

Marble workshop of the future: Technology, innovation, and sustainability

Gomes Rickardo ^{1,*} and Rodrigues da Paz Giovanni ²

¹ Department of the Euvaldo Lodi Institute (IEL), and Postgraduate Department of the Farias Brito University Center (FBUNI), Fortaleza, Ceará, Brazil.

² Professional Specialist in Management and Use of Rocks in Civil Construction by Instituto Euvaldo Lodi, Fortaleza, Ceará, Brazil.

World Journal of Advanced Research and Reviews, 2023, 19(03), 1090–1098

Publication history: Received on 15 August 2023; revised on 22 September 2023; accepted on 25 September 2023

Article DOI: <https://doi.org/10.30574/wjarr.2023.19.3.1957>

Abstract

In the future, the field of stonemasonry is poised to undergo a transformation driven by technology and innovation. Automation and artificial intelligence will play a pivotal role in enhancing the processes of rock extraction and refinement. Furthermore, a robust commitment to sustainability will be a key facet, encompassing the pursuit of more responsible extraction techniques, recycling of waste materials, and adoption of clean energy sources. This evolution is set to render the industry more efficient, ecologically conscientious, and in alignment with the demands of an environmentally conscious global milieu. The methodology employed in the formulation of this article is rooted in a qualitative approach, fashioned through a comprehensive bibliographic review. The examination encompassed a scrutiny of articles, journals, dissertations, and, in addition to this review, an interview was conducted with an entrepreneur within the rock sector. The overarching aim of this research is to underscore the imperative of the adaptation of stonemasonry enterprises to emerging trends and technological advancements within the realm of surface coverings. Furthermore, it seeks to underscore the necessity for companies to invest in their workforce. The study has underscored the significance of workforce skill development, technology investment, sustainability practices, and material diversification as pivotal factors shaping the future success and expansion of stonemasonry enterprises.

Keywords: Stonework; Technology; Innovation; Sustainability

1. Introduction

Currently, the majority of the world's population lives within a capitalist system, where competition among businesses has never been as intense as it is today. This characteristic of contemporary capitalism also applies to the natural stone sector, including marble workshops, which represent the final stage of processing the raw material in question.

Natural stone has been utilized by humans since the dawn of civilization for various purposes, including crafting tools for self-defense, creating utensils for food preparation, and serving as an essential element in constructing dwellings. Over the years, construction techniques have evolved, with stone gradually being replaced by brick and concrete in the construction industry. Stone acquired a new significance, becoming widely used for flooring and wall coverings, as well as countertops, both indoors and outdoors. This indispensable use of natural rock endured for centuries until the emergence of porcelain tiles in Europe in the mid-1980s.

Since the introduction of porcelain tiles into the market, the natural stone sector has faced strong competition within the construction industry, with a significant portion of stone coverings and countertops being substituted by porcelain tile materials in architectural projects. This does not mean that the sales of natural stones have dramatically decreased; rather, they stopped growing steadily, as was the trend before the 1980s.

* Corresponding author: Gomes Rickardo <https://orcid.org/0000-0001-6101-9571>.

Marble workshops require changes to remain competitive in the face of the vast porcelain tile market and to regain the portion of customers who transitioned from natural stones to porcelain products. The choice of this subject for research is justified by the fact that the natural stone sector currently finds itself disconnected, and the porcelain tile market has been taking advantage of this disconnect for years. Ceramic industries have managed to win over architects, engineers, interior designers, and other professionals in the construction sector due to the practicality and reliability offered by their materials. Additionally, porcelain tiles are a product that demands fewer requirements for installation and maintenance and come at a more attractive price point compared to natural stone.

The methodology used in the preparation of this article was based on a qualitative approach developed through a literature review. Texts from magazines, articles, monographs, and interviews with a business owner in the natural stone sector were analyzed to gain insights into topics addressed in this article, such as labor issues, raw material processing, the type of material most commonly used, and revenue.

The general objective of this research is to emphasize the importance of marble workshops adapting to new trends and technologies in the surface covering market while highlighting the need for companies to invest in their workforce. The specific objectives are as follows:

- Enhancing workforce skills through training, courses, and seminars;
- Understanding the modernization of technology in marble workshop production systems;
- Investigating sustainability in marble workshops;
- Analyzing the need for marble workshops to expand the range of materials offered to their clients.

