



SELECTION OF AREA FOR THE IMPLEMENTATION OF A LANDFILL IN THE CITY OF CANINDÉ – CE

Karina Albuquerque da Silva¹
Ana Bárbara de Araújo Nunes²

ABSTRACT

Objective: The objective of this work is to apply multi-criteria analysis to choose a suitable area for the implementation of a sanitary landfill in the city of Canindé.

Theoretical Reference: This study covers concepts and theories related to waste management, environmental impact, legal regulations and best practices in sanitary engineering, focusing on the final disposal of solid waste and the importance of the best decision to choose an area for landfills.

Methods: The methodological procedure was carried out through the application of the PROMETHEE I and PROMETHEE II methods using the Visual Promethee Academic software.

Results and conclusion: The result shows that among the four alternatives analyzed, Alternative 3 is the best choice considering the criteria established in accordance with Brazilian legislation pertaining to landfills.

Research implications: This research involves several implications of considerable magnitude. These implications include the environmental impact and quality of life of the local population, public health issues, economic impacts, as well as legal and regulatory considerations, making this topic of critical social and environmental relevance, with significant consequences for the community and sustainability. long term of the city.

Originality/value: This research has social, economic, scientific and environmental relevance, both due to the data analysis and the originality of the discussions offered.

Keywords: Multicriteria Analysis, Landfill, Area Selection, Appropriate Final Destination.

SELEÇÃO DE ÁREA DESTINADA A IMPLANTAÇÃO DE ATERRO SANITÁRIO NA CIDADE DE CANINDÉ – CE

RESUMO

Objetivo: O objetivo deste trabalho é aplicar a análise multicritério para a escolha de uma área adequada para a implantação de um aterro sanitário na cidade de Canindé.

Referencial teórico: Esse estudo abrange conceitos e teorias relacionados à gestão de resíduos, impacto ambiental, regulamentações legais e as melhores práticas em engenharia sanitária dando enfoque a disposição final de resíduos sólidos e a importância da melhor decisão de escolha de área para aterros sanitários.

Métodos: O procedimento metodológico se deu por meio da aplicação dos métodos *PROMETHEE I* e *PROMETHEE II* através do software *Visual Promethee Academic*.

Resultados e conclusão: O resultado aponta que dentre as quatro alternativas analisadas, a Alternativa 3 é a melhor escolha tendo em vista os critérios estabelecidos conforme a legislação brasileira pertinente a aterros sanitários.

¹ Universidade Federal do Ceará, Fortaleza, Ceará, Brazil. E-mail: karina.silva@crateus.ufc.br

Orcid: <https://orcid.org/0000-0002-4148-6890>

² Universidade Federal do Ceará, Fortaleza, Ceará, Brazil. E-mail: abarbara@deha.ufc.br

Orcid: <https://orcid.org/0000-0001-5845-6252>



Implicações da pesquisa: Esta pesquisa envolve diversas implicações de considerável magnitude. Essas implicações incluem o impacto ambiental e na qualidade de vida da população local, questões de saúde pública, impactos econômicos, bem como considerações legais e regulatórias, tornando esse tema de relevância social e ambiental crítica, com consequências significativas para a comunidade e a sustentabilidade a longo prazo da cidade.

Originalidade/valor: Esta pesquisa apresenta relevância social, econômica, científica e ambiental, tanto devido à análise dos dados quanto à originalidade das discussões oferecidas.

Palavras-chave: Análise Multicritério, Aterro Sanitário, Seleção de Área, Destinação Final Adequada.

RGSA adota a Licença de Atribuição CC BY do Creative Commons (<https://creativecommons.org/licenses/by/4.0/>).



1 INTRODUCTION

The increasingly pronounced forms of consumption linked to changes in the means of production and to the growth of urban centers have over the years caused a significant increase in the generation of municipal solid waste (MSW). In this sense, alternatives need to be found to minimize negative impacts mainly on the incorrect way of final disposal of such waste.

According to the Brazilian Association of Public Cleaning Companies - ABRELPE (2020), between the years 2010 to 2019, Brazil produced about 79 million tons of MSW per year, with generation per capita of 379 kg/year. Solid waste production increased by about 1%, reaching a total of 216,629 tons of MSW per day in the country. This index is higher than the country's population growth rate in the period, which corresponds to 0.77%.

The National Policy on Solid Waste (PNRS), Law No. 12.305 of August 2, 2010, provides principles, objectives and instruments, as well as guidelines on integrated management and management of solid waste determining, among others, that the environmentally appropriate final disposition for waste must be by means of ordered distribution of waste in landfills, observing specific operational standards in order to avoid damage or risks to public health and safety and to minimize adverse environmental impacts. (BRAZIL, 1998).

Even if the PNRS stipulates that landfills must be the environmentally correct final destination of household waste, the fact is that the reality is still far from it. In the vast majority of Brazilian cities, the final disposition is still made through dumps, which characterizes the release of waste in the open air, thus putting at risk the environment and human health.

According to the National Sanitation Information System (SNIS) in its Diagnosis of Urban Solid Waste Management (2021), in Brazil, in 2020, about 92.7 million tons of solid waste mass were collected, with only 48.2 million of these adequately disposed in landfills, with the other 44.5 million destined to landfills, controlled landfills and other unaccounted for destinations.

This problem becomes more worrying when analyzed among the Brazilian regions, where the Northeast shows little assistance, when it comes to the presence of sanitary landfills, specifically the state of Ceará and its hinterland.

Thus, it is possible to note that the problems surrounding the management of solid waste affect not only large urban centers, but also the municipalities and small towns, due to the scarce resources and the lack of studies focused on these themes.

