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ECONOMIC VIABILITY STUDY OS USE WASTE ORNAMENTAL STOBNES IN RED CERAMICS

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ABSTRACT

Brazil is known worldwide as one of the main producers of ornamental stones, which generates a significant amount of waste. Since 1990, research has been carried out on the use of these wastes in ceramic artifacts and other materials, with promising results, which point to a more sustainable production, with a reduction in the deposition of wastes in nature and better quality products. In this context, the objective of this work was to analyze the economic viability of transporting and directing waste from ornamental stone processing companies to the red ceramic industries, focusing on some companies in the southern region of the state of Espírito Santo. Data were collected on the locations of stone companies, ceramic industries and waste landfills, as well as information on the distances between them and the costs involved in transporting and depositing waste in landfills. The results indicated that, for 87% of the stone processing companies in the region, directing waste to the red ceramic industries is more economically viable than deposition in landfills.

KEYWORDS: Viability, ornamental stones, wastes, red ceramic.

ESTUDO DA VIABILIDADE ECONÔMICA DA UTILIZAÇÃO DE RESÍDUOS DE ROCHAS ORNAMENTAIS EM CERÂMICA VERMELHA

RESUMO

O Brasil é reconhecido mundialmente como um dos principais produtores de rochas ornamentais, o que gera uma quantidade significativa de resíduos. Desde 1990, pesquisas vêm sendo realizadas sobre a utilização desses resíduos em artefatos cerâmicos e outros materiais, com resultados promissores, que apontam para uma produção mais sustentável, com redução na deposição de resíduos na natureza e produtos de melhor qualidade. Nesse contexto, o objetivo do trabalho foi analisar a viabilidade econômica do transporte e direcionamento dos resíduos das empresas de beneficiamento de rochas ornamentais até as indústrias de cerâmica vermelha, com foco em algumas empresas da região sul do estado do Espírito Santo. Foram coletados dados sobre as localizações das empresas de rochas, indústrias cerâmicas e aterros de resíduos, além de informações sobre as distâncias entre elas e os custos envolvidos no transporte e deposição dos resíduos em aterros. Os resultados indicaram que, para 87% das empresas de beneficiamento de rochas da região, o direcionamento dos resíduos para as indústrias de cerâmica vermelha é mais economicamente viável do que a deposição em aterros.

PALAVRAS-CHAVE: Viabilidade, rochas ornamentais, resíduos, cerâmica vermelha.

1 INTRODUÇÃO

The main raw material used in the red ceramic industries is clay. They are found in sedimentary deposits, and one of their biggest applications is for the manufacture of bricks, tiles and other artifacts (SANT'ANA; GADIOLI, 2018). According to ANICER (2023), Brazil has approximately 5,437 red ceramic industries. Ceramic products have evolved throughout history. Its use was and still is applied in several areas. Civil construction is one of the areas that most use red ceramics in the world, and masonry constructions are the ones that consume the most red ceramics (ANICER, 2023).

The use of other raw materials as an alternative in ceramic mass, along with clay, has been studied for years. An alternative much researched and studied by large centers and researchers is the possibility of applying the fine waste from the processing of ornamental stones, generated by a multiwire gangsaw, in the partial incorporation of the ceramic mass, together with the clays, for the manufacture of artifacts such as bricks and roof tiles. According to ABIROCHAS (2022), Brazil exported US$ 1.34 billion, about 2.40 million tons of ornamental stones in the year 2021, and the state of Espírito Santo was one of the largest producers and exporters of ornamental stones in the country. During the ornamental stone processing process, a large amount of waste is generated. According to Silveira, Vidal and Souza (2014), about 26% of a block of ornamental stones, when processed, is transformed into waste. The use of this waste in the formulation of masses for the manufacture of red ceramics would help to reduce the environmental problem and reduce the costs of clay extraction.

