Review Article

Decision-Making Methods in the Public Sector during 2010–2020: A Systematic Review

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The aim of this article is to analyze the scientific developments in public sector decision making during the period 2010–2020, to identify which decision-making methods are preferred in different sectors of the public sector, and to determine which integrated methods are applied in this sector. In total, 468 scholarly articles were selected covering a near comprehensive review of the literature, as described below in the search process. We found that 271 studies utilized a single method, whereas 180 studies utilized integrated methods. Data envelopment analysis (DEA) was the most common, used by 97 studies. However, an analytic hierarchy process (AHP) was utilized by 178 studies when counting both simple and integrated methods. It was shown that single methods were more commonly used in education, environment, health, and public services, and integrated methods were relatively favored in economics/finance, energy, site selection, and waste management. We conclude that multiple decision-making methods are used in the public sector, and during 2010–2020, there has been a tendency to use unified methods in decision-making processes.

1. Introduction

Multicriteria analysis is a set of methods used to evaluate multiple criteria as part of the decision-making process. Several empirical studies have shown that multicriteria analysis constitutes a useful tool for making decisions, as it allows the examination of multiple goals, the use of various formulas and data, as well as the participation of various stakeholders [1]. During the last decade, multiple literature reviews have been published on the methods used for multicriteria analysis. These studies aimed to compare and select the most suitable methods for particular fields. Indicatively, Huang et al. [2] examined more than 300 articles published since 2000 in the field of environmental studies. It was ascertained that there is a significant increase of successful applications of multicriteria analysis methods. Toloie et al. [3] studied 628 scholarly articles from 20 high-ranking journals in order to gather the most recent developments from leading experts in the foundational theories, methodologies, and applications for methods of multicriteria analysis. Darius Danesh [4] studied more than 1,400 articles that examined the application of the eight most popular methods of multicriteria analysis for the evaluation of plans in complex organizations. Diaz-Balteiro et al. [4] assessed 271 scholarly articles that examined the usage of multicriteria decision-making techniques for defining system sustainability through an approach dealing with criteria and indicators. Furthermore, this study confirmed that the usage of multicriteria decision-making techniques that are hybridized with group decision-making techniques is very frequent. Thus, the usage of both techniques for evaluating sustainability issues has increased in recent years. The aim of this hybridization process is to include in the analysis the preferences of stakeholders regarding the indicators that were initially proposed.

It is worth noting that during the last decade, studies have focused on the application of a combination of multicriteria analysis methods, as well as on the inclusion of algorithms in existing methods. Thus, the processes of project assessment can be optimized. Within this framework, literature reviews were implemented regarding unified methods of multicriteria analysis. Namely, William Ho [5]
examined the application of unified AHP methods through a literature review and classification of international journal articles from 1997 up to 2006. Renganath and Suresh [6] presented a comprehensive literature review regarding the selection of suppliers in various fields by integrating fuzzy logic and algorithms in the methods of multicriteria analysis.

The literature review conducted in this article focuses on decision making in the public sector. This study examines the methods and combinations of methods applied in various public sector fields. It was ascertained that there are numerous studies regarding literature review for various decision-making methods in various fields, e.g., an overview regarding decision making regarding environmental issues or for sustainability. This study covers a range of scientific research, which has not been studied extensively, firstly focusing on combinations of decision-making methods, and secondly, on methodologies of decision making in the public sector. Furthermore, studies of the last decade are recorded to examine the developments in decision-making processes. This study aimed to ascertain the scientific developments in decision making in the public sector during the last decade, to identify which decision-making methods are preferred in

