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Multi-criteria Decision Support Method AHP-TOPSIS-2N applied in bids to improve the control of public expenses

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Abstract

Everywhere in the world, in various scenarios and situations, it is necessary to deal with the need to make decisions. In the context of public management, this need is often seen. However, this process is not always finished with satisfactory and positive results. It was proposed to use the hybrid method to support decision-making AHP-TOPSIS-2N, which is the combination of the AHP (Analytic Hierarchy Process) method with the TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) method to assist the decision maker to improve the control of public spending. Several studies were presented that prove the veracity and effectiveness of the method being used in different contexts. The present study proved to be effective in presenting the method as a great tool that can assist public management in the bidding processes, and thus ensure results with greater transparency and effect, in addition to presenting to society favorable results with the use of this systematized and structured method.

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Keywords: Multicriteria method; Bidding; Public Management; AHP-TOPSIS-2N; Decision Making.

1. Introduction

The decision-making process can be understood as a consequence of a preference for the best option among the possibilities through a person or group, which, in turn, receives the denomination of decision-maker [1].

The need to make a decision, for the most part, is due to a problem situation that has at least two circumstances that differ from each other and more than one possibility of solution [2].

To facilitate this process, the so-called Multiple Criteria Decision Method (MCDM) is used. These are methods that can assist decision-makers in the context of doubts and complexities, each with its specificities and limitations [3–6].

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The public administration is faced with scenarios in which it needs to make major decisions because it concerns the contracting of works, services, purchases, and sales with public money, and, often, these decisions are immersed in a complex context, involving doubts and different possibilities of a solution.

The search for new solutions that achieve effective results in these processes leads to the study of new methods and work in the area [7].

Multicriteria methods to support decision-making can be great allies of public agencies to facilitate decision-making and thus, with the best solution, bring better results and numbers about bids, for example.

Among the wide range of multi-criteria methods in the literature, the hybrid method AHP-TOPSIS-2N was chosen, which is a combination of the AHP methods – Analytic Hierarchy Process (Hierarchical Analysis Method) and the TOPSIS-2N method, which stands for Technique for Order Preference by Similarity to Ideal Solution.

The objective of the work is to assist the bidding process of great importance, in which the main purpose is to assist the decision maker in choosing a better proposal, in which several criteria will be considered and analyzed by an expert, and the decision will be based only on mathematical models. As a result, the verdict is accurate and impartial without the influence of personal preferences.

The proposal is based on the aid to the bidding process of relevant importance, in which its objective is to assist the decision maker in choosing the best proposal, in which several criteria will be considered and weighted by a specialist, in which the decision will be based only on mathematical models, resulting in a precise and impartial verdict.

Among the expected benefits is greater efficiency of the department responsible for the bids and a better use of public money because the mathematical models bring a result based on importance distributed by the experience of a specialist, resulting in a more effective and satisfactory result.

Knowing the need and relevance of bidding processes, decision-making obtains a primary function in its procedures, considering that a mistake or mistake during this process can cause many problems and inconvenience to the server member of the bidding commission, such as fines and other penalties [8].

2. Theoretical Reference

Discussions about public spending are raised in every part of the world, especially about the conditions that every public agency must have to promote the improvement of the quality of spending [9]. Thus, one of the most addressed themes in the context of public management of countries is bids due to the representativeness of financial volume disbursed by governments [10].

According to Costa [11], the bidding process is preceded by the execution of government contracts. This process aims to respond to public administrations at the federal, state, district, and municipal levels, in addition, the administrations of the Legislative, Executive, Judiciary, Courts of Auditors, and the Public Prosecutor's Office are also encompassed [12].

One can consider the use of mathematical models through Multi-criteria methods to assist the decision-maker in the procedures of public spending, as it is a more assertive way to ensure better results and more favorable solutions [13, 14].

Considering systematic methods for the decision-making process is of great relevance because, even if decision-makers believe in their instincts and understandings (based on their a priori experience), there is still a divergence between instinct and thinking capacity [15].

