Referred to as the risk architecture, strategy and protocols (RASP), risk management framework is defined in ISO Guide 73:2009 as a "set of components that provide the foundations and organizational arrangements for designing, implementing, monitoring, reviewing and continually improving risk management throughout the organization."

RASP forms the foundational elements of a risk management framework. The risk architecture defines the structure, roles, and responsibilities for managing risk, ensuring the effective flow of risk-related information across the organization. The risk strategy outlines the organization's approach, including its risk appetite, objectives, and methods for identifying, assessing, and mitigating risks. Risk protocols provide the systems, standards, and procedures to support the strategy, promoting consistency in risk management. This framework is integrated into the broader risk governance structure of the organization.

The risk management process, in turn, as outlined in ISO 31000:2018, is a process with well-defined phases, ensuring risks are managed systematically. This structured approach encompasses five key steps, each requiring thorough communication and consultation with the organization: plan, assess, treat, record, and monitor and control.

The following image illustrates the structured design of the risk management process, based on ISO 31000.

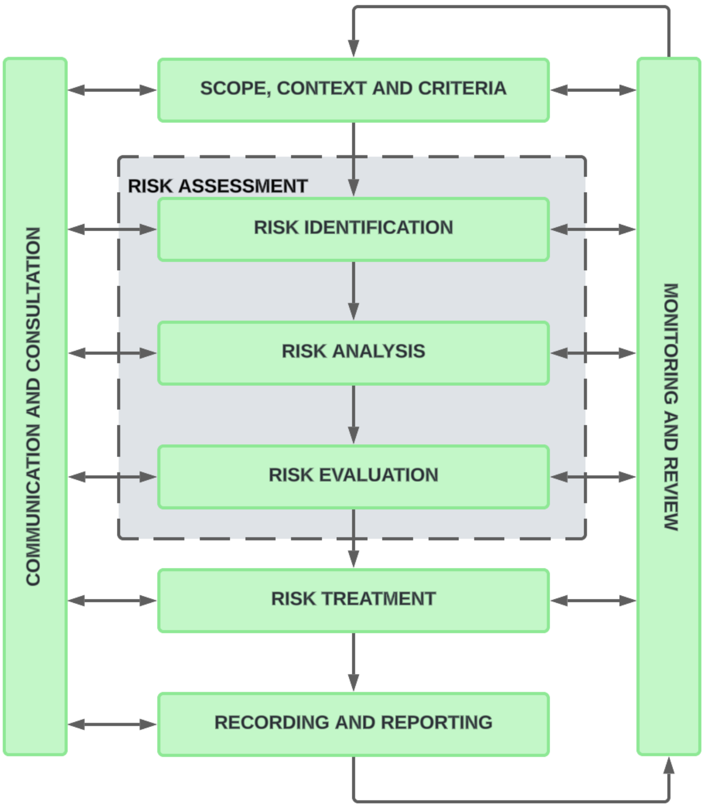

Figure 2 – Risk management process

Before delving into the merits of each phase of the risk management process, it is crucial to emphasize the intrinsic connection between risk management and intelligence. Strategic analysis techniques, widely used in the field of security, are vital throughout the risk management process. These techniques include a range of tools and methods designed to assess and understand various aspects of a business or organization, allowing for the development and execution of effective strategies.

"Structured analysis is a mechanism by which internal thought processes are externalized in a systematic and transparent manner so that they can be shared, built on, and easily critiqued by others."[38] Some of the most commonly used techniques are SWOT analysis, PESTEL analysis[39], brainstorming, starbursting, process maps, Gantt charts, mind maps, timelines, and

[38] HEUER JR., Richards; PHERSON, Randolph H. – **Structured Analytic Techniques for Intelligence Analysis**. 3rd edition. Thousand Oaks: Sage, 2021, p. 3-4. ISBN 978-1-5063-6894-8.

[39] SWOT analysis refers to the technique that evaluates Strengths, Weaknesses, Opportunities, and Threats related to a business or a project. PESTEL analysis refers to the technique that examines the Political, Economic, Social, Technological, Environmental, and Legal factors that can affect an organization or project.

cross-impact matrices, to name a few.[40] Intelligence gathering and analysis provide the critical information needed to identify potential risks and evaluate their impact accurately.

The initial step in the risk management process is planning, which establishes the foundation for the entire process. During this phase, objectives are defined, and the scope, context and criteria for risk assessment are determined. The scope outlines the boundaries and limits of the risk management process, specifying what will be included and excluded and identifying the areas, processes, or activities to be considered. By clearly setting the scope, organizations can ensure that their risk management efforts are focused and aligned with their objectives.

The context involves understanding the internal and external environment in which the organization operates. Internally, this includes the organization's structure, culture, activities, capabilities, resources, and the expectations of internal stakeholders. It also involves examining objectives, capacity, core business processes, decision-making, and identifying strengths, weaknesses, opportunities, and threats within the organization. Externally, it considers the organization's operating environment, including stakeholder expectations, industry regulations, market conditions, competitor behaviour, legal requirements, social factors, and the broader economic and political landscape. It also considers trends and drivers that impact the organization's success and ability to meet its goals presenting external opportunities and threats.

Criteria refers to the standards or benchmarks used to evaluate and prioritize risks. These criteria are based on the organization's objective, risk appetite, and tolerance levels, helping determine what constitutes an acceptable level of risk and guiding decision-making throughout the risk management process. Criteria may include financial thresholds, legal requirements, safety standards, and other relevant measures.

Therefore, the first phase not only serves as a guide to the entire process but also helps to identify the factors that can impact the organization's risk profile and to ensure that the risk management process is tailored to these factors.

[40] This study does not aim to provide an in-depth exploration of strategic and structured analysis techniques. For a comprehensive overview of these techniques, including detailed descriptions and applications, please refer to the third edition of "Structured Analytic Techniques for Intelligence Analysis" by Randolph H. Pherson and Richards Heuer Jr. This edition presents sixty-six structured analytic techniques that represent the most current practices in intelligence, law enforcement, homeland security, and business analysis.

With the scope, context and criteria defined, the second phase begins. Risk assessment involves identifying potential risks, analyzing their likelihood and impact, and evaluating them based on this analysis. This step requires a detailed understanding of both internal and external factors that could influence the organization, demonstrating that the phases of the risk management process are interconnected and interdependent, necessitating a step-by-step approach.

ISO 31073:2022 defines risk identification as the "process of finding, recognizing, and describing risks", which includes identifying risk sources, potential triggers, causes, and possible consequences. This process may involve historical data, theoretical analysis, expert opinions, and stakeholder considerations. A key part of risk identification is determining the risk owner – the individual or entity responsible for and authorized to manage the risk.

Risk analysis, as defined by the same standard, is the process of understanding the nature and level of risk, forming the basis for evaluating and deciding on risk treatment. Practitioners often use a 5x5 risk matrix tool to assess risks by mapping the likelihood of an event occurring against its potential impact, where risks' likelihood and impact are rated on a scale from very low to very high.[41] This allows organizations to categorize and prioritize risks, guiding decisions on which risks require immediate action, monitoring or acceptance, thereby enhancing overall risk management.

RISK MATRIX					
	1	2	3	4	5
IMPACT / LIKELIHOOD	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH
5 VERY HIGH	5 VERY LOW RISK	10 LOW RISK	15 MEDIUM RISK	20 HIGH RISK	25 VERY HIGH RISK
4 HIGH	4 VERY LOW RISK	8 LOW RISK	12 MEDIUM RISK	16 HIGH RISK	20 HIGH RISK
3 MEDIUM	3 VERY LOW RISK	6 LOW RISK	9 LOW RISK	12 MEDIUM RISK	15 MEDIUM RISK
2 LOW	2 VERY LOW RISK	4 VERY LOW RISK	6 LOW RISK	8 LOW RISK	10 LOW RISK
1 VERY LOW	1 VERY LOW RISK	2 VERY LOW RISK	3 VERY LOW RISK	4 VERY LOW RISK	5 VERY LOW RISK

Figure 3 – 5x5 Grid Risk Matrix

[41] This study is not intended to serve as a manual for risk management practices. For comprehensive guidance on developing and analyzing a risk matrix, refer to the sixth edition of "Fundamentals of Risk Management: Understanding, Evaluating, and Implementing Effective Enterprise Risk Management" by Paul Hopkin and Clive Thompson.

The second phase ends with the risk evaluation, defined by ISO 31073:2022 as the "process of comparing the results of risk analysis with risk criteria to determine whether the risk is acceptable or tolerable." This ensures that risks are assessed in alignment with organizational standards and thresholds.

Once risks are assessed, organizations must develop strategies and implement treatment options to address identified risks. The objective is to mitigate or eliminate risks consistent with the organization's risk appetite. Risk treatment strategies typically fall into one of four categories: avoidance, reduction, sharing, or acceptance. In this sense, the method known as the 4T approach includes tolerating, treating, transferring, and terminating risks. Each of these strategies corresponds to different types of control mechanisms within an organization, namely, detective, corrective, directive, and preventive controls.

Tolerating a risk involves accepting and retaining it, often because the potential impact is considered acceptable, or the cost of mitigation outweighs the benefits. When an organization decides to tolerate a risk, it implies that no further action will be taken unless circumstances change significantly. This approach is supported by detective controls, procedures designed to "identify when the hazard has materialized"[42].

Treating the risk implicates taking actions to reduce its likelihood or impact. By implementing control measures, an organization can constrain the risk to an acceptable level while continuing the related activities. This approach is often the most common in risk assessment, as it effectively uses corrective controls to manage and mitigate potential losses or damage.

Transferring risk requires shifting the burden to a third party, usually through insurance or contractual agreements. This approach is particularly effective for managing financial risks or risks to assets, as it places the responsibility on an entity better equipped to handle them. In this context, directive controls play a crucial role by providing clear instructions and relying on established procedures and guidelines to ensure specific outcomes and prevent losses.

[42] HOPKIN, Paul; THOMPSON, Clive – **Fundamentals of Risk Management: Understanding, Evaluating and Implementing Effective Enterprise Risk Management**. 6th edition. London: Kogan Page, 2022, p. 188. ISBN 978-1-3986-0286-1.

Lastly, in some situations, the best course of action is to eliminate the activity that generates the risk. Terminating a risk, although not always a viable option, is the most straightforward way to ensure it is no longer a concern, especially when the risk cannot be adequately treated or transferred. Preventive controls are crucial for this strategy, as they are designed to prevent undesirable outcomes from occurring in the first place.

After thoroughly analyzing and defining the most appropriate strategy for each identified risk, the fourth phase begins: recording and reporting. Documenting the risk management process is vital for maintaining transparency and accountability within an organization. This phase involves systematically recording all identified risks, assessment methodologies, treatment plans, and monitoring activities to ensure traceability and continuous improvement.

The final step, monitoring and controlling, is essential to ensure that risk management measures remain effective. This ongoing process requires regular reviews of the risk environment, reassessing risks as necessary, and adjusting treatment plans whenever needed.

Moreover, continuous consultation and communication with all relevant stakeholders within the organization are crucial throughout the entire risk management process. This ongoing dialogue helps maintain awareness and support for risk management activities and ensures that risks are managed proactively.

At every step of the risk management process, integrating intelligence and strategic analysis techniques enhances the effectiveness of risk management efforts. By systematically applying the risk management process, organizations gain a more comprehensive understanding of potential challenges and opportunities, leading to more informed and resilient decision-making across all levels. This enhanced perspective not only mitigates risks but also empowers decision-makers to proactively navigate complexities, capitalize on emerging opportunities, and drive sustainable growth. Ultimately, effective risk management serves as a vital tool in ensuring that decisions are not only reactive but also strategic, enabling organizations to thrive in an ever-changing landscape.

Despite its potential, risk management remains underutilized in many countries in the Global South. The case study results, which will be examined in detail in Chapter 4, reveal that risk management is frequently applied in a fragmented manner, addressing only specific types of risks in isolation. However, as will be demonstrated in the following section, risks are often interrelated and impact one another, underscoring the limitations of isolated approaches. This highlights the need for a more integrated and comprehensive risk management strategy that addresses the interconnected nature of risks to improve overall effectiveness.

2.3 Categorizing Risk: Types and Strategies in Risk Management

Numerous types of risks exist within the organizational landscape, including market risk, credit risk, enterprise risk, compliance risk, cybersecurity risk, data protection risk, among others. This enumeration is not exhaustive, as the risk environment is dynamic and multifaceted. Moreover, these categories of risk are not mutually exclusive; for instance, a compliance risk can concurrently manifest alongside cybersecurity risks, illustrating the complex and interconnected nature of risk factors that organizations must manage.

Recognizing the variety of risks that exist is fundamental in risk management. Different types of risks demand tailored approaches, underscoring the necessity of a nuanced understanding of each risk category. This is especially pertinent in granite quarry operations, where the nature and magnitude of risks can vary significantly, impacting both operational efficiency and safety.