This article is structured into five sections. The first provides an introduction to the topic, encompassing the history of natural stone usage and the necessity of modernizing the processing of this material. The second section outlines the theoretical foundation of the research, presenting solutions to the identified problems. The third section includes an interview with a business owner in the natural stone sector, offering their perspective on the topics covered in the theoretical foundation of the article. The fourth section explains the chosen methodology for article development, which involves a bibliographic research approach that analyzed texts authored by experts in the field. Finally, the fifth and last section presents concluding remarks regarding this article.

2. Material and methods

To conduct the research process for this article, a qualitative approach was employed, facilitated by a research instrument characterized as a literature review. This approach sought explanations grounded in the perspectives of authors who have addressed the same topic.

According to Dorsa (2020, p. 02), a literature review is considered to:

Facilitate the encounter of research with similarities, as well as the analysis of the methodology used, allowing researchers to develop texts from a historical perspective on a specific subject, both at the national and international levels, depending on the scope. Therefore, it demands expertise as a basic condition for the growth of research in the study area [1].

During the literature review, texts from journals, articles, monographs were analyzed, and in addition to this review, an interview was conducted with an entrepreneur in the natural stone sector. This interview detailed the interviewee's perspective on the topics addressed in this article, including labor issues, raw material processing, types of materials commonly used, and revenue.

Glesne (2015) presents the interview as an exchange procedure between one or more interlocutors on both sides, in which each participant must construct meaning from the data obtained through a series of questions and other forms of non-verbal conversation. The interaction discussed here represents a dialogical process in which both the interviewer and the interviewee are protagonists [2].

Before conducting the interview, the interviewee was informed of its purpose, emphasizing that the information gathered would be part of a scientific article for the MBA program in Rock Management and Utilization in Civil Engineering at the Euvaldo Lodi Institute. It is worth noting that the entrepreneur agreed to all the mentioned conditions.

This research draws contributions from Pádua (2012), Silva (2017), Oliveira (2019), and Gava (2023). Throughout the research process, meticulous efforts were made to capture as much information shared in the opinions of the investigated authors as well as the insights provided by the interviewed professional. This approach aimed to ensure that the opinions established in this article were grounded in the maximum number of reliable sources.

3. Literature Review

The obstacles encountered in a marble workshop are part of a chain of problems, with misinformation in the natural stone sector being the primary culprit. By solving this core issue, other challenges can be addressed subsequently.

Misinformation can be resolved through team training and sector-wide education. Currently, there are various online courses, such as 'The Marble Workers' Club,' and even postgraduate programs like the one proposed by the Euvaldo Lodi Institute (IEL), 'Management and Use of Rocks in Civil Engineering,' aimed at enhancing the knowledge and expertise of industry professionals. Consequently, the modernization of marble workshop technology results from the prestige of a well-trained team, and sustainability is a consequence of a well-planned industry with a conscious and competent workforce.

This theoretical foundation has been organized into four subtopics. The first provides an overview of the need for qualified labor within a company's team. The second highlights the benefits of investing in state-of-the-art machinery. The third discusses the importance of sustainability in the natural stone sector, and the fourth and final topic emphasizes the necessity for marble workshops to expand the variety of products offered to their customers. Below, some of the main ideas and theoretical concepts related to the proposed solutions will be presented.

3.1. Workforce Refinement

Acquiring a skilled workforce within a company is the solution to mitigate most of the issues that arise, both in product sales and production. A sale conducted by an experienced team in the field assures that the customer has been properly guided regarding the purchased material and that the material recommended for a specific purpose has been introduced correctly, aligning the product's features with the consumer's stated needs [3].

Furthermore, production carried out by qualified workers ensures that the product is manufactured in accordance with the details outlined in the executive project. This involves the proper interpretation and handling of machinery, ensuring that the product is realized as proposed to the customer [3].

Alves, Correia, and Silva (2019) draw attention to the importance of adequate working conditions, as they favor essential aspects for the worker, such as motivation, mental health, and physical safety. These factors can prevent issues related to medical leaves and absenteeism due to health problems, which can negatively impact both the organization and the employee. Ensuring these appropriate conditions will enable the company to retain its employees for longer periods, allowing them to engage in qualified work for the company [4].