Nowadays, some studies have proven the viability of using the waste generated by sawing blocks of ornamental stones (with multiwire gangsaw) in the formulation of masses for making ceramic artifacts. According to Aguiar (2012), ceramic artifacts made with ornamental stone waste have a reduction in the porosity of the material, providing an improvement in its technological properties. According to research carried out by Sant'Ana and Gadioli (2018), the use of 50% of ornamental stone waste in the mass of ceramic artifacts can increase their mechanical resistance by up to 45%. In 2022, work was carried out to incorporate waste in the percentages of 10%, 20%, 30%, 40% and 50% in red ceramics (AGUIAR et al., 2022). In the work, the raw materials were characterized and water absorption, shrinkage and resistance tests were carried out. Ceramic pieces manufactured with the waste showed low water absorption, less shrinkage and greater mechanical resistance when compared to ceramics without waste. In the same year, Gadioli et al. (2022), carried out an environmental test on the ornamental stone waste used to study its incorporation into the ceramic mass. The result showed that the waste was within the limits of the ABNT NBR 10004 standard, therefore classified as Class II B (non-hazardous and inert). The studies prove that the incorporation of the waste in the ceramic masses can be an alternative to reduce and/or eliminate the environmental problems generated with its deposition in landfills.

The use of dimension stone waste does not depend only on the technological and structural characteristics of the final product. A preponderant factor is the cost of transporting waste from the processing industry to ceramic companies. It is very important that it is more viable to direct the waste to the ceramic company to use in its processing, than transporting and depositing it in landfills. The amount spent on transportation and disposal of waste generated directly affects the final cost of the produced stones, in addition to the environmental impact.

Therefore, the main objective is to analyze the economic viability of transporting and directing waste from ornamental stone processing companies to the red ceramic industries in the southern region of the state of Espírito Santo.

2 REVISÃO BIBLIOGRÁFICA

2.1 The ornamental stone sector

Brazil is a country recognized worldwide for its great potential in the production of ornamental stones, it is in fourth place in the international ranking of the sector, exporting approximately 2.4 million tons in the year 2021 (ABIROCHAS, 2022).

The state of Espírito Santo is the largest producer and exporter of ornamental stones in the country, accounting for more than 83% of exports (ABIROCHAS, 2022). In the same year, the growth and greater participation in exports of quartzite and marble slabs, as well as blocks of quartzite stones. The same survey shows that the products with the highest added value in exports are quartzite slabs, marble and soapstone products (ABIROCHAS, 2022).

2.2 Generation of waste in the processing of stones

The mining and processing stages of ornamental stones generate considerable material losses, generating waste, which throughout the production chain represents losses of up to 90%. Only 74% of a block becomes slab when processed, the remainder is transformed into fine waste (SILVEIRA; VIDAL; SOUZA, 2014). Therefore, there is a large amount of waste that can be used. These wastes come from two main categories: coarse wastes from the extraction or mining stage in the quarries; and fine waste from processing industries. Most of them are coarse mining wastes, usually from blocks that do not meet the aesthetic standards of the sector, in addition to other irregular ones, which, depending on the mining method as well as the geological type and the stone itself, can reach losses of millions of tons.

In processing, there are also losses of coarse material in the. This material is known in the sector as quarry waste. In the deployment of the block into slabs, in the sawmill, the fine processing wastes are produced. It is estimated that in Brazil today, around 2.5 million tons of fine waste from processing are generated annually, of which, in the state of Espírito Santo alone, 2.0 million tons are deposited in associative and private landfills (CAMPOS et al., 2014). With this, it can be estimated that in Espírito Santo approximately 18 million tons of fine waste were generated in the last 9 years. In addition to the considerable amount, the problem worsens since most industries do not manage their waste correctly.