In order both to comply with the legislation in force and to pursue sustainable development, in the area of solid waste management, it is necessary to have landfills for proper disposal. Therefore, the selection of the best possible area for landfill sites should be made in a way that complies with the legal requirements of the legislation, as well as taking into account



the environmental well-being of the environment. Methods of multi-criterion analysis, through criteria and alternatives, have been used to solve similar problems leading to the decision maker arriving at the best possible alternative.

The Multi-Criterion Methods of Decision Analysis (MMAD) found roots for its development, initially in the period of World War II, at which time Operational Research was widely disseminated and used by the British military corps and later by the US as an analytical tool for strategic management and problem-solving found in the military context (BONINI et al., 2016).

Thus, the objective of the work is to apply the multi-criteria analysis for the choice of the area of a landfill site in the city of Canindé, located in the state of Ceará, as well as, to contribute to the identification of locational alternatives providing regional development, focusing on the environmental, social and economically correct destination of solid waste of the city.

2 THEORETICAL BENCHMARK

For Gonzaga et. Al (2021), after the Industrial Revolution, humanity has observed, through climate change and scarcity of non-renewable resources, the effects caused by development generated in an unbalanced way. According to Nascimento et al. (2015), there is a close link between waste production and the economy of a country, which transforms solid waste into important socio-economic indicators, both for the quantity of generation and for its characterization, predominantly formed by recyclable materials. Environmental problems related to the generation of solid waste are complex and difficult to solve, since they depend on the reflection and attitude of a part of society that is unaware of the impacts generated by waste when not managed properly (MACEDO et al., 2015).

After nearly twenty years of debate in the National Congress, on August 2, 2010, Federal Law No. 12.305 was established as the National Policy on Solid Waste (PNRS), with the objective of integrated management and adequate waste management. This legal document created tools that facilitated the planning and adoption of important targets in relation to reduction, reuse and recycling, and the use of solid waste by establishing the targets for their disposal.

With regard to the definitions contained in the law, it is important to highlight some of them, starting with the definition of solid waste (Article 3, paragraph XVI):

goods, things, objects or good waste from human activities in the community, where the storage area continues, proposes to continue or is obliged to continue, in solid or solid form, as well as gases contained in containers and liquids, the specifications of which make it impossible to release them into the sewage treatment system or into water installations, or to require solutions that are technically or economically impossible because of the best available technology.

The Brazilian Association of Technical Standards - ABNT 10004, in the third item, defined solid and semi-solid residues:

[...] activities of the local community: industrial, domestic, hospital, commercial, agricultural, services and sweeping. Sludge from water treatment systems, machine-generated sludge and 1. Installation to control soil pollution, and certain liquids from the discharge of information to the sewage treatment system or bodies of water that require these technical solutions cannot be economically viable.

According to ABRELPE (Brazilian Association of Public Cleaning Companies and



Special Residues), in 2022, the generation of MSW (Urban Solid Residues) in Brazil was 81,811,506 t/year, being the northeast generator of 24.7% of this, the second largest region falling behind only the southeast region that generated 49.7%.

Also according to ABRELPE, in Brazil, most of the collected MSW (61%) continues to be sent to landfills, with 46.4 million tons sent for environmentally suitable destination in 2022. On the other hand, areas of inadequate disposal, including controlled dumps and landfills, are still in operation in all regions of the country and have received 39% of the total waste collected, reaching a total of 29.7 million tons with inadequate destination. In the northeast, in 2021, only 515 municipalities made adequate disposal of their municipal solid waste while 1279 performed inadequately (ABRELPE, 2022).

The estimate is that in the world today there are more than 6 billion inhabitants, with generation in the order of 570 million tons/year of waste. The developed countries are the largest generators, the USA, for example, generate around 232 million tons/year; Japan: 100 million tons/year; England: 40 million tons/year; France and Germany: 30 million tons/year (EPA, 2002).

For Souza et al (2023), tax benefits and economic incentives from Brazilian states are fundamental for the functioning of municipalities.

According to the National Sanitation Information System (SNIS), in its Annual Diagnosis of Solid Waste, there were in 2020, 5,018 MSW processing units in operation in municipalities of Brazil, of which 1,545 landfills, or 30.1%.

3 METHODS AND PROCEDURES

3.1 Characterization of the Study Area

With an area of 3,218.5 km², the city of Canindé is located in the Central-North region, in latitude 4° 21' 32" south and longitude 39° 18' 42" west, at an altitude of 149.73 m (IPECE, 2017). The city is at a distance of 114 km in a straight line from the state capital and its neighboring municipalities are shown in Table 1.

Table 1. Municipalities Bordering Canindé

| NEIGHBORING MUNICIPALITIES | | | |
|----------------------------|-----------|----------|----------------|
| NORTH | SOUTH | EAST | WEST |
| Charity | Itatira | Itapiúna | Irauçuba |
| Paramoti | Magdalene | Aratuaba | Sombral |
| General Sampaio | Choró | Mulunga | Santa Quitéria |
| Tejuçuoca | | Charity | |
| Irauçuba | | | |

Source: IBGE, 2010.

The location of the city of Canindé on the map of the state of Ceará is represented in Figure 1.

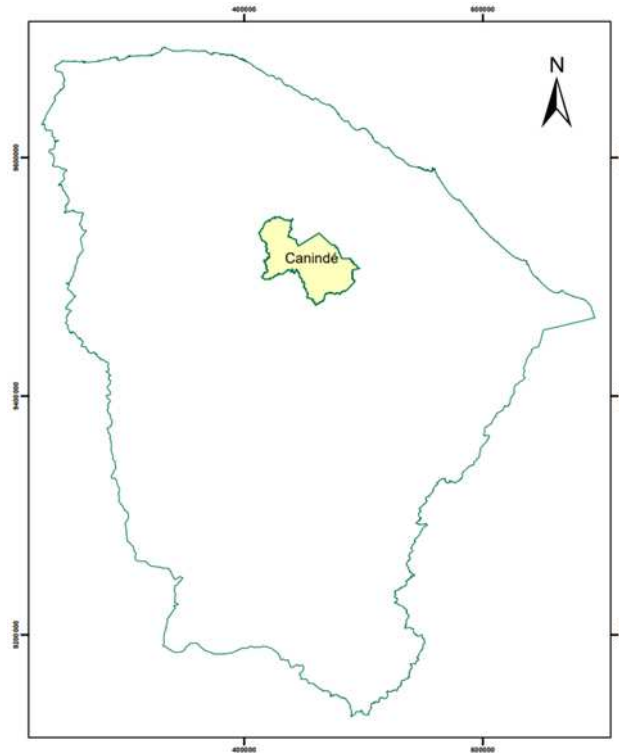


Figure 1. Geographical location of the municipality of Canindé in a state context
Source: IPECE, 2019.