| Number of Google search queries with terms used / number of examined articles |
|---------------------------------------------|
| Ahp government 34700 / 400                |
| ahp public 39000 / 400                    |
| Anp government 20100 / 400                |
| anp public 21900 / 400                    |
| Topsis government 17600 / 400             |
| Topsis public 18400 / 400                 |
| Electregovernment 143 / 143               |
| Electre public 226 / 226                  |
| Dea government 51500 / 400                |
| Dea public 72600 / 400                    |
| Dematel government 8340 / 400             |
| Dematel public 9250 / 400                 |
| Vikor government 8260 / 400               |
| Vikor public 9580 / 400                   |
| Ahp - Anpgovernment 12400 / 400          |
| Ahp - Anppublic 1250 / 400                |
| Dea - Anpgovernment 4140 / 400            |
| Dea - Anppublic 4030 / 400                |
| Vikor – Ahp government 5960 / 400         |
| Vikor – Ahppublic 6110 / 400              |
| Anp – Electre government 98 / 98          |
| Anp – Electre public 76 / 76              |
| Ahp – Electregovernment 7070 / 400        |
| Ahp – Electrepublic 7470 / 400            |
| Vikor – Electree government 13200 / 400   |
| Vikor – Electrepubilc 2780 / 400          |
| Vikor – Anpgovernment 3400 / 400          |
| Vikor – Anppublic 3360 / 400              |
| Anp – Topsispublic 6790 / 400             |
| Anp – Topsisgovernment 6660 / 400         |
| Ahp – prometheegovernment 6970 / 400      |
| Ahp – prometheegovernment 6670 / 400      |
| Promethee – Electrepublic 5480 / 400      |
| Promethee – Electregovernment 4420 / 400  |
| Ahp – Topsispublic 16800 / 400            |
| Ahp – Topsisgovernment 15900 / 400        |
| Vikor – Topsispublic 5580 / 400           |
| Vikor – Topsisgovernment 5790 / 400       |
| Topsis – Deapublic 4640 / 400             |
| Topsis – Deagovernment 4720 / 400         |
| Topsis – Electrepublic 5690 / 400         |
| Topsis – Electregovernment 9110 / 400     |
| Anp – Dematelpublic 4620 / 400            |
| Anp – Dematellgovernment 4550 / 400       |
| Ahp – Dematelpublic 5010 / 400            |
| Ahp Dematelegovernment 5060 / 400         |
| Topsis – Dematellgovernment 3870 / 400    |
| Topsis – Dematelpublic 3850 / 400         |
| Vikor – Dematellgovernment 2490 / 400     |
| Vikor – Dematelpublic 2520 / 400          |

From these 18,943 articles we selected 569 articles and examined their abstracts.

From these 569 articles we selected 461 articles as relevant to the scope of the study.

In queries that yielded numerous results the 400 first google search results were examined, as it was ascertained that after that point the findings lose their association with the keyword. In queries that yielded a small number of results, all findings were examined in relation to their title.

Figure 1: Flow diagram of the included studies.
Various public sector fields, and to determine which integrated methods are used in this sector. It is noteworthy that in the present literature, there is no frequent reference to the analysis of the literature of integrated methods, as the introduction of the application of integrated methods is a scientific trend of recent years, in contrast to the past where traditional decision-making methods were used autonomously. In addition, a specialized bibliographic review was conducted on multidecision-making methods applied to public projects and programs.

2. Methods

2.1. Definitions of Examined Methods of Analysis. The following sections present the multicriteria decision-making methods that have been applied more widely in public projects and programs, as shown by the international literature in case studies as well as in literature review studies.

2.1.1. Analytic Hierarchy Process (AHP). AHP is a decision-making process developed by Saaty. It aims to quantify the relevant priorities for a given set of alternatives and emphasizes the importance of the decision-maker’s judgment, as well as the consistency of comparing alternatives in the decision-making process [7].

2.1.2. Analytic Network Process (ANP). ANP is a more general form of AHP, structuring a decision problem as a network, as opposed to a hierarchy. As a multicriteria theory of measurement, its main use is deriving relative priority scales of absolute numbers from individual judgments. Alternatively, it can also use actual measurements normalized to a relative form. These judgements also belong to a fundamental scale of absolute numbers and represent the relative influence between elements in a pairwise comparison. Based on an underlying control criterion, it examines whether one of two elements in the pairwise comparison influences a third element in the system [8].

Table 1: Count of type.

| Count of type | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Grand Total |
|---------------|------|------|------|------|------|------|------|------|------|------|------|-------------|
| Integrated    | 17   | 15   | 12   | 15   | 8    | 19   | 19   | 13   | 24   | 34   | 14   | 190         |
| Single        | 23   | 12   | 26   | 21   | 27   | 22   | 25   | 29   | 38   | 25   | 23   | 271         |
| Grand total   | 40   | 27   | 38   | 36   | 35   | 41   | 44   | 42   | 62   | 59   | 37   | 461         |

Figure 2: Count of methods.
2.1.3. Technique of Order Preference by Similarity to Ideal Solution (TOPSIS). TOPSIS presents a principle of compromise for multicriteria decision-making processes. Namely, that there should be the shortest distance between the chosen solution and the positive ideal solution, as well as the longest distance between the chosen solution and the negative ideal solution. Thus, a k-dimensional objective space is reduced to two dimensions, using a first-order compromise procedure. Consequently, membership functions of fuzzy set theory are used to represent the satisfaction level for both criteria [9].
2.1.4. **Elimination and Choice Translating Reality (ELECTRE).** ELECTRE is a practical decision-making system developed by Bernard Roy. It establishes a set of common criteria of evaluation and proceeds to systematically analyze the relationship between all possible pairings of the different options, based on each option’s scores. As a result, it can measure the degree to which each option may outrank the others. The methodology entails the construction of an outranking relation, the generation of concordance and discordance indices (including the notion of relative importance of each criterion), and an analysis of the results obtained from an overall evaluation of all the outranking relationships derived [10].