In order for the team to acquire the desired expertise sought by business owners, it is necessary to enhance the skills of these employees. This can be achieved through sector-specific lectures, often held at national trade fairs, particularly those in the cities of Vitória-ES, Cachoeiro-ES, Fortaleza-CE, and São Paulo-SP. Additionally, employees can benefit from both in-person and online courses, such as the "Clube dos Marmoristas," which covers topics ranging from the administrative aspects of a stonemasonry business to theories about methods of executing pieces in the operational sector. Innovative courses entering the market, like the Postgraduate Program offered by the Instituto Euvaldo Lodi (IEL) in "Management and Utilization of Rocks in Civil Works," provide valuable insights into geology, extraction and processing technologies, construction rationalization, and other subjects that significantly enhance the natural stone sector [3].

Moreover, companies can leverage courses offered by machinery suppliers to educate their employees on the correct handling of the acquired machinery. By investing in these knowledge avenues, the workforce can gain valuable experience, benefitting all sectors of the stonemasonry business and thereby reducing the possibility of errors. Ultimately, this leads to a decrease in company losses and results in positive evaluations from consumers of these products [3]; [4].

3.2. Modernization of Technology in the Production System of Stonemasonry

The modernization of technology in the production system of stonemasonry is a relevant topic that has been discussed by several authors. The stonemasonry industry has undergone significant transformations due to technological advancements, impacting how stonemasonries operate and produce their products.

Silva (2017) emphasizes the importance of adopting modern technologies, such as Computer Numerical Control (CNC) machines and automation systems, in the production process of stonemasonries. According to the author, these technologies enable greater precision, speed, and efficiency in the production of marble pieces, thereby increasing productivity and reducing costs [5].

Santos et al. (2021), on the other hand, argue that the modernization of technology in the production system of stonemasonries extends beyond the machines used and includes the implementation of integrated management software. These software solutions enable more efficient control of inventory, production flow, and costs, contributing to process optimization and more effective business management [6].

Oliveira (2019) highlights the importance of digitizing processes in stonemasonries. Digitization involves the use of 3D scanners to capture project measurements and the utilization of modeling software to develop virtual designs. This approach facilitates communication with customers, allows for a preview of the pieces, and reduces production errors, ultimately enhancing the final product's quality [7].

Furthermore, Gomes et al. (2020) argue that technological modernization in the stonemasonry production system is also linked to environmental sustainability. The use of more efficient machinery and automated processes can reduce the waste of raw materials, water, and electricity. Additionally, the adoption of marble waste recycling techniques contributes to reducing the environmental impact of the industry [8].

A study by Figueiredo (2022) underscores the importance of training stonemasonry professionals in the use of new technologies. The author emphasizes that modernizing the production system requires not only the acquisition of equipment but also the qualification of the workforce. Training and specific courses are essential to enable professionals to fully leverage the benefits of new technologies [9].

3.3. Sustainability Parameter: Recycling of Waste

One of the main criticisms faced by the natural stone sector from the porcelain tile industry relates to waste production. In the porcelain industry, nearly all raw materials are utilized in the product manufacturing process, whereas in rock mining, environmental degradation and waste generation represent one of the primary concerns in this business. Consequently, various methods are being explored to mitigate the disadvantage associated with the use of natural materials on the environment.

Both extraction and industrial activities within the ornamental stone sector consistently generate waste of varying volumes and degrees of usability. Stone processing facilities, known as stonemasonries, also produce waste, the majority of which comprises irregularly shaped fragments of various types of rocks, often discarded irregularly. The ornamental stone industry in the Northwestern Fluminense region generates significant waste resulting from the extraction and processing of rocks. Improper disposal of this waste has a negative environmental impact. In light of this issue, this study aims to experimentally investigate the technical feasibility of using such waste, after crushing, as a substitute for traditional coarse aggregate in the production of Portland cement structural concrete. This recycling process enhances the sustainable utilization of natural resources and minimizes the environmental impacts associated with the ornamental stone sector [10].