2.3 National solid waste policy

The amount of ornamental stone mining wastes presents an expressive and worrying value, however, there are also other wastes from other Brazilian sectors. Therefore, thinking about reducing the impact of solid waste on the environment, on August 2, 2010, Law No. 12,305 of the National Solid Waste Policy was implemented (BRASIL, 2010). This federal law determines the guidelines and regulations for the management of solid waste produced in the country. It divides management responsibility between: public and private power. Therefore, the government and the productive sectors sign an agreement for the implementation of the product's life cycle.

The production chain of ornamental stones in Espírito Santo has some aspects that deserve a better approach, due to the large amount of waste that is produced. The precepts of sustainability and the circular economy must always be evaluated. The issue of waste generated in mining and processing calls for special attention, not only because of the existence of the most diverse possibilities of industrial application, in view of the large volume produced, but also because of the potential uses that such materials would have in other industrial segments that still have not been effectively standardized.

The National Solid Waste Policy establishes an order of priority in relation to waste generation. They are, in sequence: non-generation, reduction, reuse, recycling, treatment and final destination. Following this approach, the use of waste from ornamental stone processing in ceramic mass for the manufacture of artifacts would enter the reuse segment. Thus, it collaborates to reduce its final destination in landfills.

Sustainability is more than an environmental concept; It is a profound commitment to balance between the human being, the planet and the universe, reflecting the essential meaning of existence. It implies an effective connection with our daily actions, where each decision impacts not only our immediate surroundings, but also reflects on larger scales (PONTES; FIGUEIREDO, 2023). Society's commitment to solid waste is a key part of this commitment. It requires a conscious approach that goes beyond simple disposal, requiring actions that promote the reduction, reuse and recycling of materials, thus minimizing the negative impact on the environment and future generations (ALMEIDA et al., 2022).

2.4 Red ceramic industry

Brazil has approximately 5,437 red ceramic companies, generating around 18 million annual revenues, in addition to generating around 293,000 direct jobs and 900,000 indirect jobs (ANICER, 2023). 4.6 billion ceramic blocks or 1.8 billion tiles are produced per year (ANICER, 2023). Red pottery is produced from the raw material clay. The artifacts created can be coatings (tiles, porcelain tiles, inserts, mosaics, tiles), construction materials (sealing blocks, structural blocks, tiles, tiles, pipes, bricks) and household items (filters and pans clay). In the manufacture of red ceramic products, the most varied types of clay and processing techniques can be used, with this variety, there can then be several different properties among them. Clays can vary according to the region of the country, due to this, they can have different characteristics and properties, this can also be related to their geological formation (MACEDO, 2008). The formation of clays is due to the decomposition of rocks by hydrothermal and weathering actions.

2.5 History of waste use

Since the 1990s, the use of dimension stone wastes has been studied as an alternative for making products. The authors CALMON et al. (1997) were one of the first to think of alternative routes for the use of these wastes. In 1997, Calmon already stated that the large volume of waste generated was worrying for the environment. He also noted that the growing production of ornamental stones would directly influence the volume and inappropriate disposal of waste, thus generating environmental problems. In his preliminary studies, he proved that the wastes had chemical-physical properties to be used in the manufacture of various materials.

Over the years, several researchers have addressed the use of waste in various products. One of the main and most viable alternatives was the manufacture of red ceramic artifacts. According to Aguiar (2012), stone wastes, when applied in the manufacture of red ceramic artifacts, help to reduce the porosity of the material. In this way, the product tends to have better technological properties, mainly resistance.

Carneiro et al. (2019) evaluated the use of gneiss wastes in the production of ceramic tiles. The results showed that the addition of up to 40% of gneiss wastes improved the mechanical strength and reduced the water absorption of the tiles. In addition, the use of waste provided a significant reduction in energy consumption and greenhouse gas emissions during the production of tiles. More current works also show the possibility of using ornamental stone waste in red ceramic artifacts. Aguiar and Gadioli (2020) carried out laboratory tests incorporating dimension stone waste into ceramic masses in the proportions of 20% and 40%, fired at temperatures of 850°C and 950°C. The result showed an increase in resistance when 20% of waste was incorporated. It also showed a decrease in water absorption according to the incorporation of the waste. The specimens fired at 950°C meet the standards used for the manufacture of red ceramic tiles. The same authors carried out work in 2021 that studied the incorporation of dimension stone waste in the manufacture of roof tiles in the state of Espírito Santo (AGUIAR; GADIOLI, 2021). 10% and 20% of waste were incorporated in manufacturing. The tiles met the limits of mechanical resistance.