2.1.5. **Decision-Making Trial and Evaluation Laboratory (DEMATEL).** The DEMATEL method is used to effectively identify cause-effect chain components in a complex system. It uses a visual structural model to evaluate interdependent relationships among factors and to find those that are critical [11].

2.1.6. **Data Envelopment Analysis (DEA).** As a mathematical programming procedure developed by Charnes, Cooper, and Rhodes [12], DEA is used to measure relative efficiency in cases where there are multiple inputs and outputs. It is especially useful in cases where it is difficult to objectively aggregate either inputs or outputs into a meaningful index of productive efficiency [13].
Figure 6: Crosstabulation of studies by year and specific method.
2.1.7. Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE). The PROMETHEE method is used to construct a preference model by eliciting preferential parameters. This model is then accepted by the decision maker as a working hypothesis in the decision-aiding study. If a decision maker was to directly elicit these parameters, it would require a high cognitive effort from their part. On the contrary, an interactive aggregation-disaggregation approach is proposed, which infers the PROMETHEE parameters indirectly from holistic information, i.e., training examples. In this approach, a linear program is used to formulate the determination of PROMETHEE parameters that best restore the training [14].

2.1.8. VIKOR. Vlse Kriterijumska Optimizacija Kompromisno is translated as a multicriteria optimization and compromise solution method (VIKOR). In cases of conflicting and noncommensurable (different units) criteria in MCDM problems, the VIKOR method is the ideal choice. Where compromise can be achieved for conflict resolution, the decision maker requires a solution that is closest to the ideal. Thus, the method ranks and selects solutions from the examined alternatives and proposes one or more compromise solutions. The VIKOR method can be extended with a stability analysis determining the weight stability intervals, as well as with analysis of tradeoffs [15].

2.2. Search Process. Google Scholar was used to locate eligible articles published from 2010 until 2020. The following keywords and their combinations were used as follows: AHP government/AHP public, ANP government/ANP public, TOPSIS government/TOPSIS public, ELECTREE government/ELECTREE public, DEA government/DEA public, DEMATEL government/DEMATEL public, and VIKOR government/VIKOR government/VIKOR public.

The process is presented in detail in Figure 1 and included the following. From 520,133 Google Scholar entries, we examined 18,943 articles. In queries that yielded extensive results, the 400 first Google Scholar search results were examined, as it was ascertained that after that point, the findings lost their association with the keyword. In queries that yielded a small number of results, all findings were examined in relation to their title. From these 18,943 articles, we selected 569 articles and examined their abstracts. From these 569 articles, we selected 461 articles as relevant to the research process.

A total of 461 scholarly articles were recorded, analyzed, and classified in the following categories: applied method of assessment, author name, year of publication, geographical reference of the article, field of application, and field specialization. The complete tabulation of all included studies is presented in Table 1.

From 520,133 Google Scholar results, 18,943 articles are examined as follows:
3. Results

Of all studies, 271 utilized a single method, whereas 190 studies utilized integrated methods (Table 1). The most common method used was DEA, being utilized by 97 studies. However, AHP was utilized by 178 studies, when counting both simple and integrated methodologies. The distribution of methods for all studies is presented in Figures 2 and 3.

The distribution of publications by year was relatively uniform, with most studies having been published in 2018 with 62 articles.

Regarding the geographical distribution, most of the examined studies originated from Europe followed by the Middle-East and Southeast Asia (Figure 4).

In terms of sector, most studies were concerned with transportation, health, education, and economics/finance in descending order, whereas the least regarded sectors were construction, politics, telecommunications, and tourism (Figure 5).

The crosstabulation of studies by year and method produced significant results showing that the use of single versus integrated methods over the years was not uniform and there was no time-related trend toward using the one over the other; indeed, there appears to be rise-and-fall fluctuations throughout. For instance, in 2018, 2019, and 2020, 38.7%, 57.6%, and 37.8% of studies used integrated methods.

