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ARTICLES

THE COMBINED USE OF VALUE-FOCUSED THINKING AND THOR 2 TO CHOOSE A BIODIGESTER IN A BRAZILIAN PUBLIC UNIVERSITY

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ABSTRACT. There are liabilities for society because of the increase in the amount of waste. This work will choose a biodigester to treat organic waste at Universidade Federal Fluminense. For this, the VFT approach was used to structure the problem and the multicriteria decision support method THOR 2 was used to choose the option that has the most excellent preference considering three scenarios. The experts say that six criteria can be used to choose a biodigester, namely Capacity, Input of organic matter, Input of water, Average expected production of biogas and average output of biofertilizer. The research showed that biodigester 7 had the best performance as a result. The relevance of the study refers to the contribution to the reduction of organic solid waste in the environment. This research applies THOR 2 method in a new context.

Keywords: Circular Economy, VFT, THOR 2.

1 INTRODUCTION

The increase in consumption has caused some problems, one of which is an unbalanced environment. This is due to the inability to generate resources at a speed compatible with what humanity uses for consumption. (Vieira, 2018). Companies employ a management practice model to manage demand processes, operations, and assets (De Barros et al., 2015).

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The concern regarding the damage caused by man to the environment also grew, and one of the concepts of sustainability became the form of development that meets the population's current needs without compromising those of future generations (WCED, 1987).

According to Cruz (2005), the dumping of waste in an inappropriate location generates pollution (water, soil, and others) that simultaneously causes environmental degradation and corroborates epidemiological aspects due to some components present in these wastes attracting macro vectors (flies, cockroaches, rats, pigs, dogs, vultures) and micro vectors (bacteria, fungi, and viruses), being pathogenic, that is, causing diseases and harm to man.

Even though there are considerable challenges to be solved, Higher Education Institutions (HEIs) are essential in the sustainable development process as they shape thought and opinion and can intensify the creation and dissemination of information (Leal Filho et al., 2015).

Sustainability in organizations is important, including in public administration, with environmental education at all levels of education as a key factor so that the State can develop sustainable actions. The importance of HEIs is highlighted, due to their specificity in the development and dissemination of knowledge (Almeida, 2015).

Sales (2017) also states that in Brazil wastepaper, plastic, and metal, for example, are largely recycled and/or reused, which does not occur with organic waste, which is placed inappropriately in the environment.

Considering the amount of waste generated by public universities, this work focuses on choosing a suitable biodigester for Universidade Federal Fluminense.

To support the analysis, decision-making methods were used to support the systematization of the process. The AHP methods (Saaty, 1990), TOPSIS (Hwang et al., 1993), MACBETH (Bana and Costa et al., 1995), THOR (Gomes, 1999, Gomes et al., 2010), THOR 2 (Tenório et al., 2021) are examples of multicriteria methods.

Among the existing methods, the research was carried out using the Value-Focused Thinking (VFT) approach and the THOR 2 method.

No papers about sustainability that used the combination of the VFT approach and the THOR 2 method were found. Thus, this combination is original and can be compared with the combination of other methods and approaches.

The VFT approach, according to Keeney (1992), is an approach that represents value-focused thinking for structuring problems, it can capture the values and objectives of individuals.

The THOR 2 method was applied because all the uncertainty present in the attribution of the classifications of the alternatives and the weights is quantified (Tenório et al., 2021). This method is used when the decision maker wants to measure, by fuzzy numbers, the certainty of the available data or the weight assigned to the criterion. Using algorithmic hybridity and the ability to eliminate redundancies and quantify imprecision, it combines theories from the American and French schools. For this reason, the method was chosen.

This paper shows a combination of VFT and Multicriteria Decision Method (THOR 2). Sections 2.1 and 2.2.1 expand on this explanation.

This paper is organized into six sections: 1- Introduction, 2- Theoretical Framework, 3- Methodology, 4- Results and Discussion, 5- Conclusion, and 6 - References. In addition to this first introductory section, section 2, Theoretical Framework, presents the topic in a more specific way. Section 3 presents all the methodologies used in the research. In section 4, you can find the research results and the discussion linked to these results. Later, in section 5, the paper is concluded. And finally, in section 6, you can find the references used in the work.

2 THEORETICAL FRAMEWORK

According to Albuquerque and Coluna (2018), organic waste, when placed in dumps or landfills, suffers the action of bacteria that generate methane, a process called methanization. However, methane gas generates harmful effects on health and the environment, considered a greenhouse gas, with a capacity 28 times greater than that of CO2.