2.6 Viability and logistical costs with transport

Transport logistics is a critical part of the supply chain and represents a large proportion of the company's total costs (Govindan et al., 2020). According to the Brazilian Association of Logistics (ASLOG), logistics transport costs in Brazil represent about 60% of costs in the final product (ASLOG, 2019). Therefore, it is essential to carry out a technical and systematic analysis to minimize the operating costs of transport in industries. In this sense, good planning, which involves a systemic view, is essential to organize an efficient transport system.

In the specific case of ornamental stone waste, transport can represent a significant additional cost for the industry. This is because, in addition to the cost of transport itself, there are also costs involved in the proper disposal of waste. According to Almeida and Souza (2016), the final destination of this waste is a critical and costly issue, as it requires a environmental control measures and the use of specific technologies. These additional costs can be reflected in the final price of the product, making it less competitive in the job market.

Therefore, it is important to carry out an analysis of the economic viability of transporting ornamental stone waste, in order to identify ways to reduce the costs involved in the process and make the final product more competitive. In addition, it is essential to look alternatives for the use of waste in the red ceramic industry, in order to reduce the amount of waste generated and minimize the costs of its disposal.

3 MATERIALS AND METHODS

3.1 Collection of geographic data and map production

At first, a data collection was carried out to obtain information on the geographic location of the red ceramic industries present in the south of the state of Espírito Santo. The work began in direct contact with the Instituto do Meio Ambiente e Recursos Hídricos – IEMA and some city halls in the state. Information was also collected from some ornamental stone processing companies and waste landfills. This information was obtained through a search on the internet and on the site of the Sindicato das Indústrias de Pedras Ornamentais – Sindirochas. With the data, it was possible to quantify and create a map showing the proximity between the red ceramic industries, ornamental stone processing companies and waste landfills present in the south of Espírito Santo.

It is noteworthy that location data were not collected for all ornamental stone processing companies in the south of the state, only for some.

3.2 Collection of cost data

Data were collected on costs of deposition of waste in landfills. The values were informed by 3 landfills present in the southern region of Espírito Santo. Information on waste transportation costs was also collected. With the data, the average cost was calculated.

3.3 Histogram of mileage variation

A histogram was created, displaying the distances in kilometers from the stone processing companies to the nearest waste landfills and to the red ceramic industries. With this, a percentage comparison was carried out to identify the number of stone processing companies that are closer to the red ceramic industries.

3.4 Economic viability analysis of transport

A comparative calculation was carried out to evaluate the economic viability of transporting ornamental stone waste to the ceramic industry or landfills. The equations take into account the following variables: freight cost, waste disposal value, distance in kilometers (km) from the stone processing company to the landfill, and also to the red ceramic and the quantity in tons that the truck can carry.

With this, the following calculation operations were carried out: first, the freight mileage cost value (reais per kilometers) is multiplied by the number of kilometers traveled. The calculation is made for the journey from the stone processing company to the landfill and from there to the red ceramic industry. Then, the value of the cost of depositing a ton in reais is multiplied by the total amount of waste transported in the truck, also in tons. Finally, the cost of transportation to the landfill is added to the cost of deposition. Therefore, we get two cost variables. The first is the cost of taking the waste to the red ceramic industry and the second is the sum of the cost of transport plus the disposal of waste in landfills.