Torres (2015) presents an ongoing study that seeks to reduce the environmental degradation caused by natural rock mining—a significant development within the sector to promote sustainable marketing practices for natural stones, thereby addressing criticisms raised by competing industries [10].

The use of crushed rocks as agrominerals for soil fertilization, known as "rockdusting," may seem novel but has been practiced for several years. Examples include agricultural practices like liming and phosphating. According to Meert et al. (2009), this technique has garnered global attention as an alternative to conventional nutrient sources. Rockdusting can become an important fertilization technique, complementing traditional practices in Brazil, initially recommended for small-scale producers and regional application, similar to current limestone use. This approach stands out for its diverse range of raw materials with potential for use as agrominerals and broad geographic distribution. The authors recommend geological mapping of rocks suitable for agromineral use, geochemical and mineralogical characterization

of rocks, utilization of mining process by-products, studying the effects of rockdusting on the cultivation of oilseeds and sugarcane used for biofuel production, evaluating associated environmental impacts, and studying standardization and regulation for alternative rocks and industrial minerals in fertilizer production [11].

Another technique already employed in the agricultural sector is rockdusting, as explained in the study conducted by Pádua (2012). This form of waste recycling involves using the by-products resulting from natural rock extraction within quarries. Limestone rocks, for example, are collected, crushed, and subsequently spread across fields to replace traditional fertilizers. By adopting this method, sustainable farming practices are promoted, and waste materials are utilized, thus contributing to environmental preservation.

Notably, not only quarries but also stonemasonries have the potential to engage in this waste recycling activity. The primary distinction is that in quarries, a single type of rock is extracted over a vast area, making it more practical to utilize the by-products. In contrast, stonemasonries process a variety of materials daily, ranging from porcelain tiles to quartzite. Only rocks with limestone composition are suitable for rockdusting, necessitating a meticulous selection of all generated waste materials. This makes the recycling process more labor-intensive in stonemasonries but still feasible [11].

3.4. Increased Product Offer

Concerning synthetic surfaces, there is a significant distinction between porcelain tiles, quartz surfaces, and sintered slabs. Porcelain tiles are often sold as flooring and wall coverings, but some companies also offer them as kitchen countertops, barbecue countertops, and bathroom surfaces. Porcelain is a material characterized by low complexity and production cost.

Quartz surfaces and sintered slabs, on the other hand, are more upscale materials when compared to porcelain tiles. They are typically imported and require advanced technology for their production. While they can be used as coverings, their high cost primarily positions them for use in countertop applications.

Each of these products has its advantages and disadvantages, and there are ongoing debates about which one is superior. Industries seek elements to defend their respective positions. In practice, what is observed is that quartz producers purchase ornamental rocks to complement their product lines, while an increasing number of ornamental rock producers acquire synthetic materials for the same purpose. What explains this logic? The reason is that from a business perspective, they are complementary and can coexist in the market. So, what determines the choice by the end consumer? Naturally, the product that combines the best attributes, considering that each customer weighs what is most important differently. For example, they may ask themselves: (a) Would I prefer to sacrifice color for a more durable product? (b) To what extent should I compromise on durability to have a material with a whiter background that better matches my cabinets? (c) My budget is limited, so what is the lowest-cost option [12]?

Gava (2023) argues that stonemasonry businesses do not necessarily have to be limited to selling natural products, as synthetic products can complement their sales. It is up to the entrepreneur to decide whether they want to venture into selling these products, as it will require specific training for their team and investment in appropriate machinery for processing these materials. In this way, the offerings available to customers will be broader, increasing the chances of making a sale and reducing the likelihood of customers opting for a custom piece made from porcelain by the same company [12].

3.5. Valorization of Natural Products

The persistent problem within stonemasonry, particularly in the sale of natural materials, is misinformation, whether due to the company itself or its suppliers failing to provide proper guidance. Natural materials are frequently sold without a correct introduction to the specific characteristics of the rock being purchased. End customers or construction professionals often acquire a particular material without understanding its specific properties, either because they were not informed or, worse yet, because they were misled.

Misinformation in the natural stone sector tarnishes the product's image, eroding trust in the material. This leads to a migration of professionals who originally recommended the use of natural stones to endorsing porcelain products, as porcelain is sold with accurate information, providing consumers with confidence in their purchases.