The Canindé cartography, cut by BR-020 and CE-257 and their main routes, is represented in Figure 2.

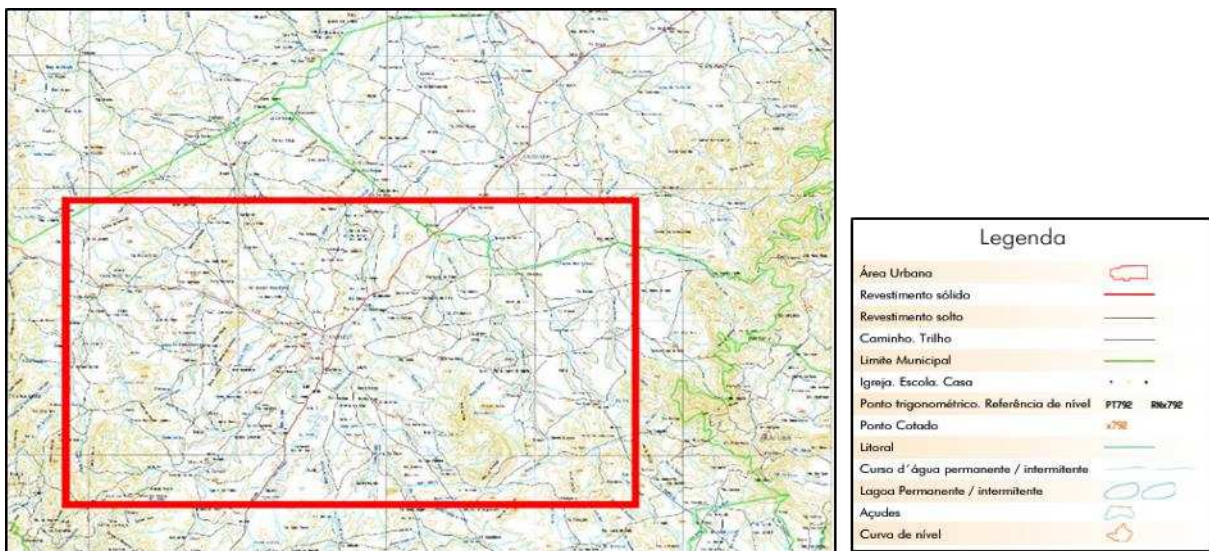


Figure 2. Map of Canindé
Source: IPECE, 2017.

According to the 2010 IBGE demographic census, the estimated population of Canindé was 74,473 inhabitants, of which 62.94% were urban residents. Located in the Northeast of Brazil, the climate of the municipality is tropical hot semi-arid and tropical hot semi-arid mild, with rainfall of 756.1 mm (millimeters) distributed mainly in the months of February to April, with higher values of rainfall of the year. September has the lowest level of precipitation, with only 1 mm (millimeter), and March, with the highest level, with an average of 183 mm



(millimeter). The city has no rainfall stations, which explains the lack of data from the National Meteorological Institute (INMET).

The waste collected in the city of Canindé and to be disposed of in the landfill site comes from the municipality itself, that is, it will not receive waste from the neighboring towns. Its origin tends to be domiciliary, commercial establishments, the tourist spots of the city, the sweeping of public roads and services. It will not receive hospital waste and it will not be hazardous, so it is Class II waste - non-hazardous.

3.2 Methodological Procedures

The present study has as its methodology a descriptive, explanatory and exploratory research that seeks to list alternatives of environmentally, socially and economically appropriate areas, defined according to the relevant environmental legislation, for the establishment of landfill, using multi-criteria analysis through the methods *PROMETHEE I* and *PROMETHEE II*.

According to Campos (2011), the family of multi-criteria methods known as *PROMETHEE* (*Preference Ranking Organization Method for Enrichment Evaluation*) was first presented by Brans, Vique and Mareschal in 1984. Roy (1996) states that this method is a method of peer-to-peer overclassification and comparison, where the decider's argument is sufficient to state that, comparatively, an alternative is as good as the one compared.

For these methods, their structuring can be done in two stages. The first is by the construction of the overclassification analysis and the second by the ordering analysis considering the variables presented in the problem. In the case of this study, criteria and alternatives were used. The *PROMETHEE* method was chosen for the practicality of application and intuitiveness that the decision maker now has, as well as taking into account the methods of overcoming, which makes the binary comparison between alternatives analyzed.

Finally, after understanding the problem, mapping criteria and alternatives for the conclusion of the problem, the data collected was applied in the *Visual Promethee Academic* software.

Thus, in order to achieve the objective of this work, the steps followed are described in Figure 3.