That is, as much as decision-makers have an impulse to choose by instinct, they value and appreciate data that is valuable and convincing for their decision-making [16].

Thus, it is up to the decision analysis process, above all, as a tool to assist the decision agent [17].

This fact can be applied to the bidding process since it has as its principles transparency, efficiency, speed, and isonomy, seeking to combat corruption and favoritism based on personal interests [18]. Thus, using Multi-

criteria methods ensures that the decisions made have a more systematized, impartial, and qualified character since it discards any interference with human preferences.

2.1 Multi-criteria Methods to Support Decision Making

Multi-criteria approaches consist of ways to model decision processes, in which there is a need for a decision to be made, as well as unknown situations that are capable of shaking the results, possible courses of action, and the result itself, in this way, are quite relevant approaches, especially in scenarios in which there are conflicts between decision-makers or even when the perception of the problem is not completely defined [19].

Several Multi-criteria methods of decision support are available and are extensively explored in the literature. Among such methods, the one chosen for the proposal was the hybrid method AHP-TOPSIS-2N which is a junction of the AHP methods – Analytic Hierarchy Process method, being one of the first methods designed to solve decision problems with multiple quantitative and qualitative criteria, and the TOPSIS-2N method which stands for Technique for Order Preference by Similarity to Ideal Solution, in which it evaluates performances of alternatives through the similarity of the same with an ideal solution working, in this variation, with elliptical distances.

The AHP method was proposed by Thomas L. Saaty [20] that aims at the selection/choice of alternatives within a process that encompasses multiple criteria. The method is based on the dissolution and synthesis of the relationships between the criteria according to a scale, as illustrated in Table 1, until the prioritization of its indicators is obtained, making the results come closer to the best single performance measurement response [20].

Table 1. Performance scale

Intensity of Importance	Definition	Explanation
1	Equal importance	The two activities contribute equally to the objective
3	Weak importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another.
7	Very strong importance	One activity is very strongly favored over another; Their domination of importance is demonstrated in practice
9	Absolute importance	The evidence favors one activity over another with the highest degree of certainty
2, 4, 6, 8	Intermediate values	When looking for a compromise condition between two definitions

The AHP is based on a process of active weighting, in which the various important criteria are represented through their relative importance [20]. AHP has been widely used by academics and professionals, especially in applications involving financial decisions associated with non-financial attributes [20].

In addition, the AHP is a method of hierarchical evaluation of criteria with applicability in different sectors of the social sciences, mainly because it provides that analyses with qualitative and subjective character are operationalized through numerical properties [21].

The fundamental concept of AHP is to transform system studies into sequences of comparisons to peers, to minimize failures [22, 23].

The method is based on three principles: (1) construction of hierarchies, (2) definition of priorities, and (3) logical consistency [24].

In the first principle, it is necessary to define the objective, the criteria, and the alternatives. In the second principle, it is necessary to satisfy steps such as parity judgments (to judge peers by pairing each element of a level of the hierarchy in the light of each element in connection at a higher level [25]. In the third principle, the AHP method proposes to calculate the Consistency Ratio of the judgments, denoted by CR = CI/IR, in which RI is the Random Consistency Index achieved for a reciprocal matrix of order n, with non-negative components and

randomly generated. The Consistency Index (CI) is given by CI = (λ max –n)/(n-1), where λ_{max} is the largest eigenvalue of the judgment matrix. According to Saaty (2000), the condition of consistency of the judgments is RC ≤ 0.10.

The great benefit of the AHP method is to enable its users to assign relative weights to multiple attributes or multiple alternatives to a given attribute while performing a peer-to-peer comparison between them [20].

Thus, it is possible that, even when two attributes are divergent, human understanding can identify which of the attributes is more relevant to the decision-making process [26].

The TOPSIS method, in turn, provides adherence to a non-restricted portion of criteria to evaluate a non-restricted amount of alternatives [27].