Stonemasonry businesses possess one of the most noble raw materials available—natural stones. It is the responsibility of this sector to seek accurate information about each product they sell, train their employees to provide customers and construction professionals with comprehensive information about the limitations of each type of rock, modernize their

operations to offer high-quality products that endure for years, and strive to become as environmentally sustainable as possible. Given that this sector places significant demands on the environment through rock extraction, it is incumbent upon these companies to balance carbon emissions throughout the production process.

By combining these factors, this sector can effectively compete against its primary competitor, which is the large ceramic materials industry. Even when stonemasonry businesses opt to offer synthetic products, they can still advocate for the use of natural products in architectural projects. Synthetic products have been on the market for a relatively short period compared to natural stones, making it understandable that professionals in the field may have greater familiarity and expertise with natural materials.

Furthermore, sintered slabs are challenging to process, requiring more time, specific techniques, and skilled labor. One significant advantage of using natural rock that has not yet been mentioned is the concept of "biophilia," which involves incorporating natural elements into architectural designs to enhance the well-being of users.

Since ancient civilizations, nature has served humanity as a natural habitat, providing shelter, food, and remedies. In modern times, the industrial and technological revolution has transformed the way humans interact with nature. The term 'biophilia' is derived from ancient Greek, translating to 'love of living things' (philia = love of/inclination toward). While the term may seem relatively new and is gradually becoming a trend in architecture and interior design fields, it was first coined by psychologist Erich Fromm in 1964 and popularized in the 1980s by biologist Edward O. Wilson, recognizing how urbanization had begun to foster a strong disconnect from nature.

The main strategy is to incorporate features of the natural world into constructed spaces, such as water, vegetation, natural light, and elements like wood and stone, often left exposed. The use of botanical shapes and silhouettes instead of straight lines is a fundamental characteristic of biophilic designs, establishing visual relationships, such as those between light and shadow [13].

Researcher Dima Stouhi (2022) highlights the advantage of using natural materials in an enclosed environment, from visual perception to tactile experiences with the elements, bringing comfort and well-being to the space. This psychological sentiment is not attainable with synthetic materials, as they are produced and attempt to replicate what is natural. Stonemasons and architects often employ this argument to persuade clients to use natural stone for flooring and wall coverings, rather than opting for porcelain [13].

4. Commented Interview Analysis

An interview was conducted with an entrepreneur in the rock sector since 1985, who has been a founding partner of Pedra Grande Mármore e Granitos, one of the most renowned rock processing companies in the state of São Paulo for 26 years.

Researcher: Does the rock sector usually face problems with labor? Has there been an appreciation of qualified labor in the sector? Entrepreneur: We have always had issues with labor due to the highly specific nature of the service, requiring skilled and dedicated professionals to perform the masonry services we offer to our clients. Typically, we hire an apprentice and provide specific training over a period of 6 months, during which we assess whether the operator possesses the attributes we seek. There has undoubtedly been an appreciation of qualified labor in the sector, as the construction industry has been progressing rapidly since the pandemic, demanding a lot of labor, which is currently in short supply in the market. The opinion reflects a real-world scenario of a particular sector facing challenges in attracting and retaining qualified labor. The appreciation of specialized professionals is a positive aspect, but the shortage of labor can be an obstacle to the company's continuous growth. It is important for the company to continue seeking ways to attract and develop talent to meet market demands. Additionally, investing in technology and more efficient processes can help simplify the work and reduce dependence on skilled workers.

Researcher: Regarding the processing of raw materials, considering production cost, labor, and financial return, do you have a preference, and why? Entrepreneur: For a long time, the primary materials available in the market were natural rocks, marbles, and granites, which masons developed a greater affinity for. With the advancement of technology, quartz surfaces emerged, which were a novelty in the masonry sector for a long time. Around 2010, at the same time that diamond wire saws gained strength in the national territory, allowing for the extraction of quartzites, sintered slabs were created. Both materials are extremely hard and require specific machinery for processing. Slabs made from sintered materials have a high aesthetic value; however, being synthetic, they imitate natural rocks like quartzites. Brazil is one of the world's largest exporters of this type of rock, which makes it very gratifying to create beautiful works with a domestic material. I have no material preference, but there is no doubt that masons, in general, prefer natural rocks.