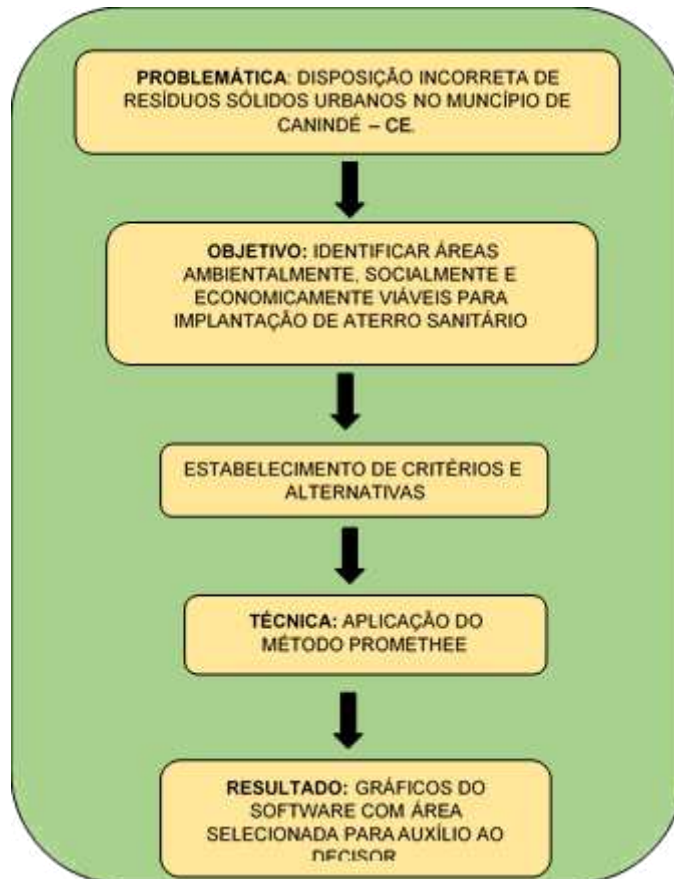


Figure 3. Methodological flowchart used for research

Source: Prepared by the authors.

For the application of the *PROMETHEE* method, 4 technical criteria were analyzed and 4 local alternatives for the landfill were selected. The criteria were chosen, based on and focusing on the environmental, social and economic pillars, according to ABNT Standard NBR 13.896 (ABNT, 1997) which provides for landfills of non-hazardous waste addressing criteria for design, deployment and operation.

NBR 13.896 (ABNT, 1997), presents the minimum conditions required for the location of landfills, taking into consideration the economic, social and environmental spheres. Also according to the Standard, in general, a site to be used for landfills of non-hazardous waste must be such that the environmental impact to be caused by the landfill site is minimized, the acceptance of the facility by the population is maximized, is in line with the zoning of the region and can be used for a long time, requiring only a minimum of works to start the operation.

The specific criteria set out in the Standard for assessing the suitability of a site for landfills include those relating to existing topography, geology and soil types; water resources, vegetation, accesses, available size and useful life; costs and minimum distance to population centers. Four of these were selected to apply criteria in this work.

The first of them selected is water resources, in which it provides that the possible influence of the landfill on the quality and use of nearby surface and groundwater must be assessed. Thus, the Standard recommends that the landfill should be located at a minimum distance of 200 meters from any water collection or watercourse. The agricultural potential of the selected area should also be analyzed and taken into account as vegetation can act favorably in the choice of an area as regards the aspects of reduction of erosion, dust formation and odor transport as well as avoiding the location of landfill sites in areas of large agricultural potential



in order to maintain these without anthropic action and with their natural characteristics remaining.

Access to the established site of the landfill is also another criterion addressed by the Norm where it states that it should be facilitated by emphasizing its uses under any climatic conditions and emphasizes that it is a factor of obvious importance in a landfill project, since they are used throughout its operation. Another established criterion is the minimum distance to population centers that according to the Standard, it is recommended that the distance to the landfill should be more than 500 meters. The criteria set out in Table 2 are presented.

Table 2. Established criteria for research

| Established Criteria |
|-------------------------------------|
| Distance of bodies of water (m) |
| Agricultural Potential (10-1) |
| Accessibility (scale) |
| Distance from population nuclei (m) |

Source: Prepared by the authors.

The alternatives, as well as the values and scales presented in each alternative, were chosen according to local availability in the city of Canindé and its surroundings considering the relevant legislation. Table 3 presents the matrix with the alternatives and the decision criteria of the problem.

Table 3. Decision Matrix for the Issue

| | Alternative 1 | Alternative 2 | Alternative 3 | Alternative 4 |
|-------------------------------------|---------------|---------------|---------------|---------------|
| Distance of bodies of water (m) | 500 | 480 | 900 | 470 |
| Agricultural potential (1-10) | 4. | 5 | 4. | 6 |
| Accessibility (scale) | very good | good | median | Good |
| Distance from population nuclei (m) | 500 | 1,100 | 900 | 750 |

Source: Prepared by the authors.

For the application of the *PROMETHEE* method it is necessary to create a matrix with criteria and alternatives, comparison between alternatives, normalization of values by preference functions, application of weights for each criterion, calculation of the global preference indices and obtaining the flows of importance.

According to Campos (2011), the alternatives are compared among themselves by the binary relations that indicate performance of each one for a given criterion. In this way, maximum or minimum functions are established for each criterion. In relation to preference functions, according to Brans, Vincke and Mareshchal (1986), the *PROMETHEE* method can be made of six generalized forms in which are true criterion, quasi-criterion, semi-criterion, pseudocriterion (discrete variation), pseudocriterion (linear variation) and Gaussian. The preferred function chosen for this work was the pseudocriteria or it could be called as linear variation.

Once the preferred functions have been defined, weights must also be established for the degrees of importance assigned to each criterion. This stage was determined by the authors. For the overall weighted preference indices, the overall weighted preference index is calculated for each pair compared, indicating the preference percentage of the alternatives, taking into account the weights assigned to each defined criterion. Another important feature of *PROMETHEE* second Campos (2011), is that it is related to the relationships of preferences capturing situations of indifference and preference as well as the association of the function



used for the performance of the analysis thus helping to make clear to the decision agent about the parameters to be collected that are the limits of indifference (q) and preference (p) being also defined by the decision maker, in this case, by the authors.