This method was created by Hwang and Yoon [28] and has become a method of great knowledge and its use is related to the evaluation of the performance of the alternatives through the similarity of the same with the ideal solution [28].

The method stands out for offering benefits such as rationality that portrays the principle of human choice; value on a scale that symbolizes the best and worst alternatives simultaneously; simple computing methodology having the possibility of programming in a spreadsheet of uncomplicated format, and the possibility of visualizing the performance measures of the criteria alternatives in a polyhedron, at least for any two dimensions (SHIH, 2007).

Thus, the best alternative is the one that is closest to the positive ideal solution (PIS) and farthest from the non-ideal or, also called, negative ideal (NIS) [29].

It is understood that the positive ideal solution is the same one that improves the opportune criteria and reduces the cost criteria, that is, the solution is composed of the best attainable values of the benefit criteria and the worst attainable values of the cost criteria [30].

According to Barbosa [31], one of the great advantages of the method is the adaptation to problems with a high number of criteria and alternatives, especially when the criteria are quantitative.

2.2 AHP – TOPSIS – 2N

The AHP – TOPSIS – 2N method consists of a hybrid method between the AHP method and the TOPSIS-2N method developed due to a collaboration between the Military Institute of Engineering (IME), the Center for Naval Systems Analysis (CASNAV) and the Fluminense Federal University (UFF) [32].

AHP–TOPSIS–2N performs two normalization mechanisms throughout its execution [33].

The method, although recent, has already been used in different scenarios and has presented favorable and positive results, such as when Costa et al. (2020) took advantage of the AHP-TOPSIS-2N method as a form of selection strategy for an attack helicopter for the Marine Corps (CFN). It was also used by Moreira et. al. [1] for the choice of the urban transport system in the municipality of Magé in Rio de Janeiro.

We can also mention the use of the method to select the best oil well configuration for the development of a field proposed by Colombo, Maêda [34]. In this study, the authors predetermined three configurations by multidisciplinary teams, namely: geology, reservoir, elevation and flow, subsea systems, drilling, etc., and the AHP-TOPSIS-2N method defined the best configuration to be used. The method was then able to help the company determine the improved alternative according to the criteria stipulated by the multidisciplinary group of decision-makers.

All applications of the method proved to be effective and favorable so that they helped the decision makers in a solution. The results of the study by Souza et al. [35], for example, revealed the potency of the hybrid method to deal with issues of prioritization of investment projects.

In the area of technology and safety, the use of the hybrid method is also of great relevance. Studies such as that of Oliveira [36], with the application of the method for prioritizing vulnerabilities in the development of

cybersecurity solutions, generated a result of the best vulnerability to be prioritized among those that were previously cataloged.

To apply the method, some steps are necessary as explained by Costa, Santos, and Gomes [11], namely:

1. Determination of the Decision Matrix: Expresses the score of each alternative referring to each criterion, demonstrating how much the alternative influences or is influenced by the others;

2. Determination of the Weighting Matrix: The fundamental scale of Saaty is used, and through a multidisciplinary group each criterion is evaluated against each criterion;

3. Determination of the weight of each criterion: by applying the AHP method. It is important to evaluate the consistency ratio and if it is greater than 0.1 perform a new evaluation of the criteria and a new weighting matrix;

4. Normalization of the Decision Matrix: in the case of the AHP-TOPSIS-2N method, two different normalizations are used [27].

5. Construction of the Weighted Normalized Decision Matrix: the matrices weighted by the 1st and 2nd normalization are weighted using the weights obtained in step 3;

6. Determination of the Positive Ideal Solution (SIP) and the Negative Ideal Solution (SIN);

7. Calculation of distance measurements: Euclidean distance measurements of each of the alternatives are achieved about SIP and SIN;

8. Calculation of the proximity relative to the ideal alternative: it is obtained by the ratio R equal to the distance to the SIN point by the sum of the distance to the SIP point and the distance to the SIN point.