Classifying risks "also enables the organization to identify who should be responsible for setting the strategy for management of related or similar risks."[43] This ensures that those with expertise and authority develop and implement strategies to manage these risks, leading to more efficient risk management practices.

The types of risks inherent in granite quarrying are diverse, ranging from environmental risks and safety hazards to financial uncertainties, regulatory compliance challenges, and operational risks directly related to the quarrying activity. Additionally, granite mining companies face a variety of risks beyond those specific to their operations, including strategic, market, reputational, political, supply chain, process, project, data privacy, cybersecurity, human resource, and labour dispute risks, like challenges faced by other companies.

[43] HOPKIN, Paul; THOMPSON, Clive – **Fundamentals of Risk Management: Understanding, Evaluating and Implementing Effective Enterprise Risk Management**. 6th edition. London: Kogan Page, 2022, p. 127. ISBN 978-1-3986-0286-1.

Among the many risks granite quarrying companies face, some emerge as more frequent and impactful, necessitating focused attention and specialized management strategies. This section will briefly address the most significant umbrella risks in granite quarry operations.[44]

An umbrella risk is a broad category encompassing multiple types of specific risks under a single overarching framework. It is a comprehensive term that includes various sub-risks related to different areas of an organization's operations, strategy, or environment. Addressing the umbrella risk involves managing and mitigating the individual risks that fall under it. For instance, strategic risk can be considered an umbrella risk because it includes various specific risks like market changes, competitive pressures, regulatory changes, and shifts in consumer preferences. Similarly, operational risk might include risks related to processes, systems, people, and external events. Thus, by considering the interconnectedness of different risks, organizations can take a holistic approach to risk management.

2.3.1 Enterprise Risks and Business Continuity Management

Enterprise risk is a broad and comprehensive concept encompassing a wide range of potential threats and vulnerabilities that an organization may encounter. This broad term includes operational risks, which pertain to failures or inefficiencies in day-to-day activities; financial risks, which involve uncertainties related to the organization's financial health and stability; sales or customer risks, which are related to customer behaviour; cyber risks, which are associated with threats to information systems and data security; and compliance risks, which relate to the adherence to laws, regulations, and internal policies.

Thus, enterprise risk management (ERM) is a comprehensive approach that consolidates intelligence from various organizational risk management practices. This methodology addresses strategic and enterprise-wide risks, evaluating them against the organization's capacity and tolerance to bear these risks.

ERM encompasses all areas of organizational exposure, including financial, operational, reporting, compliance, governance, strategic, and reputational risks. It evaluates the risk

[44] This study is not intended to serve as a manual for risk management practices. For a comprehensive overview of the different categories of risk, including detailed descriptions and applications, please refer to "The Orange Book" published by the United Kingdom Government, and to the second edition of "The risk management handbook: A practical guide to managing the multiple dimensions of risk" by David Hillson.

portfolio in the context of significant internal and external environments, systems, circumstances, and stakeholders, recognizing the interrelationship of individual risks and their combined exposure, which often differs from the sum of particular risks.[45]

The essence of ERM is to assess risks based on their potential impact on the organization as a whole and to align risk tolerance levels with the organization's business plans and future strategies. This approach allows the organization to allocate resources more efficiently, pursue its objectives, and manage potential risks in a comprehensive manner.

Despite the ideal scenario where ERM functions as a cohesive, integrated process, many organizations still engage in isolated risk management practices, with departments such as finance, legal, commercial, operations, supply, mining assets, health and safety, marketing, and human resources each addressing their specific risks independently. This sector-based approach often leads to inefficiencies and gaps in risk management strategies due to its failure to provide a holistic view of organizational risks. An integrative approach ensures that all sector-specific risks are analyzed together, enabling more effective resource allocation, prioritization of demands, and strategy development. In addition, integrating ERM with business continuity management ensures not only a comprehensive understanding of the organization's risk landscape but also strengths organizational resilience.

Business continuity management (BCM) focuses on the impact of disruptions rather than their causes, identifying critical products, services, processes, and resources essential for the organization's survival. BCM enables an organization to determine the requirements to meet its obligations before disruptions occur, thus protecting resources such as people, premises, technology, information, supply chains, industrial secrets, and reputation. Any incident, whether significant, small, natural, accidental, or deliberate, that has the potential to disrupt operations falls under the purview of BCM. By focusing on the continuity of operations, BCM helps organizations prepare for and mitigate the impacts of disruptive events, ensuring resilience and sustained operations.

Recent research further emphasizes the importance of integrating BCM with ERM. The Covid-19 pandemic highlighted deficiencies in prearranged Business Continuity Plans,

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[45] HILLSON, David – **The risk management handbook: A practical guide to managing the multiple dimensions of risk**. 2nd edition. London: Kogan Page, 2023, p. 19-20. ISBN 978-1-3986-1061-3.

particularly when disruptions affect critical resources like energy, water, and transportation. In this context, Amani Abu Rumman[46] points out that integrating vigilance into business operations and crisis management into BCM can enhance organizational resilience by identifying potential crises early and improving response strategies. This approach helps organizations to adapt to economic disturbances, governance issues, and other threats, ensuring that BCM remains dynamic and responsive to changing conditions.

Integrating ERM with BCM thus provides a comprehensive framework that strengthens resilience and ensures continuity in the face of various disruptions, aligning risk management with strategic objectives and operational needs.

It is essential to remember, however, that risk management strategies must be tailored to each organization's specific needs and contexts. There is no one-size-fits-all solution; the strategies should be customized to address the unique risk profiles, risk appetites, and strategic objectives of the organization. This ensures that risk management remains relevant and effective, aligning with the organization's specific circumstances and goals.

2.3.2 Financial, Market, and Reputational Risks

Organizations inevitably encounter financial risks, as the achievement of their goals becomes exceedingly challenging without sufficient financial resources. Consequently, financial risk management is crucial for organizational stability. This process involves identifying and mitigating risks related to financial contracts and potential losses. Unlike general risk management, financial risks are more easily quantifiable and can be addressed through a range of risk financing options. Examples of financial risks include credit risk, market risk, liquidity risk, exchange rate fluctuations, and interest rate changes.

Market risk encompasses the uncertainties and potential losses arising from market dynamics, including commercial risks and fluctuations in market demand or competition. In the context of granite quarrying, these risks are further compounded by financial uncertainties such as

[46] RUMMAN, Amani Abu – **Impact of strategic vigilance and crisis management on Business Continuity Management**. Journal of Management Information Systems, 2022. [Accessed 13 September 2024]. Available at: https://www.researchgate.net/profile/Amani-Abu-Rumman-2/publication/358461260_IMPACT_OF_STRATEGIC_VIGILANCE_AND_CRISIS_MANAGEMENT_ON_BUSINESS_CONTINUITY_MANAGEMENT/links/620382bb3b8968353d340fe1/IMPACT-OF-STRATEGIC-VIGILANCE-AND-CRISIS-MANAGEMENT-ON-BUSINESS-CONTINUITY-MANAGEMENT.pdf.

price volatility and shifts in economic conditions. Additionally, sales and customer risks, such as changes in customer preferences and demand patterns, play a significant role. To mitigate these risks, effective management strategies should include diversifying market portfolios, employing hedging techniques, and maintaining robust financial planning. These approaches help stabilize operations, protect against economic downturns, and ensure the resilience of business strategies in the face of evolving market conditions.

Moreover, financial and market risks are intrinsically connected to reputational risk. Reputational risk pertains to the potential negative effects on a company's image and brand, which can lead to a loss of customer trust and damaged relationships with partners. Even in the absence of direct financial losses, reputational risk can substantially increase business transaction costs, as considerable time, energy, and resources are redirected toward rebuilding stakeholder trust and confidence.[47]

A notable example of reputational risk can be seen in the mining sector in Brazil. The tragedies of Mariana and Brumadinho have severely tarnished the reputation of mining companies. These incidents were so impactful that public perception turned negative, affecting all mining companies regardless of their involvement in such scandals.

The tragedies of Mariana and Brumadinho were catastrophic failures of mining dams in Brazil, causing immense loss of life, environmental destruction, and long-lasting social impacts. In Mariana, on November 5, 2015, the Fundão dam, owned by Samarco, burst, releasing approximately 60 million cubic meters of iron ore tailings, leading to 19 deaths and widespread environmental damage, contaminating the Doce River and affecting thousands of people. Similarly, on January 25, 2019, the Brumadinho dam, operated by Vale S.A., collapsed, releasing around 12 million cubic meters of mining waste, resulting in 270 fatalities and devastating the surrounding community and ecosystem.

These disasters highlighted significant lapses in safety regulations and corporate responsibility within the mining industry, leading to severe reputational damage not only for the companies involved but to the entire mining sector, as well as increased scrutiny from the public and regulatory bodies.

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[47] HILLSON, David – **The risk management handbook: A practical guide to managing the multiple dimensions of risk**. 2nd edition. London: Kogan Page, 2023, p. 113. ISBN 978-1-3986-1061-3.

Mariana and Brumadinho tragedies underscore the critical importance of managing reputational risk, particularly in industries with high public visibility and potential for severe environmental impact.

Effective reputational risk management involves addressing the concerns of various stakeholders, including customers, employees, shareholders, society, and regulatory bodies. A mining company with a poor reputation may face frequent inspections from environmental agencies and labour courts, risking penalties that could disrupt operations and cause a significant financial impact.

Furthermore, in family-owned businesses, reputational damage can have extensive and far-reaching consequences. The name and image of the family are directly linked to the company, and in the public's perception, any wrongdoing by the company is often attributed to the actions or negligence of its owners. Consequently, the family is seen as reflecting the company's values and ethics. This intertwined relationship means that reputational harm not only affects the business but also tarnishes the family's personal reputation, potentially leading to significant social and professional repercussions.

In conclusion, risk management strategies must be tailored to the unique financial, market, and reputational risks of each organization. A one-size-fits-all approach is inadequate; instead, strategies should be customized and regularly reassessed and updated to remain effective in a changing environment.

2.3.3 Operational Risks

Operational risk is an inherent aspect of any business, encompassing a wide range of potential issues that may arise within an organization or from external factors. This type of risk includes threats such as disruptions, fraud, human error, malicious acts, legal and regulatory breaches, digital attacks, and natural disasters.[48] By definition, operational risk refers to the potential for loss resulting from inadequate or failed internal processes, people, systems, or external events. Although the causes of operational risk are non-financial, they often result in substantial financial losses.

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[48] HILLSON, David – **The risk management handbook: A practical guide to managing the multiple dimensions of risk**. 2nd edition. London: Kogan Page, 2023, p. 56. ISBN 978-1-3986-1061-3.

Managing operational risk is a complex and decentralized task that is embedded in every business operation and requires the involvement of all members of the organization. Effective operational risk management (ORM) therefore demands a multidisciplinary approach that integrates strategies from various risk management domains. ORM teams must work collaboratively to address the full range of operational risks, which continuously evolve alongside the business and its environment.

Operational risks are particularly critical when disruptions can halt business and production operations or cause supply chain interruptions, accidents, and other relevant incidents. The Covid-19 pandemic underscored the vulnerabilities in many companies' supply chains, revealing the severe consequences of inadequate planning for such disruptions. Businesses that had not anticipated these events struggled to maintain operations and meet client demands amidst shortages of goods and workforce.

This pandemic experience underscored the importance of robust supply chain risk management (SCRM), which aims to ensure business continuity and mitigate any disruptions that could impact an "organization's operations and its ability to deliver products and services".[49] SCRM involves coordinating activities to manage risks across the entire supply chain, from raw materials to end customers.

The diverse causes of supply chain disruptions – ranging from talent shortages and transportation failures to adverse weather, health and safety incidents, cyber-attacks, and political changes[50] – demand a holistic approach to risk management. To effectively prepare for such disruptions, companies must thoroughly examine their supply chain exposures and evaluate the potential impacts from financial, legal, reputational, and social perspectives.

Granite quarrying involves significant operational risks that require careful management, from the inherent hazards of the quarrying process to broader challenges like equipment failures, inefficient methods, and logistical complications. To mitigate these risks, stringent safety protocols and continuous monitoring are essential to protect workers and prevent accidents. Moreover, granite quarrying operations must address supply chain risks, including

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[49] HILLSON, David – **The risk management handbook: A practical guide to managing the multiple dimensions of risk**. 2nd edition. London: Kogan Page, 2023, p. 91. ISBN 978-1-3986-1061-3.
[50] Ibid., p. 158.

equipment availability, transport logistics, and potential delays from regulatory changes or environmental factors.

Environmental risks can become operational risks when they impact production. For example, disposing of waste material (sterile) within the mine site can enhance productivity and reduce operating costs by minimizing travel time and fuel consumption between the quarry and disposal area. However, this practice requires rigorous and regular monitoring, as an unstable waste pile can cause landslides that may obstruct the quarry site, directly disrupting production.