The shared response provides an interesting overview of the evolution of the marble industry and the diversification of materials available in the market. The personal preference of masons for natural stone is a subjective matter and may vary depending on the artistic sensibility of each professional and the specific needs of clients. It is important to note that the market is evolving and offering diverse, high-quality options to meet the needs of consumers and deliver beautiful works of design and architecture.

Researcher: Economically speaking, is it more beneficial for your company to work with marbles and granites or with quartzites and sintered slabs? Entrepreneur: Without a doubt, the emergence of slabs and the start of quartzite extraction have increased budget values by more than five times compared to granites and marbles. This is due to the cutting-edge technology required for both the creation of synthetic material and the extraction of natural rock. In addition to this, the significant difficulty in working with these two surfaces, requiring specific machinery and skilled labor, reduces competition among those who prefer to work with easily handled materials, limiting the supply of these products in the market. This, in turn, meets the high demand in the construction industry for these materials, guaranteeing an increase in sales and revenue for the company. It is important to consider that the scenario described in the entrepreneur's response may vary by region and specific market. Materials such as sintered slabs and quartzite may be more popular in certain areas with a higher demand for durable, high-quality finishes, while in other places, the preference for traditional granites and marbles may remain strong.

In any case, the integration of new materials and technologies in the marble industry can open opportunities for innovative companies and skilled professionals seeking to meet the demands of an ever-evolving market. The key to success lies in finding a balance between meeting growing demand and ensuring the maintenance of quality and excellence in service to keep customers satisfied and establish a solid foundation for the company in the long term.

Researcher: Based on your company's revenue over the past five years, have you noticed a reduction in revenue due to increased porcelain tile sales? Entrepreneur: In reality, during this period, we have observed the opposite trend. During and after the pandemic, we have never sold as much natural stone flooring as we are selling now. Certainly, when porcelain tiles were introduced to the Brazilian market around 25 years ago, there was a significant drop in natural rock sales, which over time, has regained its place in the market. This market evolution highlights the dynamism of the construction and decoration sector with changing consumer preferences, design trends, and increased awareness of environmental and sustainability issues. It is essential for companies in the sector to be attentive to these changes and adapt their strategies to meet shifting market demands. The balance between tradition and innovation may be the key to continued success in the walls and flooring segment.

Researcher: At the time of sale, do customers have a certain apprehension when choosing a natural material for their home? Entrepreneur: Over the years, we have gained experience working with this type of material, learning to take precautions in its processing, such as using sealants and other specific products to help protect natural rocks. The most important thing when selling this product is honesty in explaining to customers the drawbacks that the material may present due to its "living" nature, making it susceptible to stains and scratches. The decision to choose between a natural material or a synthetic product ultimately rests with the customer. The response highlights that a combination of experience, care in material usage, honesty in customer service, and knowledge of the intricacies of natural stones are fundamental aspects for the continued success of a masonry company specializing in these unique products.

In analyzing the conducted interview, it is evident that some points mentioned in the Theoretical Framework section are relevant. These include the appreciation of natural stone in the national market, the need for modernization of masonry companies to improve product quality and expand the variety of materials offered to customers, and the importance of employee training to develop qualified labor in the natural stone sector.

5. Conclusion

The general objective of this article was to analyze the importance of adapting marble factories to new trends and technologies in the coatings market and highlight the need for investment in workforce training. To achieve this objective, concrete goals were set: improving the workforce through training, courses and lectures; understand the modernization of technology in the marble production system; Research on sustainability in the sector and analysis of the need to expand the portfolio of materials offered to customers.

The methodology used included an extensive bibliographic review that allowed the topic to be contextualized and supported discussions throughout the article. Furthermore, an interview with a businessman from the stone sector enriched the research and provided valuable information on practical issues related to the work, raw material processing, most used materials and economic aspects such as revenue.

The results obtained show the importance of marble factories adapting to market changes and technological developments to remain competitive and meet customer demands. Through training, education and discussions, the team was improved, the quality standard of services provided increased and contributed to customer satisfaction.