With the result of the equations, it was possible to have information on the economic viability of transport to direct the waste to the landfill or for its use in the red ceramic industry. If the value of the cost of transport to the ceramics is lower than the cost of transport plus landfilling, it becomes more viable to direct the waste to the ceramics industry. Otherwise, the cost of transport plus landfill is less than the cost of transport to the ceramics, it is unfeasible to direct to ceramics and more viable to deposit in landfills. With this calculation logic, we analyzed the stone processing companies in the southern region of Espírito Santo and the viability of using the waste in the ceramic industries. It is worth mentioning that this calculation analysis is economical, so environmental issues were not taken into account for the viability calculation.

To facilitate the calculations, an Excel table was used to automatically insert information on distances, transport and disposal costs and the amount of waste transported. It informs directly if the company has the viability or not to direct the waste to red ceramics.

4 RESULTS AND DISCUSSION

Data were collected from 45 ornamental stone processing companies present in the south of the state of Espírito Santo, 16 red ceramic industries and 24 stone waste landfills. The municipality of Cachoeiro de Itapemirim had the largest number of stone industries, there are 34, also the largest number of landfills, 12 in total. The largest concentration of red ceramic industries is in the municipality of Itapemirim, totaling 9. This municipality borders the municipality of Cachoeiro de Itapemirim, which has 6 red ceramic industries. Figure 1 shows the map with information on the locations of stone processing companies, landfill and red ceramic industries.

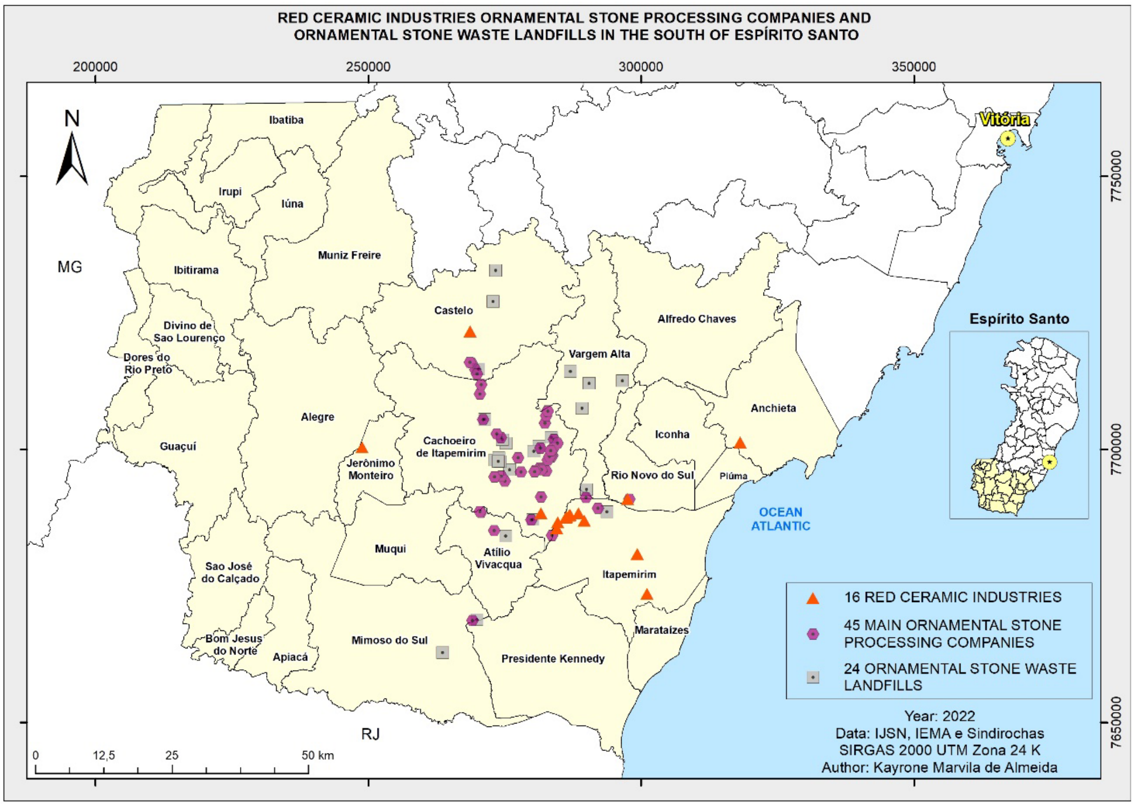

Figure 1: Map with location information of ornamental stone processing companies, waste landfills and red ceramic industries