More specifically, the crosstabulation of studies by year and specific method used showed no significant associations, and DEA remained the most popular method in all examined years except 2019, where AHP-TOPSIS was most frequently used (Figure 6).

The crosstabulation of studies by method and geographical area produced significant results showing that the use of single methods far exceeded the use of integrated methods in Europe, America, and Africa, and the use of integrated methods exceeded the use of single methods in India and the Middle East. In the other geographical areas, the use of single methods exceeded the use of unified methods by a narrow margin (Table 2).

More specifically, the crosstabulation of studies by geographical area and specific method used showed significant associations; however, the count in specific cells was too low to draw valuable conclusions. In any case, it can be said that DEA was the most popular method in most regions, except in the Middle East, which is dominated by AHP, and in East Asia, which is dominated by AHP and AHP TOPSIS (Figure 7).

The crosstabulation of studies by method and research field produced significant results. However, it was again the case that certain cells contained too few values to draw actionable conclusions. In any case, it was clearly shown that the use of single methods was markedly higher in the sectors of education, environment, health, and public services, and unified methods were relatively favored for the study of economics/finance, energy, site selection, and waste management (Figure 8).

More specifically, the crosstabulation of studies by research field and specific method used showed significant
associations; however, here also, the count in specific cells was far too low to draw valuable conclusions. Notwithstanding, for those sectors that included a sufficient number of studies to merit comparison, it can be said that DEA was mostly used except for studies pertaining to agriculture (favored AHP), economics/finance (favored AHP-TOPSIS), and energy (favored AHP) among a few others. The following graph shows the methods that appear in the literature review more than 19 times (Figure 9).

Regarding secondary findings, there is a strong increase in studies in Europe and Asia from 2017 onwards (Figure 10). There was also no notable trend or variation in studies published per research field over the examined years (Figure 11).

Finally, Asia South focuses in health studies and Asia Middle in transportation (Figure 12).

4. Discussion

This study provided extensive information regarding the decision-making methods applied in the public sector, and it was ascertained that a wide range of methods are applied in practice and that there is a tendency to apply unified methods in decision making.

It was ascertained that DEA is the preferred method in various contexts. DEA can be applied in cases where other approaches are not suitable due to the complexity and the often-unknown nature of relations between inputs and outputs involved in activities. The use of DEA has introduced new possibilities and has offered new insights into activities and entities previously evaluated by other methods [16]. Some of the advantages of DEA include the simultaneous analysis of outputs and inputs, lack of need to take into account the effect of exogenous variables on the operation. Moreover, it ignores statistical errors and is relatively efficient compared to best observation. Although it does not provide information on how to improve efficiency, it needs no information on prices.

However, when AHP is considered both as a single and as a combined method of analysis, it surpasses DEA. It appears that AHP is the most frequently used method when combined methods are used. According to Saaty [7], AHP
can more clearly delineate the influence of change in priorities of higher criterion groups on lower criterion groups. Additionally, the discrimination of the examined criterion groups is far more efficient than their investigation as a whole.

Regarding the finding that most of the examined European studies were concerned with transportation, Europe is the geographical area where multicriteria decision-making methods are primarily applied. This fact highlights the expansive scientific interest of researchers for consolidating and upgrading public administration in European countries. The transportation sector is particularly interesting for researchers, as it constitutes one of the main public sectors. Vast sums are invested in this sector, either with the State’s exclusive participation or through joint ventures between the private and public sectors. Furthermore, the transportation sector absorbs a large part of European funding. For this reason, correct decision making in this sector is of high importance. During 2018 and 2019, an increase in article publications was observed, followed by significant decrease in 2020. This decrease may have come as a result of the coronavirus disease pandemic, which caused a decrease in scientific interest and slowed the activity of the scientific field.

Some limitations of this study include that we conducted a literature review of sources in English and examined specific methods, based on prespecified criteria, as an exhaustive review of all existing methods would not be feasible; for instance, we did not select studies that were concerned with the enhancement of older methods with algorithms, although this too constitutes a scientific development.
Figure 11: Crosstabulation by research field and year.
Figure 12: Crosstabulation by research field and region.
5. Conclusions

Our findings could help in study specialization in a particular field of application for the public sector (e.g., decision-making methodologies used in public transport), in conducting further study regarding the unified methods and decision making through the use of algorithms and could finally comprise a useful tool for those specializing in the research field of public administration.

Data Availability

The data supporting this systematic review are from previously reported studies and datasets, which have been cited. The processed data are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Supplementary Materials

EXCEL- DATA. (Supplementary Materials)

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