9. Sorting of preferences.

3. Case Study

To exemplify practically how the hybrid method AHP-TOPSIS-2N can be advantageous and of great relevance in the decision-making process in the bidding procedures, a fictitious scenario of the acquisition of vehicles for public health was proposed. The criteria chosen for the evaluation were: price, consumption, maximum speed, power, and comfort. The comfort criterion is measured on a scale between 1 and 10, where 1 is very bad, and 10 is very good. The price criterion is monotonic of cost, that is, the lower, the better, while the other criteria are monotonic of profit, that is, the higher, the better.

The alternatives chosen were vehicles A, B, and C, in an illustrative way, since, for a more robust analysis, it is necessary to use other significant criteria that are not listed in the present work.

The authors used the web tool HYBRID TOPSIS CALCULATOR [33] to perform the necessary calculations and obtain assertive results. The tool also has the option of using other variations of the TOPSIS method or other ways of obtaining the weights of the criteria. The use of a Decision Support System (DSS) improves the viability of making possible a correct and trivial implementation of a mathematical model into a problematic situation, exposing the use of numerical and graphical resources [37, 38].

3.1 Decision Matrix

From the criteria and alternatives previously determined, the decision matrix is obtained (Table 2).

Table 2. Decision matrix

	Price (R$)	Consumption (km/l)	Max Speed (Km/h)	Power (CV)	Comfort
Vehicle A	R$320 280.00	15	160	143	8
Vehicle B	R$257 390.00	10	150	130	9
Vehicle C	R$191 737.00	7,8	145	130	5

3.2 Obtaining the weights of the criteria

Initially, the pairwise comparison of the criteria is performed using the AHP method, observing the Saaty fundamental scale. After the parity evaluation by the decision-makers, the evaluation matrix of the criteria was obtained (Table 3).

Table 3. Comparison matrix for criteria

	Price (R$)	Consumption (km/l)	Max Speed (Km/h)	Power (CV)	Comfort
Price (R$)	1	2	1/2	1/3	1/2
Consumption (km/l)	1/2	1	1/3	1/3	1/4
Max Speed (Km/h)	2	3	1	1	1/2
Power (hp)	3	3	1	1	2
Comfort	3	4	2	1/2	1

3.3 Obtaining the Ordinations for the Two Normalizations

Table 4 presents the ordering of the alternatives after the two normalization processes.

Table 4. Cardinal results

1st Standardization			2nd Standardization		
	Classification	Punctuation		Classification	Punctuation
Vehicle A	First	0.6651	Vehicle A	First	0.6260
Vehicle B	2nd	0.3809	Vehicle B	2nd	0.3881
Vehicle C	Third	0.3310	Vehicle C	Third	0.3696

It can be observed from the results that, both in the first and the second normalization, the results were the same, bringing the user greater confidence and security. Vehicle A stood out from the others in its score, while vehicles B and C obtained results close to each other in the first normalization and even closer in the second normalization.

Therefore, according to the analysis using the hybrid method, the best result was obtained from vehicle A, among the others.

4. Final considerations

The present studydemonstrates the great capacity of Multi-criteria methods to make the decision-making process efficient, economical, and more profitable, especially in the area of public procurement.

It is interesting to highlight the benefit of the possibility of combining these methods and, thus, seeking to obtain an increasingly assertive sensitivity analysis, generating more security in the decision-making process since it would be based on more accurate data.

As demonstrated in some studies above by great authors in the area, the use of the hybrid method is quite effective and is of such usefulness in conflict situations in which there is a need for decision-making.

It is important to emphasize that this study is another study that demonstrates how important it is to invest in new studies in the area of public sector procurement using Multi-criteria methods. There is also the possibility of encouraging new procedures in public administration using this methodology.

It can also help the development of a public procurement standard in which there is the possibility of being executed in other public agencies and entities and, in this way, generating improvement in procedures and causing more speed and safety, as well as economy and quality in the services provided to the population.

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