Table 4 presents the applied functions (minimum or maximum), the selected preference function, the values of q (value of indifference), p (value of preference), and the weights applied for each criterion, respectively.

Table 4. Decision Matrix with Roles

| Criteria | Role | Preference Function | q(indifference) | p(preference) | Weights |
|--|-------------|----------------------------|------------------------|----------------------|----------------|
| Distance of bodies of water (m) | max | <i>Linear</i> | 250 | 400 | 0.3 |
| Agricultural potential (1-10) | min | <i>Linear</i> | 1. | 2. | 0.2 |
| Accessibility (scale) | max | <i>Linear</i> | 1. | 5 | 0.3 |
| Distance from population nuclei (m) | max | <i>Linear</i> | 300 | 600 | 0.2 |

Source: Prepared by the authors.

In this way, the choice of the best area alternative according to the established criteria can be obtained in two ways. The first of these is based on the *rankings* of the overall positive and negative flows (procedure known as *PROMETHEE I*) and the overall net flows (procedure known as the "PROMETHEE II"). Therefore, the *PROMETHEE I* method offers a "partial" ranking in the sense of representing the state of incomparability by creating two scales from 0 to 1 to quickly identify the points where each of the alternatives is found in these two scalars and *PROMETHEE II* offers "total" ranking, where the state of incomparability does not exist by simplifying analysis by just creating a single scale and feeding in these cases the values of the net flows.

By collecting the information, creating the array, and defining all required functions, the data was applied to the *Visual Promethee Software*. The *Visual Promethee Software* was created by the authors of the *PROMETHEE* methods themselves, Professors Jean-Pierre Brans and Bertrand Mareschal, where the *Visual Promethee* is the only official software to aid multi-criteria decision based on *PROMETHEE*, consistent and error-proof.

Figure 4 presents the input data in the software.



| | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | <input checked="" type="checkbox"/> | | |
|-------------------------------------|-------------------------------------|--------------------------------------|-------------------------------------|--------------------------------------|--------|-----------|
| Bertrand | Corpos d'ág... | Potencial Ag... | Núdeos Pop... | Acessibilidade | | |
| Unidad | m | unit | m | impact | | |
| Cluster/Grupo | ● | ◆ | ● | ■ | | |
| Preferencias | | | | | | |
| Min/Max | max | min | max | max | | |
| Peso | 0,30 | 0,20 | 0,20 | 0,30 | | |
| F. de Preferencia | Lineal | Lineal | Lineal | Lineal | | |
| Umbrales | absoluto | absoluto | absoluto | absoluto | | |
| - Q: Indiferencia | € 250,000 | 1 | 1,0 | 300,0 | | |
| - P: Preferencia | € 400,000 | 2 | 5,0 | 600,0 | | |
| - S: Gaussiano | n/a | n/a | n/a | n/a | | |
| Estadísticas | | | | | | |
| Mínimo | € 470,000 | 4 | 500,0 | 3,0 | | |
| Máximo | € 900,000 | 6 | 1100,0 | 5,0 | | |
| Media | € 587,500 | 5 | 812,5 | 4,0 | | |
| Desv. est. | € 180,745 | 1 | 219,0 | 0,7 | | |
| Evaluaciones | | | | | | |
| <input checked="" type="checkbox"/> | Alternativa 1 | ■ | € 500,000 | 4 | 500,0 | muy bueno |
| <input checked="" type="checkbox"/> | Alternativa 2 | ● | € 480,000 | 5 | 1100,0 | bueno |
| <input checked="" type="checkbox"/> | Alternativa 3 | ■ | € 900,000 | 4 | 900,0 | mediano |
| <input checked="" type="checkbox"/> | Alternativa 4 | ● | € 470,000 | 6 | 750,0 | bueno |

Figure 4. Input data in *Visual Prometheand Academic software*

Source: The authors (2023).

4 RESULTS AND DISCUSSION

When running the application of the *PROMETHEE* method in *Visual Promethee Academic software*, the results of the PROMETHEE I method are shown in Figure 06.

Figure 5 shows the behavior of the alternatives in relation to the $+Ø$ flows on the left side distributed in a decreasing way and $-Ø$ on the right side distributed in an increasing way. It should be noted that alternative 3 is the most viable alternative according to the established criteria, followed by alternatives 2, 1 and 4 respectively.