One of the ways to minimize the emissions of this gas in landfills is the use of a system for capturing and burning the gas or using biogas for energy (Albuquerque and Coluna, 2018).

In higher education institutions, actions on sustainability are increasingly connected with the public and private sectors and occur through isolated actions with the participation of the academic community and the population (Huge et al., 2018).

At the Federal University of Campina Grande (UFCG) there was research in which the objective was to evaluate the reaction of the stages in the anaerobic digestion process, mainly in swine manure and food residues (Sales, 2017).

2.1 VFT Approach

The VFT has four procedures that enable and assist in the use of the method, they are: identify the objectives; classify goals (as means or ends); build alternatives; and examine objectives to identify decision opportunities (Keeney, 1996).

Using the techniques in Table 1, it is possible to create a list of essential goals and a basis for future observations that are expected to take place. This list may initially contain items that are not necessarily objective and may include alternatives, restrictions, and criteria. Therefore, each item will either be transformed into objectives or removed from the list, as they are both means and fundamental (Keeney, 1996).

Table 1 – Techniques for identifying objectives.

Nº	Techniques	Possible questions
1º	Elaborate on a Wish List	What do you want? What do you value?
2º	Identify Alternatives	What would be a perfect alternative, a terrible and a reasonable one? What is good or bad about each one of them?
3º	Identifying problems and weaknesses	What's right and wrong about the organization? What needs to be fixed?
4º	Predict consequences	What happened that was good and bad? What is your concern about what might happen?
5º	Check goals, restrictions, and directions	What are your aspirations? What limitations are placed on you?
6º	Evaluate multiple perspectives	What are your aspirations? What limitations are placed on you?
7º	Define strategic objectives	What are your ultimate goals? What are your core values?
8º	Establish generic goals	What goals do you have for your customers, employees, shareholders, and yourself? What environmental, social, economic, health, and safety objectives are important?
9º	Finding structural goals	Follow means-ends: why is this goal important and how can you reach it? Specify: what do you mean by this objective?
10º	Measure goals	How do you assess the achievement of this objective? Why is goal A more important than goal B?

Source: Keeney (1996).

2.2 Multicriteria decision support

Real-world decision problems are rarely using a single criterion. They generally involve a variety of criteria, often contradictory. In many practical situations, alternatives must be ranked given multiple, conflicting criteria of preference (Gomes et al., 2020).

Multicriteria decision-making is applied to select, rank, sort, or describe the alternatives in a complex decision-making process with multiple criteria and conflicting objectives (Silva et al., 2018).

The literature presents several applications combining Multiple Criteria Decision Analysis (MCDA) methods to support the decision-making process in personnel selection problems, in most cases applying a method to obtain the weights of the criteria and another one to evaluate the alternatives, taking advantage of each method's characteristics (Costa et al., 2021).

MCDA describes a set of formal approaches that seek to take explicit account of multiple criteria in helping stakeholders and groups explore decisions that matter. Despite the diversity of MCDA approaches, methods, and techniques, the basic ingredients of MCDA are a finite or infinite set of actions (alternatives, solutions, courses of action, etc.), at least two criteria, and at least one Decision-Maker (DM) (Costa et al., 2022).

MCDA seeks to assist in resolving issues that require a complex decision-making process by providing tools to managers; that is, multicriteria decision-making problems (Gonçalves et al., 2021). The Multicriteria Approach has a set of methods developed to support and guide the decision-makers when evaluating the alternatives according to a variety of criteria.

The Multicriteria methods can be classified as compensatory (AHP, MAUT, MACBETH) and no compensatory (ELECTRE Family for example) (Costa et al. 2021, 2022).

2.2.1 THOR 2

According to Gomes (1999) and Gomes et al. (2010), three scenarios need to be evaluated, given alternatives a and b, when using the THOR method, so that an alternative is perceived as better. For the review of each scenario, it is necessary to use the preference relations equations presented below (1)(2)(3):

$$aPb \leftrightarrow g(a) - g(b) > + p \tag{1}$$

$$aIb \leftrightarrow -q \leq g(a) - g(b) \leq +q \tag{2}$$

$$aQb \leftrightarrow q < g(a) - g(b) \leq p \tag{3}$$

Equation (1) illustrates a strict preference relationship (P) of one alternative over the other. Equation (2) presents a relationship of indifference between one alternative and another (I). And equation (3) exposes a weak preference relation (Q) of one alternative compared to another. The equations also contain the incomparability of one option to another (aR_jb). To quantify the alternatives, we will use the equations (4) presented below, for each of the scenarios (S_1, $S_{2,}$ and S_3). Each scenario is a different sorting algorithm, which allows the decision-maker to conduct a sensitivity analysis comparing the three results.