A permanent operational risk in granite quarrying is the disposal of sterile material. Operations cannot proceed without a designated and licensed disposal site approved by environmental agencies. This challenge is ongoing: as quarrying progresses, more overburden is generated, leading to the growth of the sterile pile. As the pile expands, it gradually reduces the available space for further disposal. Once the pile reaches its capacity, a new disposal site must be identified and licensed – a process that can take several months or even years.

Effectively managing risks in the granite industry is crucial for maintaining uninterrupted operations and meeting client demands. This requires implementing preventive maintenance schedules, optimizing quarrying techniques, and strategically planning sterile disposal. Robust supply chain management, investment in modern equipment, and personnel training in advanced methods are also essential to mitigate operational risks. ORM must be dynamic and tailored to the unique risks and circumstances of each business. In industries like granite quarrying, where operational and supply chain risks are particularly significant, comprehensive ORM strategies are vital for ensuring business continuity and long-term success.

2.3.4 Environmental Risks

Environmental risk refers to the potential for adverse impacts on the natural environment due to human activities or natural events, which can harm ecosystems, human health, and economic stability. Factors such as pollution, deforestation, climate change, habitat destruction, and improper disposal of hazardous materials are key contributors to these risks. In granite quarrying, environmental risks are particularly significant, including ecosystem disruptions and soil erosion. The specific environmental risks associated with granite quarrying and their implications are discussed in subchapter 1.1.2.

To responsibly manage environmental risks, granite quarrying companies must conduct rigorous and ongoing assessments of the environmental impacts associated with their operations. Strategic decisions on location, methodology, timing, and extraction volumes should be guided by comprehensive environmental cost-benefit analyses. This includes avoiding aggressive or unsustainable mining practices, ceasing exploration in areas with low material utilization rates, and prioritizing sustainable recovery and environmental compensation measures. Investment in equipment that minimizes environmental impact is also essential.

Additionally, periodic geological and environmental monitoring is crucial for identifying and mitigating potential risks, as well as for developing and implementing robust environmental management plans. These plans should incorporate sustainable quarrying practices, such as controlled blasting techniques and the rehabilitation of quarried areas, to reduce ecological damage and ensure compliance with environmental regulations.

In summary, managing environmental risks in granite quarrying requires identifying potential hazards, assessing their impacts, and implementing targeted strategies to mitigate or prevent damage to both the environment and quarrying operations. Effective management hinges on comprehensive environmental impact assessments, the adoption of sustainable mining practices, and ongoing environmental monitoring. These measures are crucial for minimizing environmental harm and ensuring responsible quarrying practices.

2.3.5 Health and Safety Risks

Health and safety risks refer to potential threats that can adversely affect the well-being of employees, customers, and the overall integrity of a business. These risks can impact both physical and mental health. Common mental hazards include stress, workplace bullying, excessive job demands, and poor work-life balance, which can lead to anxiety, burnout, and reduced job satisfaction. Physical risks encompass hazards like ergonomic issues, slips, trips, falls, and machinery malfunctions.

In granite quarrying, these risks are particularly pronounced due to the nature of the work, which exposes workers to dust, high noise levels, and heavy machinery. For a detailed analysis of these specific risks and their implications, refer to subchapter 1.1.3

Accidents are an inherent risk in quarrying due to the operation of large, potentially dangerous equipment such as excavators, loaders, and crushers. Common incidents include machinery malfunctions, falls from heights, and injuries from falling objects. To mitigate these risks, it is essential to adhere to stringent safety protocols, conduct regular training and safety drills, and ensure all equipment is properly maintained. Establishing clear safety procedures and emergency response plans and ensuring that all workers are familiar with these protocols, are crucial for preventing accidents and effectively managing their impact.

A dedicated health and safety department is fundamental to any reputable mining company, reflecting its commitment to managing and mitigating the diverse risks associated with quarrying operations. This department ensures workplace safety, regulatory compliance, and the well-being of employees. In Brazil, home of the case study in Chapter 4, such department is required by law if the company has 50 or more employees.

Central to the department's role is the comprehensive assessment of risks, which includes identifying potential hazards related to machinery, environmental conditions for safe production, ergonomics, psychosocial factors. Based on these assessments, the department develops and implements risk management strategies, including engineering controls, administrative measures, and personal protective equipment (PPE).

The department is responsible for establishing and maintaining robust safety protocols. This involves creating and regularly updating detailed safety manuals, standard operating procedures, and emergency response plans. It also organizes regular training sessions to ensure employees are well-versed in the use of PPE, emergency response procedures, first aid, and mining-specific safety practices.

Monitoring and compliance are crucial aspects of the department's duties. Regular inspections of work sites, equipment, and safety procedures are conducted to ensure adherence to safety standards. The department investigates incidents to identify causes and implement corrective actions to prevent future occurrences, maintaining high safety standard within the organization.

Additionally, the department often oversees health programs aimed at enhancing overall employee well-being. These programs may include health screenings, wellness initiatives, mental health support, and measures to address occupational health issues such as respiratory conditions or musculoskeletal disorders.

Emergency preparedness and response are also key responsibilities. The department develops and tests emergency response plans, conducts regular drills, and coordinates with local emergency services to ensure that employees are prepared for potential incidents.

Fostering a strong safety culture is integral to the department's success. By promoting open communication about safety issues and encouraging employee involvement, the department helps create an environment where safety concerns are proactively addressed.

Each mining company's health and safety department must tailor its strategies and programs to the specific needs and challenges of its operations, considering factors such as the size of the operation, types of mining activities, and regulatory environment. This proactive approach helps prevent accidents and injuries, ensuring a safe and healthy work environment.

2.3.6 Legal Risks

As defined by ISO 31022:2020, legal risk relates to the uncertainties stemming from legal, regulatory, and contractual matters, as well as non-contractual rights and obligations. This category of risk includes challenges associated with contractual obligations, litigation, liability, and regulatory compliance. These risks are intrinsically tied to the complex legal environment in which organizations operate, where laws and regulations can vary significantly across various jurisdictions.

Contractual risks encompass uncertainties and potential challenges associated with forming and managing agreements. These risks can include ambiguities in contract terms, breaches of contract, contractual liabilities, regulatory compliance issues, force majeure events, counterparty risks, unclear termination clauses, and disputes that may escalate into litigation.

To mitigate these risks and ensure the successful execution and enforcement of contracts, it is essential to adopt robust contract management practices. This includes thorough negotiation processes, precise drafting of contract terms, diligent monitoring of contractual obligations, and maintaining comprehensive and accurate documentation.

Litigation risk poses a significant challenge for organizations, encompassing potential legal disputes over issues such as environmental impact, worker safety, and land use. One major concern is labour disputes, which can arise from disagreements between employees and management regarding working conditions, wages, or employment terms. Such disputes may occur both during and after employment, with former employees potentially filing claims for compensation related to unsafe working conditions, night shift allowances, overtime, and moral damages arising from harassment or mistreatment. These claims can lead to costly settlements and harm the organization's reputation.

To manage litigation risk effectively, organizations should adopt a proactive legal strategy. This involves conducting regular risk assessments to anticipate potential disputes, ensuring access to skilled legal counsel to address issues promptly, and developing comprehensive contingency plans. These plans should detail steps for resolving disputes efficiently and mitigating legal challenges, thereby minimizing the impact on organizational operations and stability.

Liability risk entails the potential for an organization to face legal responsibility for damages resulting from its activities, and in granite quarrying, this risk can lead to considerable financial losses. Such risks include legal obligations for environmental damage, health and safety violations, and property damage, which can result in significant fines and penalties from regulatory bodies. Defending against claims and making compensation payments add further financial strain, while increased insurance premiums and challenges in obtaining coverage can amplify costs. Additionally, liability risks can disrupt operations, damage reputations, lead to regulatory sanctions, and invite increased scrutiny, all of which threaten the quarrying operation's financial stability and long-term sustainability.

Regulatory compliance risk pertains to the need to adhere to various laws and regulations that govern the organization's activities to avoid fines, sanctions, or operational restrictions.

Effective compliance requires staying informed about relevant regulations, conducting regular audits, and implementing management systems to ensure legal adherence.

Unlike regulatory compliance, which focuses on strict adherence to laws, legal risk management involves more flexible strategies, such as risk sharing or retention. While compliance aims to avoid any breach of the law, risk management often uses techniques like cost-benefit analysis to determine appropriate strategies.[51]

In the context of granite quarrying, where non-compliance can result in severe penalties and operational shutdowns, developing tailored legal risk management strategies is essential. This involves creating comprehensive risk management programs, staying updated on regulatory changes, and proactively engaging with regulatory authorities. As we transition to the next chapter, we will delve into the specific legal framework governing granite quarrying in Brazil and explore how international risk management standards align with these regulations. This will set the stage for Chapter 4, which will address the practical application of these theoretical and regulatory insights through a case study.

3 UNDERSTANDING THE LEGAL AND REGULATORY FRAMEWORK OF RISK MANAGEMENT IN GRANITE QUARRYING IN BRAZIL

Granite quarrying is considered a high-risk activity due to its significant environmental impacts and the potential hazards to workers. Consequently, the legal and regulatory framework that regulates, controls and monitors this practice is extensive, featuring detailed and stringent procedures aimed at mitigating environmental impacts and reducing workplace risks.

This chapter briefly explores the legal and regulatory framework governing risk management in granite quarrying in Brazil. Rather than delving into a detailed examination or extensive debate on specific legislation, the focus will be on understanding the fundamental legal aspects that oversee this activity, including jurisdictions, procedural requirements, licensing processes, and enforcement mechanisms, as the objective is only to inform which legal basis

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[51] This study does not aim to delve into the theme of compliance. For further information, refer to ISO 37301:2021, an international standard for compliance management systems. This standard provides guidelines for establishing, developing, implementing, evaluating, maintaining, and improving an effective and responsive compliance management system within organizations.

was used for the case study presented in Chapter 4. For a comprehensive list of the pertinent laws, regulations, and international standards relevant to this discussion, please refer to Annex 01.

3.1 International Standards in Risk Management

Risk management is a critical component of operational strategy across industries worldwide, and its importance is underscored by a variety of international standards that provide comprehensive guidelines for identifying, assessing, and mitigating risks. Prominent among these standards are those established by key organizations such as the International Organization for Standardization (ISO), the Committee of Sponsoring Organizations of the Treadway Commission (COSO), and the International Electrotechnical Commission (IEC). These institutions provide industry-neutral, globally recognized benchmarks, setting out principles and processes that can be tailored to different sectors and geographies.

ISO offers a broad spectrum of standards focused on quality management, environmental stewardship, occupational health and safety, and risk management, aiding organizations in meeting regulatory requirements, minimizing environmental impact, and ensuring workplace safety. IEC, in collaboration with ISO, delivers specialized standards for information security and cybersecurity, helping organizations protect their information assets. COSO contributes with frameworks for internal control and enterprise risk management, emphasizing the alignment of risk management with organizational strategy to enhance decision-making, compliance, and operational effectiveness. Together, these bodies significantly advance global organizational practices by promoting quality, environmental protection, risk mitigation, and operational resilience.

One of the foremost standards in this domain is ISO 31000, which outlines principles and guidelines for risk management applicable to any organization, regardless of its size, industry, or sector. It promotes a structured and comprehensive approach, integrating risk assessment into organizational decision-making processes. Complementing this, ISO 31010 offers a toolbox of risk assessment techniques, providing organizations with various methods to evaluate risks. Another key framework, the COSO ERM Framework, is widely used for aligning risk management with strategic and performance goals, offering a cohesive set of practices to help organizations understand and mitigate risks effectively.

In high-risk industries such as quarrying, additional standards like ISO 45001 for occupational health and safety, and ISO 14001 for environmental management, also play critical roles in guiding operational strategies and practices. Case studies from the quarrying sector highlighted the successful integration of these standards, demonstrating improvements in safety protocols, reduced environmental impact, and increased operational efficiency. These standards not only ensure regulatory requirements but also foster a culture of safety and environmental responsibility, especially in sectors such as granite quarrying.

However, the application of these risk management standards can vary significantly between jurisdictions due to differences in national regulatory frameworks. In many European Union countries, robust national legislation mandates the implementation of risk management across industries. Germany, in particular, stands out for its comprehensive approach to risk management, which is deeply ingrained in corporate governance and industrial practices.

The *Deutscher Corporate Governance Kodex* (German Corporate Governance Code) emphasizes the integration of risk management as a core element of corporate governance, encouraging companies to embed it within their strategic frameworks. Additionally, the *Gesetz zur Kontrolle und Transparenz im Unternehmensbereich* (KonTraG – Control and Transparency Act) legally mandates that companies establish risk management systems to proactively identify and mitigate risks, requiring corporate management to implement a company-wide early risk identification system. This legislation exemplifies how risk management is not only a regulatory requirement but also a cultural norm that enhances organizational resilience and transparency in the German industrial and manufacturing sectors.