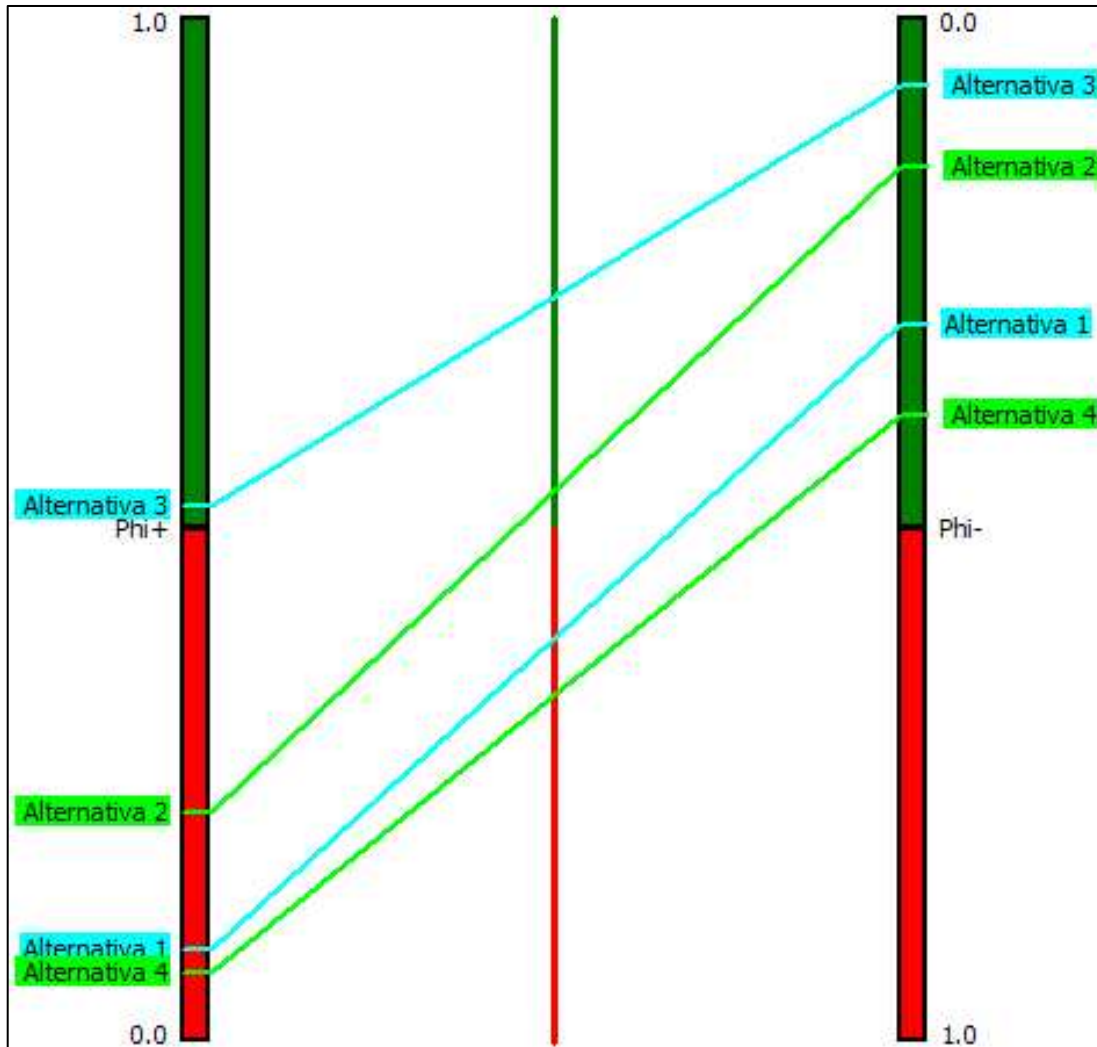


Figure 5. *PROMETHEE I* Result

Source: The authors (2023).

According to Campos (2011), the *PROMETHEE I* method solves ordering problems in which a partial preorder of the problem alternatives is obtained, in *PROMETHEE II* a complete order is obtained. The initial steps for the application of the methods are the same, the only difference being that in *PROMETHEE II* situations of incomparability are avoided. The choice of the application of the two methods was due to the fact that according to Brans (2002), this application is suitable when there is a need to compare the performances of each alternative presented.

The application of the *PROMETHEE II* method establishes a pre-order that provides an overall assessment as described in Figure 6 presenting the pre-order and software calculated values of the global flows.

According to the established criteria, alternatives 3, 2 and 1 present respectively the best areas discarding alternative 4, as the software suggests.