It was named as A1, A2 and A3, the landfills that provided information on the costs of depositing a ton of ornamental stone waste. The average value was R$ 9.33 per deposited ton. Therefore, this value was used as a calculation basis in the study. The values, together with the mean, are described in Table 1.

Table 1: Cost values charged by landfills for the deposition of each ton of waste

Company	Cost per ton deposited
A1	R$ 7,76
A2	R$ 9,93
A3	R$ 10,30
Average	R$ 9,33

The companies that reported the cost of transporting waste, referring to each kilometer traveled, were named as T1, T2 and T3. Their respective values, along with the mean, are contained in Table 2.

Table 2: Waste transport cost values

Company	km cost value traversed by truck
T1	R$ 11,66
T2	R$ 13,33
T3	R$ 18,33
Average	R$ 14,44

The average cost of transporting waste was R$ 14.44 per km traveled.

A fixed figure of 20 tons of waste per trip was stipulated for cost calculations. This value refers to the transport capacity of a medium-sized dump truck.

4.1 Economic viability analysis

With the data, it was possible to obtain two cost values: the waste transport and the waste disposal. With this, we can analyze the viability, in terms of cost, of directing the waste to the landfill or to the red ceramic company.

An average of R$ 9.33 per ton deposited, R$ 14.44 per km traveled and a capacity of 20 tons for each trip was obtained. Assuming that a stone processing company deposits its waste in a landfill 10 km away, and a red ceramics company, also 10 km away, wants to receive this waste for use in artifacts, it is then possible to have the following calculations of cost.

- Cost to dispose of waste in landfill:

Landfill cost = (R$ 14,44 x 10 km) + (R$ 9,33 x 20 t)

= R$ 331,00

- Cost to send waste to ceramics:

Ceramic cost = (R$ 14,44 x 10 km)

= R$ 144,40

In this example, it can be seen that deposition in the landfill has the highest cost with the waste. This is due to the extra amount paid for the deposition. The use of waste by the ceramic industry, in this case, would be more viable.

Observing the calculations, the cost for the landfill and for the ceramic tile has a difference of R$ 186.60. This value can be converted to kilometers to be traveled. With that, it would be viable to take this waste to a ceramic even with a greater distance. With the difference in costs between landfill and ceramics, divided by the cost per kilometer of transport (R$ 186.60/R$ 14.44), it is possible to obtain the value of more kilometers that could be traveled, in this case 12 .9 km. With this, it can be stated that with these proposed conditions and the data collected, it is viable to take the waste to the ceramic industry, even though it is 12.9 km farther from the ornamental stone industry than from the industry to the landfill. In the example that was suggested, the ceramic industry could be up to 22.9 km away from the stone processing company, as it would still be more viable to deposit there.

With the analysis of the data, we can see that to be viable, the difference in mileage between the path to the ceramics and to the landfill must be less than or equal to 12.9 km, (km ceramics - km landfill ≤ 12.9 km).

Companies that have this value even lower, achieve a greater reduction in their costs with waste disposal. With this, it was then possible to analyze the companies in the southern region of Espírito Santo that would be more viable to direct their waste to the ceramic industries than to landfills. Figure 2 shows the histogram with the mileage from the stone company to the ceramics company, the landfill and the difference between the two. As previously mentioned, a difference of less than or equal to 12.9 km indicates the viability of transporting red ceramics.