Transitioning to the Brazilian context, the contrast is striking. Brazil's legal framework for risk management remains fragmented and underdeveloped, relying on sector-specific regulations rather than a comprehensive, unified national policy. In the absence of legislation comparable to Germany's KonTraG, Brazilian companies, particularly in high-risk industries like granite quarrying, often turn to international standards to address regulatory gaps and guide risk management practices. The Brazilian Association of Technical Standards (ABNT) facilitates this process by aligning national standards with international benchmarks, providing guidelines that enable companies to meet both domestic and global compliance requirements.

This reliance on international standards highlights a critical gap in Brazil's risk management landscape: while larger companies, especially those operating on an international scale, have embraced these frameworks to mitigate risks and improve operational safety, smaller companies often lack the resources, knowledge or incentive to do so. Consequently, risk management practices remain largely confined to large organizations, particularly in the ornamental stone quarry industry, where only well-established companies tend to prioritize risk assessment and mitigation strategies.

This disparity is further underscored when compared to more developed regulatory environments in Europe, where risk management is not only a legal obligation but also a strategic priority embedded within corporate culture. In Brazil, the absence of overarching national legislation means that a risk management culture is underdeveloped, both at the corporate and governmental levels. This issue has been starkly highlighted by recent disasters, such as the dam failures in Mariana (2015) and Brumadinho (2019), which exposed significant weaknesses in Brazil's regulatory oversight and the limited adoption of proactive risk management frameworks.

In conclusion, while international standards such as ISO 31000 provide a valuable framework for mitigating risks across industries, Brazil's lack of national legislation on risk management poses a significant challenge. Without a regulatory mandate, the adoption of risk management practices remains inconsistent, largely confined to larger corporations with greater access to resources and international markets. There is, however, an increasing recognition of the need for change, spurred by high-profile industrial disasters. Nevertheless, without state or legislative incentives, the development of a robust risk management culture in Brazil remains limited, restricting the broader implementation of these crucial practices across the industry.

Addressing this gap could enhance safety and operational resilience, promote sustainable practices, and foster a risk culture that benefits both the environment and local communities. In the absence of specific legislation, operators must rely on international risk management standards while also adhering to the broader Brazilian legal framework for granite quarrying. As the discussion transitions to the next subchapter, the focus will shift to examining Brazil's legal and regulatory framework for granite quarrying and its practical application within the industry.

3.2 Legal and Regulatory Framework for Granite Quarrying in Brazil

In antiquity, the use of ornamental stones was significantly limited due to the prevailing mine property systems and available quarrying techniques. In ancient Egypt, quarries for ornamental stones were owned by the pharaohs. During Classical Greece, these resources were the property of city-states, whereas, under Roman and Byzantine laws, deposits were regarded as part of the emperor's treasury. Regulation of subsoil usage as a matter of public interest only began to emerge around the Medieval period, becoming more widespread during the Modern Age. Nonetheless, the practice of granting mining rights to private entities was already in existence during these earlier times.

In Brazil, the Portuguese Crown directly controlled mineral exploration during the colonial era. However, in the 19th century, particularly following Brazil's independence in 1822, this practice began to take a more organized form. The landmark legislation in this regard was the Mining Code of 1934, which established the framework for granting mining rights to companies and individuals. This code marked a significant development, as it allowed for the issuance of concessions enabling private entities to engage in mineral exploration under specific regulations. The 1934 code was subsequently updated by the 1967 Mining Code, which remains in force to this day.

The Brazilian legal system is structured to ensure efficient justice organization at multiple governmental levels, with competencies divided among the Union, the States, and the Municipalities. The Constitution of the Federative Republic of Brazil of 1988 (CRFB) is the supreme law, defining the principles and organization of the government, as well as the rights and duties of citizens. All norms and decisions must align with the Constitution.

The Union holds exclusive competencies in areas such as civil, commercial, criminal, and electoral law, as well as in matters of national defence, monetary policy, and the management of natural resources like water, energy, and minerals. Additionally, the Union is responsible for legislation on immigration, indigenous populations, and the organization of national systems such as employment and social security. States have the authority to legislate on regional matters, including environmental protection, health, and transportation, provided such laws do not conflict with federal regulations. Municipalities are responsible for addressing local needs, such as urban planning and waste management, and can enact local laws that comply with both federal and state legislation.

While the Union is primarily tasked with establishing general norms, States have supplementary legislative power, and in the absence of federal law, they may exercise full legislative authority to address their specific needs. Moreover, the Union can supplement state and municipal legislation when necessary, ensuring a cohesive legal framework across the country. Therefore, municipal or state environmental laws can only be more rigid or restrictive than federal ones, never more lenient.

The distribution of powers also extends across different government branches. The Legislative Branch, represented by the National Congress at the federal level, by State Assemblies at the state level, and by City Councils at the municipal level, is responsible for lawmaking. The Executive Branch, led by the President of the Republic federally, Governors at the state level, and Mayors municipally, is tasked with implementing laws and managing public administration. The Judicial Branch, including the Supreme Federal Court (STF), the Superior Court of Justice (STJ), and the state Courts of Justice, interprets and applies laws, resolving conflicts and ensuring justice.

Public administration is divided between direct administration, composed of government agencies and entities directly subordinate to the government, and indirect administration, which includes autarchies, public foundations, state-owned enterprises, and mixed-economy societies. This structure aims for efficient resource and service management while respecting the peculiarities and needs of each government level and branch.

Granite quarrying in Brazil is thus subject to a multi-layered legal and regulatory framework that integrates federal, state, and municipal authorities, each with distinct roles and responsibilities. At the national level, the CRFB designates mineral resources, including granite, as property of the Union, thereby centralizing legislative and regulatory authority. The National Mining Agency (ANM) is the primary federal body overseeing mining activities, with its role complemented by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) and the National Environmental Council (CONAMA), which set broad environmental standards and policies. Additionally, the National Institute of Historical and

Artistic Heritage (IPHAN) provides oversight to ensure that mining activities do not compromise culturally significant sites.

In Espírito Santo, a leading state in granite production and the location of the company featured in the case study presented in Chapter 4, the regulatory framework is characterized by the collaboration between the state-level branch of ANM and the Espírito Santo Institute of Environment and Water Resources (IEMA) to ensure regional environmental compliance. At the municipal level, local authorities, including the Environment Department of the Municipality, enforce land use regulations and manage the local impacts of quarrying activities. This multi-tiered approach addresses national priorities and regional specificities, creating a comprehensive regulatory framework for granite quarrying in Brazil.

To commence a granite quarrying activity in Brazil, prospective operators must adhere to a series of procedural requirements to ensure compliance with legal and environmental standards. The process begins with obtaining federal authorization from ANM, which requires the submission of comprehensive project proposals and detailed operational plans. Concurrently, operators must secure environmental licensing at the state and municipal levels, adhering to regulations outlined in Complementary Law nº 140/2011 and in CONAMA Resolutions nº 1/1986 and nº 237/1997.

This dual-layered approach ensures compliance with mining and environmental regulations and aligns quarrying activities with local land use and zoning requirements. Municipal licensing further guarantees that operations are consistent with local development plans.

The procedure for obtaining federal authorization before ANM for granite quarrying involves an authorization and concession regime, a two-phase process, where, first, authorization for mineral research is sought and, once this phase is completed, the mining concession is pursued. Recent legislative changes, through the enactment of Law nº 13.975/2020, have simplified the licensing process for ornamental stone quarrying by allowing operations under a special licensing regime.

The table below outlines the main differences between the special licensing procedure introduced by the 2020 law and the traditional authorization and concession regime. This comparative framework highlights the distinctions between the two approaches in procedural complexity, required documentation, and overall regulatory burden. While the special licensing procedure offers a streamlined and less costly process, the authorization and concession regime, despite its greater complexity, provides enhanced legal security and stability for mining operations. Once granted, a federal concession removes the need for ongoing municipal licensing, offering a stable investment environment.

	SPECIAL LICENSING	AUTHORIZATION AND CONCESSION
PROCEDURE	Simplified	Phased
REQUIRED DOCUMENTS	Formal request to ANM Simplified Mining Plan (PSL) Environmental licenses Identification documents	Formal request to ANM Research plan Proof of payment of the Annual Rate per Hectare (TAH) Final Research Report Economic Exploitation Plan (PAE) Project for the Recovery of Degraded Areas (PRAD) Environmental licenses Proof of technical and financial capability Identification documents
COST	Less costly	More costly

Table 2 – Mining Licensing: Special Licensing x Authorization and Concession

While the federal mining license issued by ANM focuses on the technical and safety aspects of mining operations, the environmental license, managed by IBAMA and state agencies such as IEMA, addresses the environmental impacts and requires detailed impact assessment and mitigation plans.

The environmental licensing process for granite quarrying is divided into three phases. Initially, operators must apply for a Preliminary License (*Licença Prévia*, LP), which establishes the environmental viability of the project. Following this, an Installation License (*Licença de Instalação*, LI) is granted to allow the construction of mining infrastructure. Finally, an Operation License (*Licença de Operação*, LO) permits the commencement of actual quarrying activities.

A summary of the dual licensing system to which mining companies in Brazil are subject is provided in the following image. This system encompasses mining and environmental licensing requirements, reflecting the regulatory framework designed to ensure comprehensive compliance with mineral and environmental protection standards.

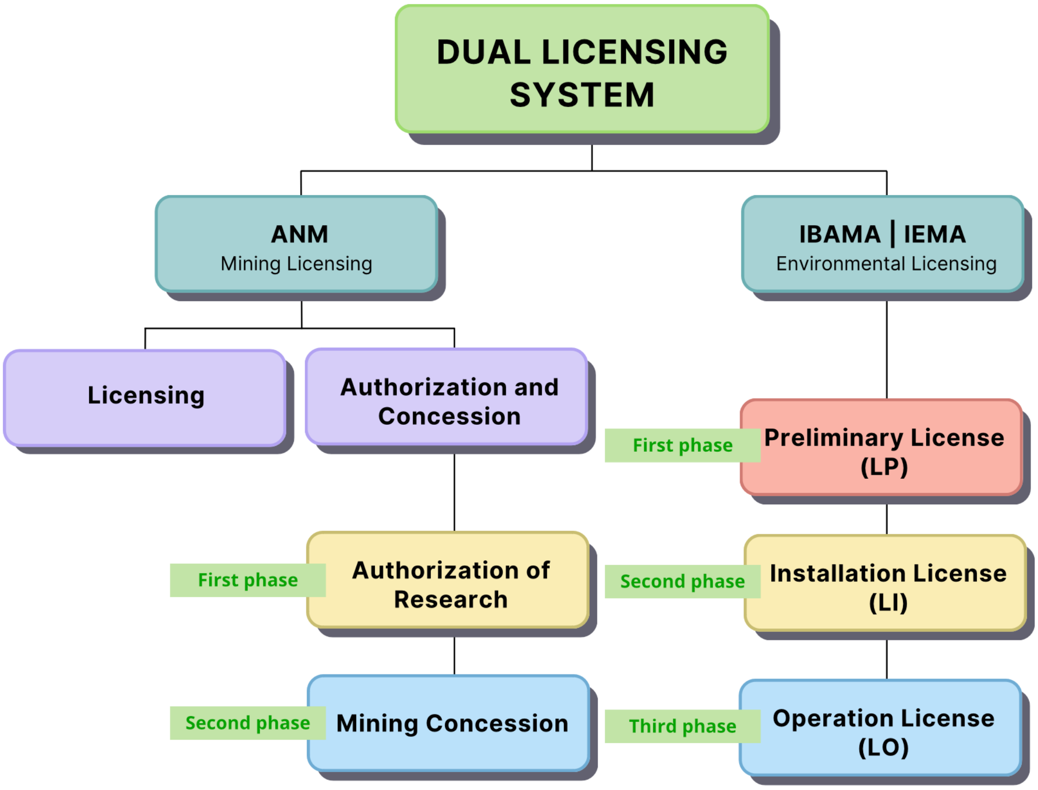

Figure 4 – Summary of the Brazilian dual licensing system

The Brazilian legal framework provides stringent enforcement mechanisms to ensure adherence to mining and environmental laws and standards through a collaborative effort among federal, state, and municipal regulatory agencies.

Enforcement is a multi-tiered process involving monitoring, inspections, and penalties. The ANM primarily manages federal oversight, ensuring that mining operations adhere to federal laws by conducting regular inspections and audits. Additionally, state and municipal authorities enforce environmental regulations and standards through their own inspection and monitoring processes.