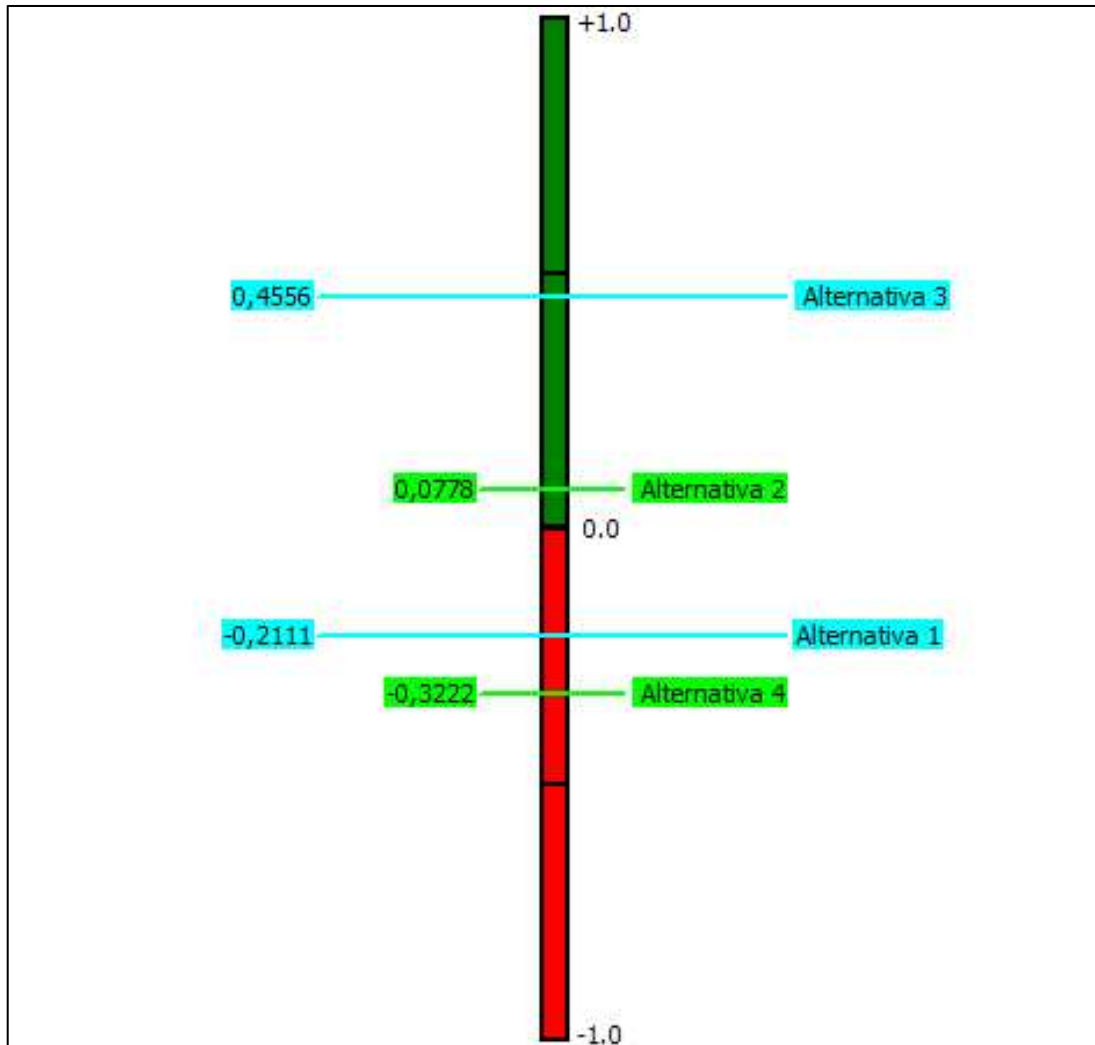


Figure 6. *PROMETHEE II* Result

Source: The authors (2023).

According to Campos (2011), the results on the graphic extension allow the analyst to manipulate in an interactive way the relative weights to evaluate their influence on the performance of the alternatives. This requires a sensitivity analysis. Also according to Campos (2011), sensitivity analysis is essential for multi-criteria problems of overclassification, as in the case of the *PROMETHEE* method, since it serves to better understand the performance of the alternatives, since its stability is observed through changes in the preferences of the decision maker.

Therefore, other weight values were adopted to perform the sensitivity analysis so that it could be compared with the previous scenario. Figure 7 shows the *PROMETHEE II* configuration with changing weights for a new scenario.

By changing the weights to perform the sensitivity analysis as shown in Figure 08, a new classification was obtained: alternative 3, alternative 2, alternative 4 and alternative 1. Even with the changes, Alternative 3 is considered the best alternative among the others presented.

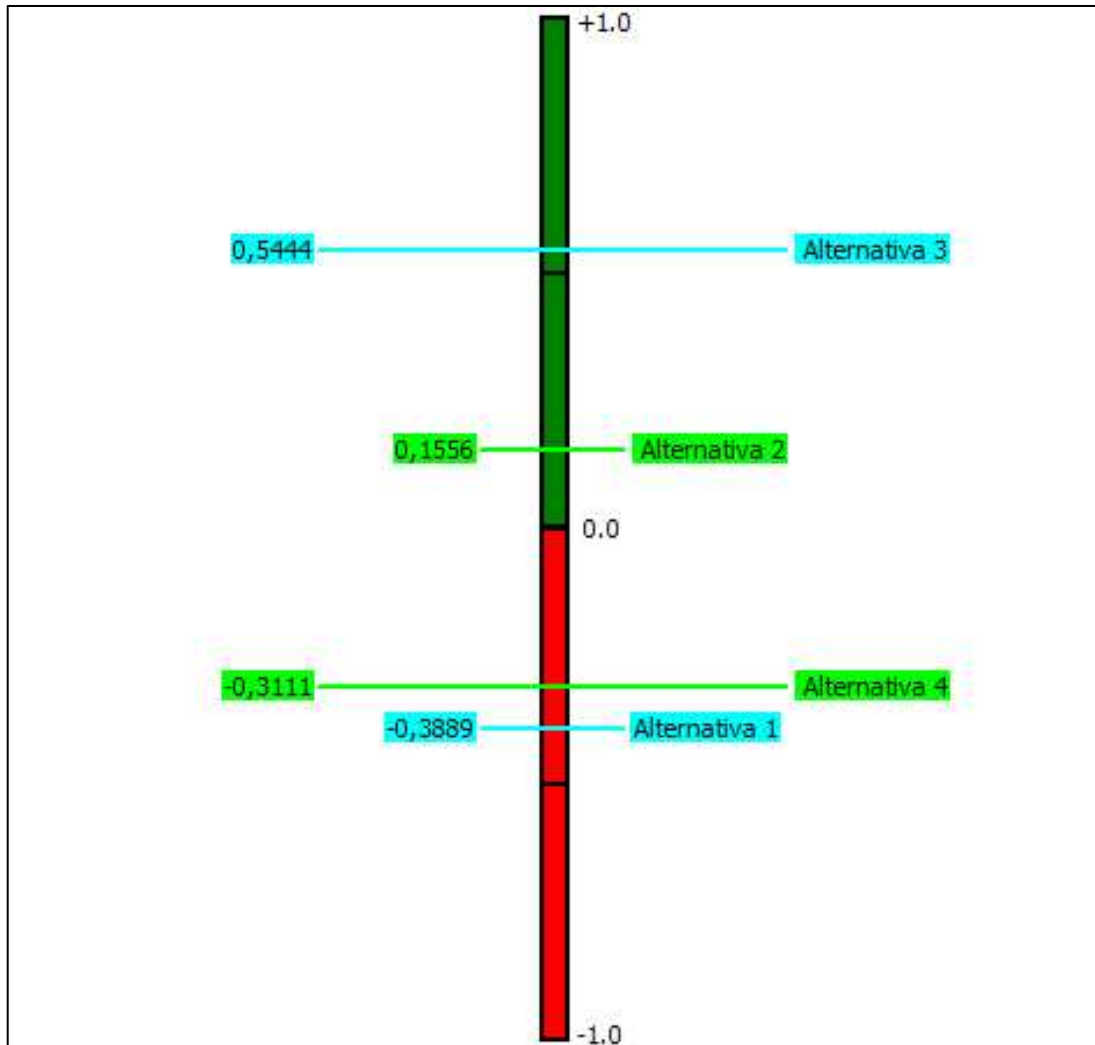


Figure 7. Application of the method with change of weights

Source: The authors (2023).