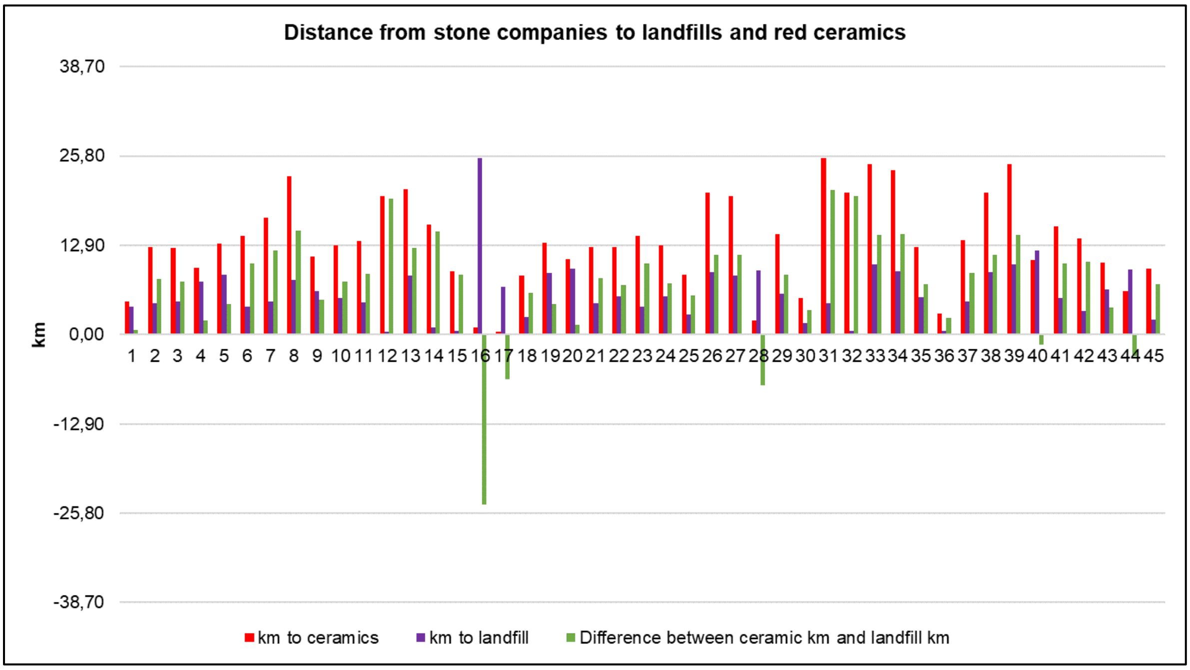

Figure 2: Histogram with the distances of the companies

Observing the histogram, it is possible to see that of the 45 stone processing companies that were scored, 37 have greater economic viability if they direct their waste to the red ceramic industries. This is because they are closer or because they do not have to pay the amount charged for landfills. Therefore, for approximately 87% of the ornamental stone processing companies in the south of Espírito Santo, it is more economically viable to direct their waste to ceramics.

The disposal of waste from these companies to the red ceramic industry would contribute significantly to reducing the environmental impact caused by the deposition of waste in landfills.

5 CONCLUSIONS

The average cost to deposit waste in landfills is R$ 9.33 per ton and its transport cost per km traveled is R$ 14.44. The results show that of the 45 stone processing companies evaluated in the south of Espírito Santo, 37 of them, about 87%, have greater economic viability if they direct their waste to the red ceramic industries. This is due to the proximity of stone companies to ceramics, thus reducing the cost of freight, and also because they do not have to pay the deposition fee that is charged in waste landfills. In addition, proving the economic viability of transport helps to reduce the environmental impact caused by the deposition of waste in landfills.

The use of waste in the red ceramic industry then becomes a possibility in addition to environmental and technological issues, and is also an alternative to reduce costs with waste disposal.

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