$$S1: \sum_{j=1}^{n} (\omega_j \mid aP_jb) > \sum_{j=1}^{n} (\omega_j \mid aQ_jb + aI_jb + aR_jb + bQ_ja + bP_ja) \tag{4}$$

$$S2: \sum_{j=1}^{n} (\omega_j \mid aP_jb + aQ_jb) > \sum_{j=1}^{n} (\omega_j \mid aI_jb + aR_jb + bQ_ja + bP_ja) \tag{5}$$

$$S3: \sum_{j=1}^{n} (\omega_j \mid aP_jb + aQ_jb + aI_jb) > \sum_{j=1}^{n} (\omega_j \mid aR_jb + bQ_ja + bP_ja) \tag{6}$$

Source: Tenório et al. (2021).

In the S_1 scenario, the alternatives will only have their attractiveness scored in cases where equation (1), aPb, occurs. In the S_2 scenario, more flexible than S_1 and more rigorous compared to S_3, the alternatives will only present a point of attractiveness where equations (1) and (3), aPb or aQb will take place. Scenario S3, which is the least rigorous of the above scenarios, includes all the equations shown in equation 4, aPb and aIb, and aQb.

As reported by Gomes (2005), considering the state of the art in MDM (Multicriteria Decision Making), THOR made the following contributions:

- Features a hybrid algorithm that simultaneously combines concepts from Approximate Set Theory (ACT), Fuzzy Set Theory, Utility Theory, and Preference Modelling.
- Sorts discrete alternatives in transitive or non-transitive decision-making processes.
- Eliminates redundant criteria, simultaneously considering whether the information is dubious (use of ACT) and whether there is an increase in imprecision in the decision process (use of fuzzy set theory).
- Quantifies imprecision and uses it in the MDM decision process.
- Allows the simultaneous entry of data from multiple decision makers, allowing them to express their value judgment (s) in a scale of ratios, intervals, or ordinal.
- The new formula used by THOR (to assign weights in the ordinal scale) was obtained after studying the three existing formulas in the literature.
- The decision maker can also execute the decision process without assigning weights to the criteria.
- Eliminates the need for some algorithms that rely on preference modeling to determine a value, usually arbitrary, for agreement.

3 METHODOLOGY

The research used the VFT and THOR 2 multicriteria decision support methods.

The VFT approach was chosen because it considers the intrinsic values of the organization, which does not necessarily occur in other Problem Structuring Methods (PSM), such as the Soft System Methodology (SSM) or the Strategic Options Development Analysis (SODA).

Real-world decision problems are rarely based on a single criterion. They generally involve a variety of criteria, often contradictory. In many practical situations, alternatives must be ranked given multiple, conflicting criteria of preference (Gomes et al., 2020). In the first phase of the VFT approach, an interview was conducted with a specialist with approximately 8 years of experience in biodigesters. In this first stage, we sought to understand what these professionals value

and consider essential characteristics for acquiring biodigesters. The questions, adapted from Table 1, in section 2.1, are part of the theoretical framework that explains the VFT approach. The questions (interview) are presented in Table 2.

Table 2 – Interview questions with the biodigester expert.

What do you look for/value in a biodigester?
What would be the characteristics of a perfect and reasonable biodigester?
What would be the differences between the ideal biodigester and those existing at the university?
What limitations would be placed on the acquisition of a biodigester?
What are your ultimate goals when purchasing a biodigester?
Why are they important? How to achieve these goals?
What is the order of importance of these goals?

Source: Authors (2021).

The result of the expert interview using Table 2 is illustrated in Figure 1 of Section 4. This result served as the basis for creating the criteria set used in the analysis.

A similar set of criteria were found in the academic research by Moreira (2017), a study carried out with a focus on one of the university restaurants at the *Universidade Federal Fluminense*, but without using a multicriteria method to support decision-making.

Specialists (experts) confirmed secondary data. Consequently, these data were used in the analysis and can be seen in Table 3, Section 4.

After choosing the criteria, the THOR 2 method is started, considered a hybrid multicriteria decision support method (Tenório et al., 2021), where the values of their weights, preferences, indifferences, and disagreements were given by the specialist and can be found in Table 6, in Section 4, results and discussion.

These values mentioned above were placed in the THOR WEB software and used to analyze the option that best fits the choices made by the specialist.

4 RESULTS AND DISCUSSION

Figure 1 illustrates how the means, fundamental and strategic objectives for the questions in Table 2 were derived from the questions presented in Table 2.

An interview with the specialist was conducted before the construction of Figure 1 above, and then she validated it.