5 CONCLUSIONS

Through the use of *Visual Promethee Academic* software, observing its various analyzes such as sensitivity analysis, it was possible to find consistency for the final decision of the best area, among the alternatives raised.

The process of analysis, for the establishment of the criteria, required knowledge of the relevant Brazilian standards, the operation of landfills respecting their limits as well as their social, environmental and economic aspects respecting all the limits established by law.

Given that the implementation of landfills has potential environmental impact, it is necessary that their areas of implementation are selected in such a way as to interfere as little as possible with negative impacts, including assisting municipal managers to select potential areas of implementation of the same contributing to Urban Planning and Environmental Zoning of municipalities. Thus, the methods of multi-criterion analysis become quite important and efficient for obtaining better results leading the decision maker to better decision.

Through the establishment of the four criteria considering the environmental, economic and social means, it was possible to obtain the four alternatives, having as a result of the best area Alternative 3, in which is located 900 meters from bodies of water and population centers, has agricultural potential 4 and accessibility considered intermediate.



The sensitivity analysis proved to be concrete, where even in the change of weights, the alternative chosen remained unchanged, modifying only the ordering of the alternatives.

In this way, the present research has a positive impact factor gaining importance and relevance for the regional development as well as for the sustainable development of the municipality of Canindé.

REFERENCES

ABRELPE. **Panorama dos Resíduos Sólidos no Brasil 2020**. Associação Brasileira de Empresas de Limpeza Pública e Resíduos Especiais. Ed. Grappa, São Paulo, 2020.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. 2004. **Resíduos sólidos - classificação: NBR-10004**. Rio de Janeiro: ABNT 63p.

ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS. NBR 13896. **Aterros de resíduos não perigosos – Critérios para projeto, implantação e operação**. Rio de Janeiro. 1997. 13 p.

BONINI, A. C. et al. Um estudo teórico sobre a história da pesquisa operacional. **Cadernos de Artigos Científicos e Resumos Expandidos**, Curitiba, v. 1, n.4, p. 1666-1670, jun. 2016. Disponível em: <https://bit.ly/3FmbMjG>. Acesso em: 12 jan. 2023.

BRANS, J. Ethics and decision. **European Journal of Operation Reserach**, v. 136, p. 340-352, 2002.

BRASIL, Lei Nº 12.305 de 02 de agosto de 2010 - **Política Nacional de Resíduos Sólidos (PNRS)**.

CAMPOS, Vanessa Ribeiro. **Modelo de apoio à decisão multicritério para priorização de projetos em saneamento**. Universidade de São Paulo, 25 de novembro de 2011. DOI.org (Crossref), <https://doi.org/10.11606/T.18.2011.tde-08022012-104925>.

DE SOUZA, D. L. A.; SOBRAL, M. do C. M.; DA PAZ, D. H. F. **PROPOSTA DE UMA METODOLOGIA ADAPTADA PARA A DISTRIBUIÇÃO DOS RECURSOS DO ICMS SOCIOAMBIENTAL REFERENTE À PARCELA DE RESÍDUOS SÓLIDOS EM PERNAMBUCO**. Revista de Gestão Social e Ambiental, São Paulo (SP), v. 17, n. 3, p. e03422, 2023. DOI: 10.24857/rgsa.v17n3-001. Disponível em: <https://rgsa.emnuvens.com.br/rgsa/article/view/3422>. Acesso em: 13 out. 2023.

ENVIRONMENTAL PROTECTION AGENCY - EPA. Disponível em: <www.epa.gov>. Acesso em: 12 jan. de 2023.

GONZAGA, N. da C.; SILVA, R. N. da; ANDRADE, L. P. de. **Gerenciamento de Resíduos do Óleo Lubrificante: Uma Revisão Sistemática da Literatura**. Revista de Gestão Social e Ambiental, São Paulo (SP), v. 15, p. e02812, 2021. DOI: 10.24857/rgsa.v15.2812. Disponível em: <https://rgsa.emnuvens.com.br/rgsa/article/view/2812>. Acesso em: 13 out. 2023.

MACEDO, M. A. A. P. T. et al. Educação ambiental e resíduos sólidos urbanos: caminho para um futuro sustentável. **EduSer-Revista de educação**, v.7, n. 2, p. 41-57, 2015.



INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). **Censo Brasileiro de 2010**. Rio de Janeiro: IBGE, 2012. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE).

INSTITUTO DE PESQUISA E ESTRATÉGIA ECONÔMICA DO CEARÁ. **Perfil Básico Municipal 2017 Canindé: IPECE**, 2017.

INSTITUTO DE PESQUISA E ESTRATÉGIA ECONÔMICA DO CEARÁ. **Perfil Básico Municipal 2019 Canindé: IPECE**, 2019.

INSTITUTO NACIONAL DE METEOROLOGIA DO BRASIL – INMET. **Normais Climatológicas (1961/1990)**. Brasília - DF, 1992.

NASCIMENTO, V. F. et al. **Evolução e desafios no gerenciamento dos resíduos sólidos urbanos no Brasil**. Revista Ambiente & Água, v. 10, n. 4, p. 889-902, 2015

ROY, B. **Multicriteria methodology for decision aiding**. Netherland: Kluwer Academic publishers, 1996.

SISTEMA NACIONAL DE INFORMAÇÕES SOBRE SANEAMENTO – SNIS. **Diagnóstico dos serviços de água e esgotos. Site institucional, 2021**. Disponível em: <http://antigo.snis.gov.br/downloads/diagnosticos/rs/2020/DIAGNOSTICO_TEMATICO_VISAO_GERAL_RS_SNIS_2021.pdf>. Acesso em: 12 jan. de 2023.