Non-compliance with mining and environmental regulations can result in severe consequences for operators, reflecting the stringent enforcement mechanisms in place to uphold regulatory standards. Violations may result in substantial administrative penalties, including significant fines imposed by regulatory authorities, as well as civil liabilities. ANM and IEMA[52] have the authority to suspend or revoke mining and environmental licenses for severe or repeated infractions. Furthermore, significant breaches can incur criminal charges

[52] Considering the context of the state of Espírito Santo. For other states, observe the state environmental agency responsible for granting, monitoring, suspending or revoking environmental licenses.

under environmental protection laws, such as Law nº 9.605/1998, which addresses environmental crimes and prescribes penalties, including imprisonment. Additionally, operators found in violation may be required to conduct environmental restoration and remediation projects to address and mitigate any damage caused by their activities.

Therefore, the legal and regulatory framework governing granite quarrying involves both administrative and judicial mechanisms to address and prosecute irregularities. When violations occur, the regulatory bodies can initiate administrative proceedings, which may result in sanctions like fines, suspension of operations, or license revocation. Entities have the right to present a defense during these proceedings, and decisions can be appealed within the administrative system.

Judicial proceedings come into play when there is evidence of criminal conduct, such as illegal mining or environmental crimes. The Public Prosecutor's Office typically leads these prosecutions, which can result in penalties including imprisonment, criminal fines, or orders to restore environmental damage. Judicial cases follow a formal trial process, and decisions can be appealed to higher courts.

Overall, Brazil's regulatory framework governing granite quarrying is meticulously designed to balance economic development with environmental conservation. This multi-jurisdictional approach ensures comprehensive oversight by integrating various layers of authority while procedural requirements and enforcement mechanisms are established to ensure compliance and mitigate environmental impacts.

Nevertheless, despite the robust framework on paper, the practical enforcement of these laws often falls short. The ideal of a well-regulated industry is frequently undermined by inadequate enforcement and pervasive corruption. The theoretical framework of Brazilian mining laws does not always translate into effective environmental protection due to several critical issues.

Recent studies highlight significant concerns with enforcement effectiveness. Nunes et al.[53] document a trend towards the militarization of enforcement, accompanied by a noticeable

[53] NUNES, Felipe [et al.] – **Lessons from the historical dynamics of environmental law enforcement in. the Brazilian Amazon**. Scientific Reports 14, article number 1828, 2024. [Accessed 13 September 2024]. Available at: https://www.nature.com/articles/s41598-024-52180-7#citeas.

decline in the number of embargoes and asset confiscations from 2018 to 2022. Despite a substantial increase in enforcement spending, this drop suggests a decrease in operational efficiency. Additionally, Serrano and Fonseca[54] point out that while post-approval legal requirements are strict, a considerable percentage of projects encounter performance issues and face administrative sanctions. This indicates that the regulatory authority's response is often slow and lacks clarity.

Furthermore, corruption remains a major issue, where public officials might overlook illegal activities in exchange for bribes, and businesses may offer financial incentives to bypass inspections. This corruption undermines the integrity of the enforcement process, leading to ineffective monitoring and enforcement of both environmental and operational standards.

Moreover, Brazil's socio-political instability exacerbates these challenges. Economic crises have heightened social tension and polarization, impacting the effectiveness of regulatory bodies. Legislative conflicts and political polarization, especially notable during the Bolsonaro administration (2019-2022), have further politicized environmental issues. Left-wing parties, while vocally advocating for environmental protection, have sometimes delivered more rhetoric than action. Conversely, right-wing policies have often prioritized deregulation, dismantling public agencies, and economic gain from extractive activities, frequently at the expense of environmental safeguards.

In conclusion, the effective management of environmental concerns in Brazil's granite quarrying sector has been significantly hampered by ideological conflicts and systemic issues. Despite having a comprehensive legal framework in place, the real-world application of these regulations is frequently undermined by corruption, socio-political instability, and conflicting interests. These challenges create a stark contrast between the regulatory ideal and its practical enforcement, complicating efforts to harmonize economic growth with environmental and social protection. To bridge this gap, it is essential to address these implementation hurdles through coordinated efforts aimed at combating corruption, minimizing political interference, and ensuring equitable and consistent law enforcement.

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[54] SERRANO, Alessandra; FONSECA, Alberto – **License to pollute? A longitudinal analysis of environmental performance, compliance, and enforcement in 232 licensed projects in Brazil**. Journal of Cleaner Production, volume 434, article number 139977, 2024. [Accessed 13 September 2024]. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0959652623041355.

Only by tackling these underlying issues can Brazil hope to develop a more effective regulatory environment that supports sustainable practices and protects both the environment and local communities.

To illustrate the application of the theoretical and regulatory framework established in this chapter, the next section will present a case study from Espírito Santo. This real-world scenario will demonstrate how the legal and risk management principles discussed are put into practice within the granite quarrying industry.

For a comprehensive list of legislative texts relevant to the matter, consult Annex 01, and for information on pertinent regulatory bodies, refer to Annex 02.

4 STRATEGIC AND APPLIED RISK MANAGEMENT IN GRANITE QUARRY OPERATIONS: A CASE STUDY FROM ESPÍRITO SANTO

4.1 CASE STUDY INTRODUCTION AND METHODOLOGY

This research employs a mixed-methods approach, combining qualitative and quantitative techniques to explore the practical applications of risk management within the Brazilian granite quarrying industry. The primary focus is a qualitative case study, supported by in-depth interviews, focus groups, and quantitative data analysis. The subject of this case study is a family-owned company of national relevance. Founded in the late 1970s as a family dream, the company only initiated its quarry operations in the early 2000s. Today, it stands as a key player in the Brazilian granite industry, demonstrating both resilience and the ability to adapt to shifting market demands. Its success and adaptability make it an ideal subject for an in-depth study of risk management practices.

This case study method was selected for its ability to provide a detailed and context-rich examination of the company's risk context and risk management practices, which are representative of broader trends in the Brazilian quarrying sector.

The qualitative aspect of the study involved conducting in-depth interviews with area managers, technicians, senior partners, and other relevant personnel, offering insights into how the company perceives and manages risks, particularly in areas like health and safety, environmental management, and legal compliance. Focus groups were also conducted with employees from different levels of the organization to explore shared experiences and collective views on risk management challenges. These qualitative methods provided a deep understanding of the operational and human factors influencing risk management in the company.

Complementing the qualitative data, the study employed quantitative methods such as data analysis and document review. Operational and safety data were analyzed to identify trends and patterns in the company's risk profile, while internal documents were examined to assess the company's historical performance. This integration of qualitative and quantitative data allowed for a more comprehensive understanding of both the subjective and measurable aspects of risk management.

Despite its robust design, the study faced significant limitations due to logistical and financial constraints, as being based in Portugal while researching a company in Brazil created challenges. Budget limitations restricted the research to just two trips, hindering the possibility of more comprehensive data collection. Time and space constraints, including character limits for the dissertation, narrowed the focus to five key risks commonly encountered by granite quarrying companies in the region. These risks, varying in impact depending on each company's context and structure, have the potential to cause substantial financial losses, disrupt operations, and threaten business continuity. Additional challenges included delays in communication due to time zone differences and limited access to local resources. Nevertheless, the mixed-methods approach proved valuable, offering insights into the common risks in the sector and the company's risk management strategies.

The research, by combining qualitative insights with quantitative analysis, provided a nuanced understanding of how risks are perceived and managed in the Brazilian granite quarrying industry. This approach, though constrained by time, budget, and logistical factors, effectively captures the complexities of real-world risk management in the Brazilian context. These findings enhance the understanding of current risks and establish a foundation for future research on risks mitigation strategies in the industry.

Given the potentially sensitive nature of the data shared throughout this research, the company's identity will remain anonymous to protect the confidentiality of its operations and internal processes. This approach safeguards the integrity of the study and ensures that no proprietary information or industrial secrets are disclosed, while still providing a valuable examination of risk management within the Brazilian granite quarrying sector.

4.2 Geographical Context

The company in question is strategically located in the state of Espírito Santo, a region of immense significance in the Brazilian granite industry. As noted in subchapter 1.2, Espírito Santo leads granite extraction and processing in Brazil, being one of the world's largest exporters of this natural resource. Its proximity to major ports and strong infrastructure further solidifies its role as a global hub for quarrying, enabling the company to efficiently serve both domestic and international markets.

However, the geographical context poses a major challenge to the company: the widespread corruption highlighted in subchapter 3.2. Various companies and technicians within the granite industry in Brazil have reported frequent coercion by public regulatory agents, forcing companies to pay bribes to avoid embargoes or penalties. This situation places companies in a difficult position, where they may feel compelled to comply with illegal demands to protect their operations, even though this participation is not voluntary but a response to unfair pressures. The ethical and legal dilemmas faced by such companies makes corruption a critical factor to consider when analyzing risks of the industry.

4.3 Organizational Context and Relevance to the Study

The company employs between 150 to 200 direct workers and specializes in the quarrying of four visually and structurally similar granite materials, which are highly sought after in both the national and international markets. While most of its sales are focused on the national market, the company is making efforts to increase its presence in the international market, where its current sales remain relatively modest.

Focusing exclusively on granite quarrying (*lavra*) and not on processing (*beneficiamento*), the company's operational scope is confined to the initial phase of granite production. Consequently, all its clients are from the processing sector, responsible for the subsequent stages of granite refinement and preparation. This specialization in quarrying helps the company avoid various risks and challenges associated with processing, including environmental, operational, safety, market, and regulatory issues.

Despite its substantial operational capacity, the company does not have a dedicated risk management sector or department. However, a risk management culture is present, albeit in a reactive form. This means that while the company takes necessary actions to mitigate risks, these actions are often triggered only after risks have materialized. The lack of a centralized risk management structure means that risk responses tend to be more responsive than proactive, which can lead to inefficiencies in resource allocation and risk mitigation.

The company's Mining Assets and Safety Engineering and Occupational Health departments stand out as exceptions, as they manage risks in a proactive manner within their specific areas of responsibility. These departments have established procedures to prevent risks from materializing, ensuring a safer working environment and more stable operational conditions.

A significant milestone in the company's safety culture was the response to a fatal workplace accident in 2012. This tragic incident led to a comprehensive overhaul of the company's occupational health and safety practices. Major investments were made in the SESMT (Safety Engineering and Occupational Health) department, and internal safety policies and standards were extensively reformed. The introduction of rigorous inspection and control procedures for PPE, along with regular training and internal awareness programs, resulted in a dramatic shift in safety culture. Over a decade later, the company has experienced only minor incidents, reflecting the success of these proactive measures.

This scenario highlights the need to raise awareness within the company – and the wider granite industry – about the importance of adopting a proactive and holistic risk management approach. In the modern industrial landscape, it is crucial not only to map existing risks but also to implement proactive measures to prevent them. By doing so, companies can minimize disruptions, optimize resource allocation, and better align their risk management strategies with broader business objectives. The absence of a comprehensive, company-wide risk management system impacts both the efficiency of risk response and the effective use of resources, hindering the achievement of strategic goals.

This company was selected as the case study for this master's dissertation precisely because it exemplifies the critical need for a more integrated and proactive approach to risk management in the granite quarrying sector. A holistic approach, incorporating all operational areas, is essential for ensuring sustainable growth and long-term success.

4.3.1 Mining Assets context

The company currently manages a portfolio of 36 distinct mining licensing processes, each associated with a potential quarry site for ornamental stone extraction. This broad portfolio reflects the company's strategic focus on identifying and investing in diverse sites. However, due to the technical, legal, and financial challenges inherent in the granite quarrying industry, only one of these sites is currently operational and profitable.

Granite quarrying is the company's core activity, with the extracted granite sold in block form to the processing sector. The diverse development stages of its mining assets play a key role in shaping organizational objectives and decision-making. These varying phases directly influence the Board of Directors' priorities and strategic direction, while also guiding the Operations and Sales departments to align their efforts with the company's broader goals.