Thus, for the analysis, we chose the criteria listed in Table 3.

Table 4 contains data provided by the author due to non-mandatory criteria units. It is possible to visualize the captions of the figures indicated in Table 3 for better understanding.

It is possible to notice that, depending on the criterion in Table 3, the figures with captions in Table 4 indicate that the criterion must be of a higher or lower value to reach the objective.

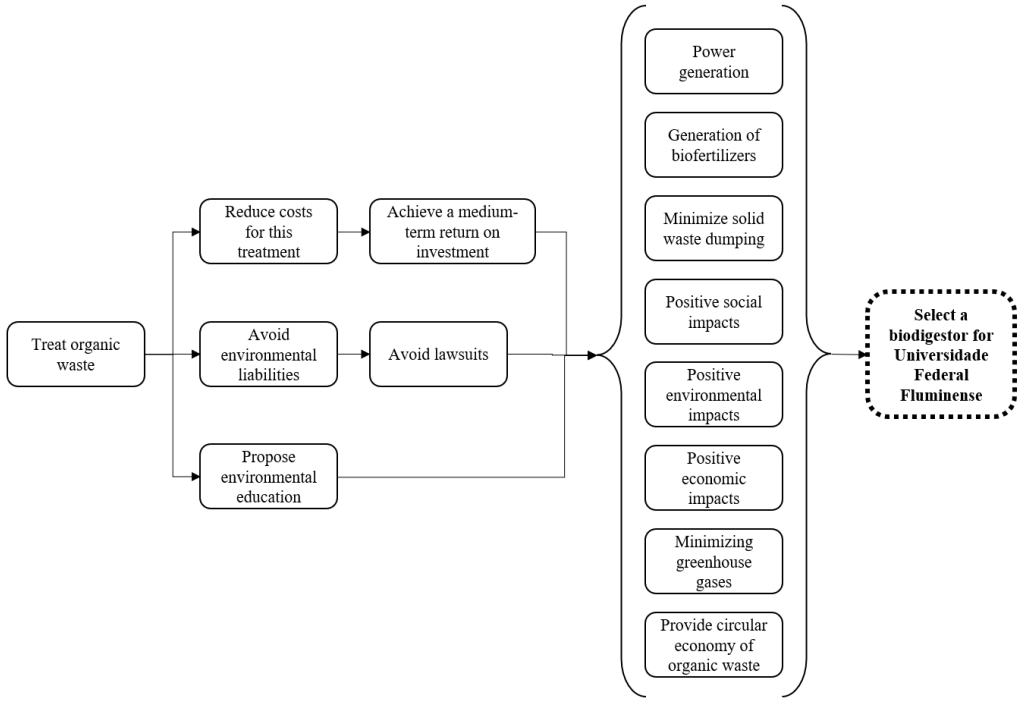

Figure 1 – Means-end goal network.

Source: The Authors (2021).

Table 3 – Criteria for evaluation and decision making.

Criteria	Measures	Unit	Goal
Capacity	The total volume that the biodigester holds	L	↑
Organic matter input	The total amount of organic matter that the biodigester can process per batch	kg	↑
Water input	The total amount of water needed by the biodigester to process organic matter	L	↓
Average expected biogas production	The average daily amount of biogas generated by the biodigester from the decomposition of the amount of organic matter supported by its capacity	m3 /day	↑
Average biofertilizer production	The average monthly amount of biofertilizer generated by the biodigester from the decomposition of the amount of organic matter supported by its capacity	L/month	↑
Price	Biodigester acquisition cost	R$	↓

Source: Adapted Moreira (2017).

Table 4 – Legend of the figures indicated in the objective column of each criterion.

↓	Cost monotonic - the lower the value, the better.
↑	Profit Monotone - The higher the value, the better.

Source: Authors (2021).

Table 5 shows the decision matrix. The criteria were found in the work of Moreira (2017) and confirmed in the interview with the specialist.

Table 5 – Decision Matrix.

Biodigester	**Criteria**					
	Capacity	**Organic matter input**	**Water input**	**Average expected biogas production**	**Average biofertilizer production**	**Price**
1	10,000	150	150	5	113	8,950
2	10,000	150	150	5	113	5,900
3	5,000	75	75	2.5	4,500	6,850
4	5,000	75	75	2.5	4,500	3,800
5	5,000	75	75	1.5	3,500	2,779
6	7,500	113	113	2.25	5,250	3,223
7	10,000	150	150	3	7,000	3,644

Source: Adapted Moreira (2017).

Table 6 shows the weight, preference threshold (p), indifference threshold (q), and disagreement (d) of each criterion:

Table 6 – Evaluation Criteria Weights.