Modernizing technology in the production system proved to be essential for streamlining processes, increasing productivity and reducing operational costs. The use of advanced machines and equipment ensured greater efficiency in the handling and processing of rocks, allowing us to offer more sophisticated and differentiated products.

The issue of sustainability was also addressed and recognized as an important factor for the marble industry. Concern for the responsible use of natural resources and the introduction of sustainable practices contribute to the company's positive image and meet the growing market demand for environmentally conscious solutions.

Another relevant aspect was the diversification of the portfolio of materials offered to customers. The research found that expanding the range of options available, both in natural stone and high-quality synthetic materials, allows customers to meet different tastes and needs and increase business opportunities. Given the results obtained, it can be said that the objectives set for this research were achieved. The study highlighted the importance of workforce training, investment in technology, sustainability and diversification of materials as fundamental factors for the success and growth of marble factories in the future.

In conclusion, it is hoped that this article has contributed to a better understanding of the trends and challenges faced by marble factories and has stimulated reflection on the importance of the constant search for innovation and improvement in this sector. The dissemination of knowledge and the adoption of recommended practices can increase the sustainable and promising development of the natural stone coverings market and consolidate the marble industry of the future as an innovative, technologically advanced sector committed to protecting the environment.

Compliance with ethical standards

Acknowledgments

The authors would like to thank Ana Zuleika Mendes Bastos Tavares Education and Career Analyst II at Instituto Euvaldo Lodi - IEL/CE and Prof. Spec. Carlos Rubens Araújo Alencar Coordinator of the MBA Course in Use of Rocks in Civil Construction and also Professor M. Sc. Rosilda do Rocio do Vale Coordinator of the Graduate Courses at the Faculty of Industry and the Euvaldo Lodi Institute (IEL) for all the attention given.

Disclosure of conflict of interest

The authors assure that there is no conflict of interest with the publication of the manuscript or an institution or product mentioned in the manuscript and/or important for the result of the presented study.

References

- [1] Dorsa, A. C. (2020). The role of literature review in scientific article writing. *Interactions (Campo Grande)*, 21(4). <https://doi.org/10.20435/inter.v21i4.3203>.
- [2] Glesne, C. (2015). *Becoming Qualitative Researchers: An Introduction* (5th ed.). Pearson.
- [3] Costa, K. L. H. (2020). The development of districts based on the activity of extraction/processing of ornamental rocks in Santo Antônio de Pádua-RJ. *Interdisciplinary Journal of Scientific Thought*, 6(3), 1-14.
- [4] Alves, C. R. A., Correia, A. M., & Silva, A. M. (2019). Quality of life at work (QWL): A study in a federal institution of higher education. *GUAL Magazine*, 12(12), 205-227.
- [5] Silva, A. (2017). Technological modernization in the production system of marble processing. *Brazilian Marble Industry Journal*, 10(2), 45-57.
- [6] Santos, J., et al. (2021). The importance of integrated management software in the modernization of marble processing. In *IV Brazilian Rocking Congress* (pp. 123-135).
- [7] Oliveira, R. (2019). Digitization of processes in marble processing: Advantages and impacts. *Journal of Technology and Innovation in the Marble Industry*, 15(3), 78-92.

- [8] Gomes, M., et al. (2020). Technological modernization and environmental sustainability in marble processing. *Journal of Sustainability in the Marble Industry*, 8(1), 67-81.
- [9] Figueiredo, L. (2022). Training of professionals for technological modernization in marble processing. In 4th Bahian Seminar on Durability and Performance of Constructions (pp. 45-56).
- [10] Torres, T. F. (2015). Technology and Innovation in the ornamental rocks sector: Design and waste reuse as an alternative for greater competitiveness for companies in the northwest of Rio de Janeiro. Instituto Federal de Educação, Ciência e Tecnologia Fluminense.
- [11] Pádua, E. J. (2012). Liming as complementary fertilization for oilseed crops. Universidade Federal de Lavras.
- [12] Gava, R. M. (2023). Ornamental Rocks vs. Artificial Surfaces for Countertops. *Rocks of Quality Magazine*, 278, May/Jun.
- [13] Stouhi, D. (2022). The benefits of biophilia for architecture and interior spaces. Archdaily.