<table>
<tr><th>PHASE</th><th>QUANTITY</th><th colspan="2">STAGE OF MINING LICENSING</th></tr>
<tr><td>Pre</td><td>03</td><td colspan="2">Application for Authorization of Research</td></tr>
<tr><td>1</td><td>30</td><td colspan="2">Authorization of Research</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">03</td><td colspan="2">Mining Concession</td></tr>
<tr><td>02</td><td>Environmental Licensing ongoing</td></tr>
<tr><td>01</td><td>Quarry operating</td></tr>
<tr><td colspan="2">36</td><td colspan="2">TOTAL</td></tr>
</table>

Table 3 – Case Study: Stage of Mining Licensing

4.3.2 Stakeholders

DEPARTMENT	RESPONSIBLE FOR
Finance	• Manage the company's finances • Monitor and control cash flow and liquidity • Perform financial transactions • Conduct financial analysis and reporting • Oversee investment strategies and portfolio management • Implement and monitor internal financial controls • Manage financial risks • Tax planning

Human Resources (HR)	• Manage the company's finances • Oversee employee relations and conflict resolution • Manage recruitment, hiring, and onboarding processes • Oversee employee engagement and retention initiatives • Develop and implement HR policies and procedures • Develop and implement training and development programs • Manage payroll • Manage internal changes • Manage internal climate and culture • Collaborates with the Legal Department in labour lawsuits
Legal	• Draft, review, and manage contracts • Manage judicial and administrative proceedings • Provide legal defense in private and public domains • Offer legal consultancy across all departments and partners • Draft, review, and manage corporate documents • Draft, review, and manage powers of attorney • Provide legal guidance on business operations • Ensure compliance with laws, regulations, and standards • Manage intellectual property and confidential information
Mining Assets	• Provide environmental impact management • Provide geological safety management • Conduct geological studies to determine quarry sites • Manage and conduct mining and environmental licensing • Develop and implement asset management strategies • Ensure compliance with environmental standards • Monitor quarry performance and productivity • Manage asset procurement and disposition • Collaborate with Operations for effective asset utilization • Advise the board of directors in decision-making involving mining assets, environmental safety and geological stability
Operations	• Daily quarry operations • Implement and monitor operational efficiency improvements • Manage production schedules • Manage resource allocation • Ensure adherence to quality standards • Optimize use of operational resources and assets • Monitor and control operational costs • Manage maintenance • Manage and mitigate operational risks • Coordinate cross-departmental collaboration for operational success
Safety Engineering and Occupational Health	• Oversee emergency preparedness and response planning • Provide first aid response • Provide periodic safety trainings and PPE • Ensure compliance with occupational health and safety regulations and standards

	• Manage occupational health programs and services • Investigate and report workplace incidents and accidents • Monitor and improve safety performance metrics • Conduct risk assessments and hazard analysis • Ensure continuous improvement in safety standards • Collaborate with Operations to integrate safety into processes
Sales	• Develop and execute sales strategies and plans • Manage customer relationships • Identify and pursue new market opportunities • Set and monitor sales targets and KPIs • Oversee sales team performance and development • Negotiate contracts and close sales deals • Analyze market trends and customer needs • Collaborate with Finance on sales billing and invoicing
Supply	• Manage procurement processes and supplier relationships • Oversee inventory management and stock control • Ensure timely and cost-effective supply chain operations • Negotiate contracts and pricing with vendors • Develop and implement supply chain strategies • Manage supply chain logistics and distribution • Manage supply chain risks and disruptions • Ensure ethical standards in procurement and sourcing • Warehouse management

Table 4 – Case Study: Stakeholders

4.4 PURPOSES

This case study advocates for a holistic approach to risk management in granite quarrying, emphasizing the limitations of addressing risks in isolation by sector or type. It argues for an integrated strategy that considers interconnected risks across the organization. By promoting comprehensive risk mapping and proactive prevention, the study encourages companies to adopt more cohesive practices that improve safety, efficiency, and sustainability in quarry operations.

4.5 RISK CONTEXT

For the purposes of this study, a structured risk management framework was implemented, classifying the key risk areas within the company’s quarry operations into distinct categories. Each category covers essential aspects critical to the operational, financial, legal, and safety performance of the business. This classification enables a more focused and effective approach to identifying and mitigating risks. The table below outlines the primary impact areas and corresponding risk categories addressed in this case study.

IMPACT / RISK CATEGORY	ENCOMPASSES
Business	• Administrative and Managerial • Public relations • Commercial and sales • Corporate • Mining Assets • Human Resources • Marketing
Financial	• Accounting • Financial • Fiscal
Legal	• Contracts • Powers of Attorney • Litigation • Legal Advisory • Compliance
Operational	• Internal processes • Operations • Maintenance • Supply • Logistics and transportation
Safety	• Asset security • Emergency protocols and response • Environmental standards • Human behaviour • Medical • Safety standards, protocols and training

Table 5 – Case Study: Risk Context

4.6 PARAMETERS

4.6.1 Likelihood

LEVEL	DESCRIPTION	LIKELIHOOD
Very low (1)	Rarely happens	Up to 5%
Low (2)	Could / may happen	From 5% to <20%
Medium (3)	Might happen / Possible to happen	From 20% to <50%
High (4)	Often happens	From 50% to <80%
Very high (5)	Almost certainly / always happens	From 80% to <100%

Table 6 – Case Study: Parameter - Likelihood

4.6.2 Impact

PARAMETER	VERY LOW (1)	LOW (2)	MEDIUM (3)	HIGH (4)	VERY HIGH (5)
IMPACT / RISK CATEGORY		**Business**			
Business continuity	No disruption, fully functional	Minor disruption, easily managed	Temporary disruption, requires planning to resume	Major disruption, operational delays	Complete business halt, long recovery time
Reputation impact	Minor isolated incident, no public attention	Small negative impact, local attention	Moderate negative impact, industry attention	Significant negative impact, national and/or public authorities' attention	Severe negative impact, international attention and/or lasting brand damage
Sales impact	<5% drop in sales	5-10% drop in sales	10-20% drop in sales	20-40% drop in sales	>40% drop in sales
IMPACT / RISK CATEGORY		**Financial**			
Financial loss	<R$ 100.000	R$100.000-R$ 300.000	R$ 300.000-R$1.500.000	R$ 1.500.000-R$ 20.000.000	>R$ 20.000.000
IMPACT / RISK CATEGORY		**Legal**			
Contract breach	Minor breach, no financial consequence	Breach with small financial impact	Breach with moderate financial impact or reputational consequence	Significant breach, major financial loss or lawsuits	Breach leading to severe financial and legal damages
Litigation	No litigation	Threat of legal action, no court filing	Legal action filed, minimal financial or operational impact	Ongoing litigation, significant financial or reputational impact	Major litigation, high financial costs, reputational damage
Regulatory non-compliance	Minor non-compliance, no legal consequence	Warning or small fine	Moderate fines or legal proceedings	Significant fines, potential court cases	Legal sanctions, operational restrictions
IMPACT / RISK CATEGORY		**Operational**			
Machinery downtime[55]	No failure	Support level (SL) 1: Up to 3	SL-1: 3 days to 1 week downtime	SL-1: 1 to 2 weeks downtime	SL-1: Over 2 weeks downtime

[55] The machinery has been classified into three levels of support based on their impact on production. <u>Level 1 machines</u> can undergo extended maintenance without affecting production, either due to available backups or their non-critical role. <u>Level 2 machines</u> can also be stopped, but only for shorter periods before causing disruption. <u>Level 3 machines</u> are crucial, and any stoppage results in significant production impacts. A detailed list of machinery and their classification into Levels 1, 2, or 3 is available in Annex 03.

		days downtime SL-2: Up to 2 days downtime SL-3: Up to 12 hours downtime	SL-2: 2 to 4 days downtime SL-3: 12 to 48 hours downtime	SL-2: 4 days to 1 week downtime SL-3: 2 to 5 days downtime	SL-2: Over 1 week downtime SL-3: Over 5 days downtime
Disruption of service	Activity stops for <5 hours	Activity stops for 5 hours to 1 day	Activity stops for 1 to 1.5 days	Activity stops for 1.5 to 3 days	Activity stops for >3 days
Granite production output[56]	<10% reduction in weekly production	10-20% reduction in weekly production	20-30% reduction in weekly production	30-50% reduction in weekly production	>50% reduction in weekly production
IMPACT / RISK CATEGORY		**Safety**			
Environmental impact	No environmental impact	Minor localized, easily contained impact	Moderate impact, requiring intervention	Significant environmental damage, legal implications	Severe, widespread environmental damage with long-term consequence
Injury severity	No injury	Minor injury, first aid only	Moderate injury, requires medical treatment	Serious injury, hospitalization	Fatality or permanent disability
Security system failure	No failure or minor glitch, no impact	Minor system issue, quickly resolved, no security breach	System failure leading to a temporary security lapse	Major failure, security breach, unauthorized access or data compromise	Complete system breakdown, severe breach, operational disruption, or loss of sensitive data

Table 7 – Case Study: Parameter - Impact

[56] Measured in cubic meters.

4.6.3 Risk matrix

RISK MATRIX					
	1	2	3	4	5
IMPACT / LIKELIHOOD	VERY LOW	LOW	MEDIUM	HIGH	VERY HIGH
5 VERY HIGH	5 VERY LOW RISK	10 LOW RISK	15 MEDIUM RISK	20 HIGH RISK	25 VERY HIGH RISK
4 HIGH	4 VERY LOW RISK	8 LOW RISK	12 MEDIUM RISK	16 HIGH RISK	20 HIGH RISK
3 MEDIUM	3 VERY LOW RISK	6 LOW RISK	9 LOW RISK	12 MEDIUM RISK	15 MEDIUM RISK
2 LOW	2 VERY LOW RISK	4 VERY LOW RISK	6 LOW RISK	8 LOW RISK	10 LOW RISK
1 VERY LOW	1 VERY LOW RISK	2 VERY LOW RISK	3 VERY LOW RISK	4 VERY LOW RISK	5 VERY LOW RISK

Figure 5 – Case Study: 5x5 Grid Risk Matrix

4.7 Risk Identification and Assessment

Due to the limitations of time and space in this research, the risk analysis focused on five key risks that may impact three or more departments within the company's operations. These risks were selected for detailed examination, and their assessment is provided in the following tables. Among them, the two most critical ones were chosen for a comprehensive risk treatment plan, provided in subchapter 4.8. It is advised that the company extends this study to map and assess risks across all departments for a more thorough risk management approach.

4.7.1 Risk identification

Risk Number	Description	Risk Cause	Impact	Impact Category
R1	Accidents during the transportation of granite blocks	1. Accidents caused by third parties 2. Inadequate transportation infrastructure / Poorly	1. Damage to granite blocks 2. Delays in product delivery to the customer 3. Injuries or fatalities	Business Financial Legal Safety

		maintained vehicles 3. Mechanical problems with transport vehicles 4. Lack of safety protocols during transport	4. Legal liabilities and fines	
R2	Conflicts with surface owner	1. Disagreements over land use rights and terms in negotiations, contracts and agreements 2. Misalignment of interests between quarry and surface owner	1. Delays or interruptions in operations 2. Potential legal disputes 3. Increased operational costs 4. Difficulty in negotiations necessary for the growth of the company	Business Financial Legal Operational
R3	Labour lawsuits	1. Non-compliance with labour laws 2. Poor worker management relations 3. Workplace conflicts 4. Inadequate workplace safety measures	1. Financial penalties, convictions and expensive agreements 2. High cost with lawyers for legal defense 3. Damage to company culture 4. Regulatory scrutiny[57] 5. Disruption of operations	Business Financial Legal Operational Safety
R4	Rainy season	1. Strong and excessive tropical rainfall concentrated in short periods of time, affecting quarry operations 2. Weather-related	1. Delays in production 2. Erosion of work area 3. Mine's pit turns a lagoon, requiring water pumping 4. Quarry site access hampered 5. Safety hazards for workers	Business Financial Operational Safety

[57] In Brazil, when a company faces multiple ongoing labour lawsuits, it often draws the attention of labour boards or regulatory authorities. This heightened scrutiny can lead to formal audits or investigations, which not only disrupt regular operations but may also result in significant fines or penalties. Such legal and regulatory actions have the potential to cause substantial financial losses, further damaging the company's reputation and increasing operational costs through legal fees, settlements, and compliance-related expenses.

		disruptions and climate change 3. Poor drainage systems	6. Temporary halts in operations	
R5	Unavailability of sterile disposal site	1. Continuous production 2. Volume produced 3. Delay in obtaining environmental licensing 4. Difficulty in finding an appropriate or viable site	1. Halt in operations 2. Inability to meet customer demands 3. Significant financial losses 4. Overload of existing sterile disposal site 5. Significant environmental impact 6. Can jeopardize the whole business	Business Financial Legal Operational Safety

Table 8 – Case Study: Risk identification

4.7.2 Risk assessment

Risk Number	Likelihood	Impact	Level of Risk	Existing Control
R1	Very low (1) – Up to 5%	Very high (5)	5	1. Standard block loading procedure with strict controls 2. Speed limit control and route planning 3. Rigorous driver training 4. Regular vehicle maintenance 5. Regular safety inspections 6. Compliance with transport regulations
R2	Medium (3) – 20 to <50%	High (4)	12	1. Robust Legal Department 2. In-house counsel with a good relationship with the surface owner's attorney 3. Conflict avoidance 4. Maintain minimal and cordial contact 5. Continuous search for new areas to expand the business and reduce dependence on conflict-prone locations
R3	Medium (3) – 20 to <50%	Very high (5)	15	1. Compliance programs that adhere to labour laws, health and safety regulations, and industry standards 2. Employee training and education