Criteria	Capacity	Organic matter input	Water input	Average expected biogas production	Average biofertilizer production	Price
Weight	8	8	5	7	6	5
P	2,500	50	50	1	500	1,000
Q	1,000	30	30	0.5	200	500
D	20,000	300	300	12	10,000	15,000

Source: Authors (2021).

These weights, preferences (p), indifferences (q), and disagreement (d) of each criterion present in Table 6 above, chosen by the specialist, were placed in the THOR WEB software and used to analyze the option that best suits the choices made by is it over there. The parameters shown in Table 6 were obtained after consultation with specialists. THOR and THOR 2 use three sorting algorithms (S_1, S_2, and S_3). The comparison of these three results allows a sensitivity analysis.

In Table 7, the results obtained using the multicriteria decision support method software, THOR, are presented.

Table 7 – Results obtained with the THOR method.

Position	S_1	S_2	S_3
1ª	Biodigester 1 – 4.038	Biodigester 7 – 4.511	Biodigester 1 – 5.173
2ª	Biodigester 7 – 3.951	Biodigester 1 – 4.384	Biodigester 7 – 5.017
3ª	Biodigester 2 – 3.91	Biodigester 2 – 4.256	Biodigester 2 – 4.818
4ª	Biodigester 6 – 3.0	Biodigester 6 – 2.454	Biodigester 6 – 2.718
5ª	Biodigesters 3,4,5 – 1.5	Biodigesters 3, 4 – 1.132	Biodigester 3 – 2.0
6ª		Biodigester – 0.0	Biodigester 4 – 1.773
7ª			Biodigester 5 – 0.0

Source: Authors (2021).

And Table 8, presents the results using the multicriteria decision support method software, THOR 2.

Table 8 – Results obtained with the THOR 2 method.

Position	S_1	S_2	S_3
1ª	Biodigester 7 – 3,685	Biodigester 7 – 3,993	Biodigester 7 – 4,861
2ª	Biodigester 2 – 3,274	Biodigester 2 – 3,483	Biodigester 2 – 4,097
3ª	Biodigester 1 – 3,27	Biodigester 1 – 3,357	Biodigester 1 – 3,744
4ª	Biodigester 6 – 3,101	Biodigester 6 – 2,347	Biodigester 6 – 2,657
5ª	Biodigesters 4 e 5 - 1,5	Biodigesters 3, 4, 5 – 1	Biodigester 4 – 1,825
6ª	Biodigester 3 – 1,0		Biodigester 3 – 1,598
7ª			Biodigester 5 – 1,088

Source: Authors (2021).

The results in Tables 7 and 8 were generated so that in the most rigorous scenario (S_1), biodigester 7 (THOR 2), and biodigester 1 (THOR) were the best options.

In scenario S_2, more flexible than S1, biodigester 7 was in the first position.

In the most flexible scenario of all, scenario S_3:

In the first dominant group, both methods (THOR and THOR 2) agree that Biodigesters 1, 2, and 7 are the best.

The second dominant group is formed by Biodigester 6 (it ranked fourth in both methods).

The set that follows is formed by Biodigesters 3 and 4.

And the group formed by Biodigester 5, which in both methods was in last place.

5 CONCLUSION

Since no sustainability document using a combination of VFT and THOR 2 has been found, this study seems original.

The VFT approach was chosen, as already mentioned because it represents a way of thinking focused on values to structure problems and one of the main advantages of its use is that it helps to identify better alternatives and reveal objectives and attributes that were not known or that had not been thought yet.

The THOR 2 method was used because it is a relatively new method where all uncertainty is quantified. As a result, it is a complete method that incorporates theories from both the American and French schools. It has a hybrid algorithm and can eliminate redundancies and quantify inaccuracies.

The THOR 2 method with the VFT approach, used for the analysis, proved to be effective for the article to reach its objective. It was possible to reduce the subjectivity of the criteria so that an analysis could be performed.

It was observed that the placement of biodigesters occurred with the criteria chosen and the weights given by the specialist, which means that the order of choice can be modified depending on the decision maker.

THOR 2 uses three algorithms to compare the results (S_1, S_2, and S_3), the comparison of the three allows a sensitivity analysis of the results.

In this case, biodigesters 1, 2, and 7 obtained the highest score in situations S_1, S_2, and S_3, proving are the most appropriate options.

Furthermore, if the location of the choice was different, with a different structure, the biodigester model chosen as the most appropriate option might be another.

For future studies, it is suggested that there be a comparison of this result with other combinations of methods and approaches.

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