R4	Low (2) – 5% to <20%	High (4)	8	1. Weather forecast monitoring 2. Flood preparedness plans 3. Improved drainage systems 4. Regular maintenance of equipment 5. Protective site measures to stabilize slopes and embankments, preventing landslides and soil erosion during heavy rainfall 6. Leverages rain season to do "counterproductive" activities such as trainings, occupational health programs, periodic maintenances in machinery and equipment, among other
R5	Medium (3) – 20 to <50%	Very high (5)	15	1. Monitoring and management of active sterile piles 2. Periodic search for new areas 3. Foster strong relationships and communication with environmental agencies

Table 9 – Case Study: Risk assessment

4.8 Risk Treatment Plan

Risk Number	4Ts	Description of Plan	Description of Action
R3	Treat	1. Enhance compliance programs	a. Conduct periodic update in compliance programs to reflect changes in labour laws and industry standards b. Conduct regular audits to ensure all labour practices comply with current laws and regulations c. Adopt as an internal rule regulate all identified irregularity d. Integrate the SESMT, Legal, Operations and Human Resources departments for the definition and implementation of strategic plans
		2. Conduct regular audits and risk assessment	a. Conduct periodic audits of employment practices and workplace conditions b. Conduct periodic risk assessments on critical internal aspects c. Enhance legal defense readiness, maintaining a proactive relationship with legal counsel and enhancing response strategies

			d. Increase regulatory awareness
		3. Improve workplace culture	a. Implement clear and fair HR policies b. Implement regular employee feedback mechanisms to identify and address potential issues before they escalate c. Foster positive work environment through team-building activities, open communication channels, and recognition programs
		4. Provide effective grievance mechanisms	a. Implement and transparent and accessible grievance procedure that allows employees to report issues or concerns without fear of retaliation b. Address grievances promptly and fairly to prevent escalation c. Develop a rigid internal policy of data protection
		5. Strengthen employee training and education	a. Provide proper training for all employees on workplace safety, legal rights, and conflict resolution b. Promote internal campaigns to ensure adherence to the use of safety equipment and procedures c. Develop and deliver targeted training programs for managers and supervisors on maintaining good worker relations and managing workplace disputes
R5	Treat	1. Foster strong relationships with regional landowners and strengthen collaboration with industry partners	a. Build trust through transparency b. Establish and maintain open communication channels with landowners, facilitating access to potential new land for sterile disposal and related business opportunities c. Partner with other companies in the industry to share disposal resources or collaborate on joint disposal site development
		2. Ongoing search for new areas	a. Establish a dedicated specialized team responsible for searching and evaluating new areas for sterile disposal b. Enhance site selection criteria, including considerations for environmental impact, accessibility, and regulatory compliance c. Use geospatial analysis tools and data to identify and prioritize the

			most suitable locations for future disposal sites d. Build relationships with local government officials, environmental agencies, and community stakeholders to gain insights into available land and regulatory considerations e. Maintain a database of potential disposal sites
		3. Strategic planning for environmental licensing[58]	a. Initiate early planning and research b. Develop projects timeline that outlines key milestones, deadlines, and deliverables related to the environmental licensing process c. Allocate resources and budget d. Prepare for public and agency reviews, public hearings, additional studies, and address promptly to avoid delays e. Establish a follow-up plan, monitoring the status of the application and maintaining regular communication with regulatory agencies
		4. Improve waste management practices	a. Explore and invest in innovative technologies and methods for waste management and disposal to enhance efficiency and sustainability b. Implement practices to convert waste into reusable materials or by-products, reducing reliance on disposal sites c. Keep informed about landowners interested in earthworks for new opportunities in sustainable waste disposal d. Stay updated on public works projects that require available materials such as clay, granite blocks that cannot be sold due to defects, and other waste materials, to identify new opportunities for sustainable waste disposal that align with public interest
		5. Develop contingency plans	a. Create detailed contingency plans for managing waste in the event of sudden or unforeseen unavailability of disposal sites

[58] Environmental licensing in the region typically takes at least 1 year.

			b. Identify temporary or emergency disposal options and establish agreements with backup disposal service providers c. Create a contingency management team and establish communication protocols, document plans d. Conduct training and drills

Table 10 – Case Study: Risk Treatment Plan

4.9 CASE STUDY FINAL CONSIDERATIONS

The case study conducted on granite quarry operations in Espírito Santo reveals several critical insights into risk management practices in the industry. Notably, the most severe risks are those affecting multiple departments and spanning various categories. This underscores the significant limitation of addressing risks in isolation.

Focusing exclusively on individual risks often results in incomplete solutions, neglecting the broader spectrum of potential issues and leaving other areas inadequately addressed, leading to gaps in risk management. Such a fragmented approach impedes comprehensive analysis and strategic prioritization, thereby effective resource allocation by management.

Our findings indicate that a holistic risk management approach – one that integrates all departments and aligns with the broader objectives of stakeholders – prover far more effective. This integrated approach enhances risk management across business, legal, financial, operational, and safety dimensions, highlighting the importance of a comprehensive view. By considering all risk aspects together, organizations can navigate complexities more adeptly, optimize resource allocation, and bolster overall resilience.

In conclusion, a holistic risk management strategy is vital for effectively addressing the complex risks in granite quarrying. By doing so, organizations can achieve a more strategic approach, leading to enhanced and resilient operational practices. Our findings highlight the need for a proactive, continuous risk mapping process and the establishment of a dedicated risk management department to ensure ongoing and comprehensive risk assessment and mitigation, enabling a dynamic response to emerging threats and opportunities and ultimately strengthening the organization's ability to manage risks effectively.

FINAL CONSIDERATIONS

The granite industry, like many aspects of life, embodies a dual nature. On one hand, it creates numerous jobs and drives economic growth; on the other, it poses significant human and environmental risks. This contrast underscores the inherent complexities and contradictions within the industry, highlighting the need for a robust response to address the deficiencies revealed in the case study of granite quarry operations in Espírito Santo.

A key takeaway is the gap between Brazil's regulatory ideals and their practical enforcement. To close this gap, it is essential to strengthen the regulatory framework as part of a broader risk management strategy. This includes enhancing enforcement mechanisms, increasing transparency, and combating corruption. Independent oversight bodies, stronger reporting mechanisms, protection for whistleblowers, and collaboration with NGOs and the private sector are vital to improve accountability and regulatory adherence. Legislative reforms, coupled with educational and technological initiatives, can foster a culture of integrity, aligning regulation with practice and supporting more effective risk mitigation.

Moreover, the study demonstrates that a fragmented approach to manage risks often leads to incomplete solutions, resulting in gaps in both risk management and resource allocation. Adopting a holistic approach to risk management within organizations is essential. Integrating risk management efforts across departments and aligning them with broader stakeholder objectives will enable businesses to address risks more effectively and enhance their resilience. Establishing dedicated risk management departments will ensure continuous and proactive assessment of emerging threats, allowing companies to adapt and respond more agilely.

The findings from this research underscores two critical recommendations: first, there is an urgent need to address corruption at all levels in Brazil to effectively enforce existing laws. Second, it is imperative for the granite mining industry to adopt a comprehensive and integrated approach to risk management. This shift is necessary not only to enhance operational resilience and adaptability but also to ensure that risk management is embedded within all levels of company operations, rather than being applied in a fragmented or isolated manner. Embracing these recommendations will be crucial for enhancing operational resilience and ensuring the preservation of the environment for future generations.

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ANNEX 01 – LEGAL AND REGULATORY FRAMEWORK

LAW, NORM OR STANDARD	YEAR	DESCRIPTION
INTERNATIONAL LEVEL		
ILO Convention nº 155	1981	Convention on Occupational Safety and Health that aims to prevent workplace accidents and diseases across all economic sectors
ILO Convention nº 170	1990	Convention on Safety in the Use of Chemicals at Work that regulates the use of chemicals in the workplace
ILO Convention nº 176	1995	Convention on Safety and Health in Mines that protects mine workers from occupational hazards and improves working conditions in mining
ILO Recommendation nº 183	1995	Recommendation that supplements Convention nº 176 by providing practical guidance for its implementation
WHO Indoor Air Quality Guidelines	2000	Defines standards and recommendations for indoor air quality, including air pollution management
UN Global Compact	2000	Promotes sustainable and socially responsible business practices based on universal principles related to human rights, labour standards, and environmental protection
WHO Guidelines on Occupational Noise	2001	Establishes limits and recommendations for occupational noise exposure to ensure hearing protection for workers
COSO ICIF	2013	COSO Internal Control – Integrated Framework
WHO Guidelines on Occupational Exposure to Chemical Agents	2014	Provides guidelines on exposure to chemical agents, including mineral dusts and toxic substances, to establish exposure limits and control measures to protect workers
UN Sustainable Development Goals	2015	Sets global targets for sustainable development by 2030, including aspects of health and safety, environmental sustainability, and fair working conditions
ISO 9001	2015	Quality management systems – Requirements
ISO 14001	2015	Environmental management systems – Requirements with guidance for use
COSO ERM	2017	COSO Enterprise Risk Management – Integrating with Strategy and Performance
ISO 22316	2017	Security and resilience – Organizational resilience – Principles and attributes
ISO/IEC 27000	2018	Information technology – Security techniques – Information security management systems – Overview and vocabulary
ISO 31000	2018	Risk management – Guidelines
ISO 45001	2018	Occupational health and safety management systems – Requirements with guidance for use
ILO Convention nº 190	2019	Convention on Violence and Harassment in the World of Work that seeks to prevent and address violence and harassment in the workplace

ISO 22301	2019	Security and resilience – Business continuity management systems – Requirements
ISO 22313	2020	Security and resilience – Business continuity management systems – Guidance on the use of ISO 22301
ISO 31022	2020	Risk management – Guidelines for the management of legal risk
ISO 22300	2021	Security and resilience – Vocabulary
ISO/IEC 31010	2021	Risk assessment techniques
BS 31100	2021	Risk management – Code of practice and guidance for the implementation of ISO 31000:2018
ISO 37301	2021	Compliance management systems – Requirements with guidance for use
ISO 31073	2022	Risk management – Vocabulary
ISO/IEC 27001	2022	Information security, cybersecurity and privacy protection – Information security management systems – Requirements
ISO/IEC 27005	2022	Information security, cybersecurity and privacy protection – Guidance on managing information security risks
ISO/TS 31050	2023	Risk management – Guidelines for managing an emerging risk to enhance resilience
ISO 14001:2015 Amd 1	2024	Environmental management systems – Requirements with guidance for use – Amendment 1: Climate action changes
NATIONAL LEVEL		
Decree-Law nº 2.848	1940	Penal Code
Decree-Law nº 3.689	1941	Code of Criminal Procedure
Decree-Law nº 3.365	1941	Provides regulations on expropriation for public utility and defines mining as being of public utility
Decree-Law nº 5.452	1943	Consolidation of Labour Laws
Decree-Law nº 7.841	1945	Mineral Waters Code
Law nº 3.824	1960	Mandates the removal and subsequent cleaning of the hydraulic basins of reservoirs, dams, and artificial lakes
Law nº 3.924	1961	Establishes that the Public Authority, through IPHAN (National Institute of Historic and Artistic Heritage), must protect archaeological and prehistoric monuments, considered assets of the Union
NBR-98	1966	Regulates the storage and handling of flammable and combustible liquids
Decree-Law nº 227	1967	Mining Code
Law nº 5.197	1967	Provides regulations on the protection of fauna
Law nº 6.567	1978	Establishes a special regime for the exploration and use of the mineral substances specified
NR-04	1978	Regulates the creation and functioning of the Specialized Services in Safety Engineering and Occupational Medicine

		(*Serviços Especializados em Engenharia de Segurança e em Medicina do Trabalho* – SESMT)
NR-05	1978	Establishes the requirements for creating and maintaining the Internal Commission for Accident Prevention (*Comissão Interna de Prevenção de Acidentes* – CIPA)
NR-06	1978	Outlines the requirements for the provision and use of Personal Protective Equipment (PPE)
NR-07	1978	Mandates the implementation of a medical control program aimed at monitoring worker's health (*Programa de Controle Médico de Saúde Ocupacional* – PCMSO)
NR-09	1978	Requires assessment and control of occupational exposures to physical, chemical and biological agents
NR-10	1978	Sets safety standards for work involving electricity
NR-11	1978	Regulates the safe transport, movement, storage, and handling of materials
NR-12	1978	Provides safety guidelines for the installation, operation, and maintenance of machinery and equipment
NR-13	1978	Provides safety guidelines for the operation and maintenance of boilers and pressure vessels
NR-15	1978	Defines conditions and limits for activities considered unhealthy due to exposure to physical, chemical, or biological agents
NR-16	1978	Defines which activities or operations are considered hazardous due to their potential to cause severe harm or pose significant risks to workers' safety and health, which entitles workers involved in such activities to additional compensation, known as "hazard pay" (*adicional de insalubridade*)
NR-17	1978	Addresses ergonomic standards to prevent workplace injuries related to physical strain
NR-19	1978	Establishes safety guidelines for the manufacture, storage, handling, transport, and use of explosives in the workplace
NR-20	1978	Regulates activities involving flammable and combustible substances
NR-21	1978	Establishes guidelines for the safety and health of workers engaged in activities conducted in open-air environments
NR-22	1978	Focused on health and safety in the mining sector
NR-23	1978	Sets out the requirements for fire prevention and protection in the workplace
NR-24	1978	Establishes the minimum requirements for sanitary and comfort conditions in workplaces
NR-25	1978	Addresses the handling, treatment, and disposal of industrial and hazardous waste generated in workplaces
NR-26	1978	Establishes the standards for the use of colours and signs to indicate hazards and provide safety information in the workplace
NR-28	1978	Addresses the inspection and penalties related to non-compliance with the norms established for occupational safety and health
Law nº 6.902	1981	Provides regulations on the creation of Ecological Stations and Environmental Protection Areas

Law nº 6.938	1981	Establishes the National Environmental Policy
Decree nº 88.351	1983	Establishes the National Environmental System
CONAMA Resolution nº 1	1986	Provides basic criteria and general guidelines for environmental impact assessment
CONAMA Resolution nº 6	1986	Provides models for the publication of licensing requests
CONAMA Resolution nº 5	1987	Approves the National Program for the Protection of Speleological Heritage
CONAMA Resolution nº 9	1987	Provides regulations on holding public hearings for environmental impact assessment
CRFB	1988	Constitution of the Federative Republic of Brazil
CONAMA Resolution nº 10	1988	Establishes regulations for Environmental Protection Areas and prohibits mining activities in these areas
Decree nº 96.044	1988	Regulation for road transportation of hazardous products
Law nº 7.735	1989	Establishes IBAMA (Brazilian Institute of Environment and Renewable Natural Resources)
Law nº 7.804	1989	Establishes the need for environmental licensing, environmental liability, regulates pollution control, and assigns competencies to CONAMA and IBAMA for national or regional[59] environmental licensing
Decree nº 97.632	1989	Requires all mining projects to present a PRAD (Degraded Areas Recovery Plan)
Decree nº 99.274	1990	Regulates Laws nº 6.902/1981 and 6.938/1981
CONAMA Resolution nº 1	1990	Establishes criteria and standards for noise emission resulting from industrial activities
CONAMA Resolution nº 3	1990	Establishes air quality standards
CONAMA Resolution nº 8	1990	Establishes maximum limits for air pollutant emissions
CONAMA Resolution nº 9	1990	Provides specific regulations for environmental licensing of ornamental stone quarrying
NBR-12.235	1992	Regulates the storage of hazardous solid waste
Law nº 9.433	1997	Establishes the National Water Resources Policy
CONAMA Resolution nº 237	1997	Revises and supplements the criteria and competencies for environmental licensing
NBR-9.547	1997	Regulates technical analysis of air quality
Law nº 9.605	1998	Environmental Crimes Law
NBR-14.063	1998	Regulates the process of treating oils and greases in mining effluents
Law nº 9.784	1999	Regulates the administrative process within the Federal Public Administration
NBR-13.030	1999	Regulates the preparation and presentation of PRAD (Degraded Areas Recovery Plan) in mining
NR-22	1999	Provides specific regulations regarding occupational health and safety in the mining industry
Law nº 9.985	2000	Establishes the National System of Nature Conservation Units

[59] An enterprise that impacts more than one state in the federation is considered regional.

MME Ordinance nº 237	2001	Ordinance issued by the Ministry of Mines and Energy (MME) approving the Mining Regulatory Standards (NRM) referred to in art. 97 of the Mining Code
Law nº 10.406	2002	Civil Code
NR-11-Annex I	2003	Technical regulation of procedure for movement, storage and handling of ornamental stone slabs
NBR-13.221	2003	Regulates the transportation of waste
NBR-10.004	2004	Regulates the classification of solid waste
NBR-10.007	2004	Regulates the sampling of solid waste
NBR-9.653	2005	Guide for evaluating the effects caused by the use of explosives in mining in urban areas
NR-33	2006	Addresses the safety and health requirements for working in confined spaces
Decree nº 6.660	2008	Provides regulations on the cutting, exploitation, and suppression of primary vegetation or vegetation in advanced and medium stages of regeneration in the Atlantic Forest
IBAMA normative instruction nº 184	2008	Defines procedures and criteria for environmental licensing in Brazil
NBR-14725	2009	Specifies the classification and labeling of chemicals, focusing on safety and environmental hazards
Law nº 12.334	2010	Establishes the National Dam Safety Policy
Complementary Law nº 140	2011	Regulates article 23 of the CRFB regarding cooperation between the Union, States, the Federal District, and Municipalities for environmental protection
IBAMA normative instruction nº 14	2011	Modifies and adds provisions to the IBAMA normative instruction nº 184/2008, updating environmental licensing requirements
Law nº 12.651	2012	Forest Code
NR-35	2012	Establishes safety requirements for working at heights
Law nº 13.105	2015	Code of Civil Procedure
NBR-ISO-14.000	2015	Guidelines and tools to promote an effective environmental management system within organizations
ANM Ordinance nº 155	2016	Establishes specific procedures for the research and quarrying of ornamental stones
Law nº 13.575	2017	Establishes the National Mining Agency (ANM); dissolves the National Department of Mineral Production (DNPM); amends legislation related to mining and provisions of the Mining Code
NBR-13.029	2017	Regulates the preparation and presentation of a project for the disposal of waste in a pile in mining
Law nº 13.709	2018	General Data Protection Law
Decree nº 9.406	2018	Regulates the Mining Code and Laws nº 6.567/1978 and 13.575/2017
NBR-10.151	2019	Regulates the measurement and evaluation of sound pressure levels in inhabited areas
Law nº 13.975	2020	Amends Law nº 6.567/1978 to include the exploration of ornamental stones and other minerals under the licensing or authorization and concession regime

Law nº 14.066	2020	Amends Laws nº 9.433/1997 and 12.334/2010 and the Mining Code
MTP Ordinance nº 672	2021	Ordinance issued by the Ministry of Labour and Social Security (MTP) regulating occupational health and safety procedures, programs and conditions
Decree nº 10.935	2022	Provides regulations on the protection of natural underground cavities within the national territory
ANTT Resolution nº 5.998	2022	Updates the Regulation for the Road Transportation of Hazardous Products

ANNEX 02 – RELEVANT BODIES AND ASSOCIATIONS

BODY	RELEVANCE
INTERNATIONAL LEVEL	
COSO (Committee of Sponsoring Organizations of the Treadway Commission)	Provides frameworks for risk management, internal control, and fraud prevention
IEC (International Electrotechnical Commission)	Sets international standards for electrical and electronic technologies
ILO (International Labour Organization)	Develops labour standards to ensure safe working conditions, fair wages, and worker's rights
ISO (International Organization for Standardization)	Establishes international standards for quality, risk management, environmental management, and safety
UN (United Nations)	Promotes sustainable development goals, influencing policies and practices across industries to align with environmental and social responsibility
WHO (World Health Organization)	Provides guidelines on health and safety, critical for protecting workers from occupational hazards
FEDERAL LEVEL	
ABIROCHAS (Brazilian Association of the Ornamental Stone Industry	Represents and promotes Brazilian ornamental stone industry by providing support, advocacy, and market development
ABNT (Brazilian Association of Technical Standards)	Develops technical standards for various industries, ensuring quality, safety, and consistency in products and processes
ANM (National Mining Agency)	Regulates mining activities, granting licenses, enforcing safety standards, and overseeing its legal aspects
ANTT (National Land Transport Agency)	Oversees land transport regulations, impacting the logistics and transportation of granite from quarries to markets
CONAMA (National Environmental Council)	Sets environmental policies and regulations, including those affecting granite quarrying, to ensure sustainable practices and minimize environmental impact
IBAMA (Brazilian Institute of Environment and Renewable Natural Resources)	Enforces environmental laws and conducts inspections
ICMBio (Chico Mendes Institute for Biodiversity Conservation)	Protects biodiversity by overseeing conservation units, which can affect granite quarrying enterprises near or within protected areas
IPHAN (National Institute of Historical and Artistic Heritage)	Preserves historical and cultural heritage, which may include regulating quarrying activities near protected historical sites
MMA (Ministry of Environment)	Develops and implements national environmental policies

MME (Ministry of Mines and Energy)	Manages policies related to mining and energy, directly affecting the regulation and development of the mining sector
MTE (Ministry of Labour and Employment)	Regulates labour laws and ensures safe working conditions, replaced the former MTP (Ministry of Labour and Social Security)
STATE LEVEL	
CEDEC (Civil Defense Centre)	Manages disaster response and emergency preparedness, including overseeing safety measures and coordinating responses to incidents at granite quarries to protect communities and manage risks
CREA-ES (Regional Council of Engineering and Agronomy of Espírito Santo)	Regulates and oversees the professional activities of engineers and technicians, ensuring that operations meet technical and safety standards
DER-ES (Department of Buildings and Highways of the State of Espírito Santo)	Manages infrastructure development, including the licensing and inspection of mining-related transport infrastructures
FINDES (Federation of Industries of Espírito Santo)	Represents the industrial sector within the state, including the granite quarrying industry, advocating for favorable policies, infrastructure development, and economic incentives
IDAF (Institute of Agricultural and Forestry Defense of Espírito Santo)	While primarily focused on agriculture and forestry, IDAF may regulate land use in rural areas, impacting quarrying activities, especially in areas with overlapping agricultural interests
IEMA (State Institute of Environment and Water Resources)	Regulates environmental aspects of quarrying, including issuing permits, monitoring environmental impacts, and ensuring compliance with state environmental laws
SEAMA (State Secretariat for the Environment and Water Resources)	Develops and implements environmental policies and regulations that affect the granite quarrying industry, working closely with IEMA to ensure sustainable practices; responsible for regulating water use and managing water resources
SINDIMARMORE (Union of Marble and Granite Workers of Espírito Santo)	Represents and protects the rights of workers in the granite and marble industries located in Espírito Santo, advocating for fair wages, safe working conditions, and labour rights
SINDIROCHAS (Ornamental Stone, Lime and Limestone Industry Union of Espírito Santo)	Represents the interests of companies in the ornamental stone industry, providing support, advocacy, and negotiating with government and other entities on behalf of the industry
MUNICIPAL LEVEL	
Municipal environmental departments	Oversees local activities by issuing permits, monitoring compliance with environmental standards, enforcing regulations, and addressing public complaints

ANNEX 03 – CASE STUDY:
OPERATIONS MACHINERY AND SUPPORT VEHICLES

Machinery or Support Vehicle	Quantity	Function	Support Level
Air compressor	14	Supply compressed air to power pneumatic drills and other tools that use compressed air	1
Crane truck (Munch truck)	1	Equipped with a crane for lifting and moving heavy blocks of granite and other materials	1
Diamond wire saw machine	35	Cut granite with a diamond-coated wire, allowing for precise and continuous cutting of large blocks	1
Down-the-hole drilling rig	7	Drills deep, vertical holes into rock for blasting	1
Dump truck	23	Transport large volumes of excavated rock, debris, sterile, and other materials	1
Excavator	10	Heavy machines used for digging, removing, and transporting soil, rock, and other materials	2
Flatbed truck	5	Transport large and heavy granite blocks within the quarry from the extraction site to the block yard[60]	1
Gantry crane	1	Used for lifting and moving large blocks of granite within an area	1
Generator	7	Provide electrical power to machinery and equipment, especially in the extraction site where access to a power grid is limited	1
Large wheel loader	4	Handle and move large blocks of granite and other substantial volumes of material	3
Motorcycle	8	Quick and efficient transportation across the quarry site, allowing for rapid inspections, monitoring, emergency response, and communication within the large and often rough terrain of the quarry	1

[60] In a quarry, a block yard is an area designated for the storage, sorting, and handling of large blocks of stone or granite. It is typically equipped with machinery and equipment to organize and manage the blocks before they are processed or transported. The block yard serves as a central location for managing inventory and preparing blocks for further processing or shipment.

Pickup truck	8	Used for site inspections and operational oversight, transporting personnel, small equipment, and tools, responding to emergencies, and supporting general maintenance and logistics	1
Pneumatic drill	2	Used to drill holes in rock to prepare for blasting or to create space for other quarrying operations	1
Pneumatic hammer (Jackhammer)	20	Tool powered by compressed air used to break and fragment granite rock	1
Three-wheel cargo motorcycle	7	Cost-effective transport for small tools and materials used for short-distance logistics	1
Water truck	3	Carry and deliver water for cooling and dust control in the quarry	1
Wheel loader	8	Transport and load granite blocks and other materials	2
Wooden flatbed	1	Transport heavy materials within the quarry	1