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A systematic literature review regarding the use of multicriteria methods towards development of decision support systems in health management

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Abstract

This article aims to characterize scientific production regarding the development of Decision Support Systems based on multicriteria methods for the health management sector. Using the bibliometrics technique, health management segments applying multicriteria methods were identified, and an examination was conducted of the multicriteria methods employed, the countries where these studies were carried out, the most cited authors, the number of papers published per year, and the most frequent keywords. Findings indicated that the Analytic Hierarchy Process was the multicriteria method employed most often and that Health Technology Assessment was the most prominent segment for multicriteria application.

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Keywords: Health management; Decision Support Systems; Multicriteria methods; Bibliometrics

1. Introduction

The management of hospital environments presents a great number of variables to be considered in decision-making processes by the directors of these organizations. Scarce resources demanded by various sectors of these institutions, the number of staff and patients, and quality of service are just a few of the variables that must be considered in the management process.

In problems with this level of complexity, it is possible to use operations research methods for the development of Decision Support Systems (DSS), including multicriteria methods. These mathematical methods can establish

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relationships and hierarchies between variables in order to identify the location of the critical points of the system being studied.

In recent decades, multicriteria methods have been applied in many areas of society, including the health management area. Accordingly, the proposal of this work is to analyse the scientific literature dealing with the development of DSS based on multicriteria methods in health management, in order to support managers and researchers in this area.

This paper is organised into seven sections. Once the introductory framework is established, section two and three discusses, respectively, the overview of multicriteria methods and their application in health management. Section four presents the methodological procedures, while section five presents the data analysis and the section six discusses the results. Finally, section seven establishes the final considerations, goals achieved, and limitations of the work, as well as recommendations for future research.

2. Multicriteria Decision Analysis Methods

The Multicriteria Decision Analysis methods (MCDA) have been used in the development of DSS in several areas of study.

Belton and Stewart[1] define MCDA methods as scientific tools that support the decision-making process, which have several goals in complex situations. Broadly, this occurs due to the division of objectives into criteria, which receive importance values and decision alternatives are evaluated for each of the criteria. Having formulated the DSS, the overall evaluation of any proposed alternative can be carried out, taking into account the weight of each criterion and its performance in the model.

Thokala and Duenas[2] describe a four-stage process for DSS based on MCDA methods: identifying the alternatives that will be considered in the model, establishing the criteria with which the alternatives will be evaluated, determining scores that reflect the expected value of the performance presented by each criteria previously described, and calculating the importance weights for each criterion, thereby establishing an importance relationship which can be measured among these criteria.

There is a variety of MCDA methods used in the development of DSS: AHP–Analytic Hierarchical Process, developed by Thomas Saaty[3]; MACBETH–Measuring Attractiveness by a Categorical Based Evaluation Technique, developed by Bana e Costa and Vansnick[4]; and TOPSIS–Technique for Order Preference by Similarity to Ideal Solution, developed by Hwang, Lai and Liu[5]; among others.

In the literature, there is also a variation of the MCDA nomenclature, termed MCDM (MultiCriteria Decision Making). The acronym MCDA, itself, is also sometimes referred to as MultiCriteria Decision Aid.

Although methods may differ in mathematical perspective or naming, they are all employed for the same purpose: the development of DSS based on multicriteria analysis.

3. MCDA methods applied to health management

According to Diaby, Campbell and Goeree [6], the great difference between health management and other areas is the fact that health is an irreplaceable and invaluable asset that directly affects people. Such aspects raise the degree of complexity of management's decision-making process, as any wrong decision puts the health and lives of patients at risk. The situation worsens when the decision has ramifications that affect the entire chain of health services provided to society.

Marsh et al[7] exemplify this complexity by illustrating that a decision made by a healthcare manager can benefit the treatment of a disease in a given number of patients, and at the same time, lead to the deterioration of health for another group of patients. In this sense, interest in the application of MCDA methods in health management is relatively new, with the first study published in the mid-1990s. Since then, the number of publications in the area has grown substantially[7].

Mitton and Donaldson[8] applied MCDA in the development of a DSS to evaluate three health regions in Canada in order to identify different financial and material resource management techniques, detecting the most effective techniques and ways to optimise administrative processes.

Sloane et al[9] developed a DSS using a multicriteria method to assess the use of new technologies in hospitals and their effects on the hospital in general. More specifically, their study evaluates, for example, what type of fan should be purchased for the hospital's neonatal sector, assessing which are the most important features needed.

Baltussen et al[10] used MCDA in a DSS to assess health management priorities in Ghana, showing which health programs are prioritised in this nation and indicating where government efforts should be focused.

Wu, Lin and Chen[11] used MCDA as a background methodology to develop a DSS for selecting the best geographic position within the borders of Taiwan to construct a hospital in order to generate a competitive advantage for this hospital in relation to other established hospitals.

Ju, Wang, and Liu[12] evaluated the efficiency of responses by hospital emergency sectors with the application of a fuzzy multicriteria method. The developed model considered various factors to arrive at this evaluation.

Moreover, implementing MCDA as the base methodology, Longaray et al[13] developed a DSS to be used by managers of Brazilian university hospitals to evaluate the managerial performance of these hospitals and compare them with the minimum quality criteria set forth by the Brazilian Ministry of Health and the Ministry of Education.

4. Methodological design

The study design is within the framework of exploratory research as Stebbins[14] suggest, which seeks to identify what has been scientifically produced in the area of DSS development based on multicriteria methods in health management.

The data sample was collected using the Google Scholar search system, the ISI *Web of Knowledge* system, and the *Web of Science*, CAPES, and *Science Direct* portals, in addition to the annals of the main national scientific publication journals in the management area. The search was conducted using keywords such as MCDA, MCDM, MCDA-C, *healthcare*, *Multicriteria Analysis*, *Analytic Hierarchy Process*, *Hospital Management*, and *Health Management*.

The sorting of articles relevant to the study was carried out in conjunction with the collection of the same, thus identifying items in line with the study proposal. This selection was carried out using the keywords and a verification of available summaries was subsequently conducted to check whether the publications were aligned with the purpose of the study.

The data collected were analysed using the bibliometric method, described by Pritchard[15] as the use of mathematical and statistical techniques for the quantification of books, articles, and any other forms of written communication.

Upon completion of the analysis, the results were organised into the following categories: most prolific authors in the area, most prolific institutions in the area, their geographic location, major periodicals in which the area was disclosed, the number of publications over time, the main authors cited, the multicriteria methods applied, the area where the methods were applied, and the most frequently used keywords.

5. DataAnalysis

This section presents the data obtained from the research. The reference search using the keywords described in the previous section revealed a total of 1764 articles.

In an initial analysis, performed after reading the title of the articles, 1438 were eliminated because they did not relate to the subject or were duplicates, leaving 326 articles. In a second analysis considering the articles' abstracts, it was possible to eliminate another 147 articles, leaving 179 articles. The third stage comprised the complete reading of the 179 articles. At this step, 22 articles were eliminated.

The final sample of studies obtained in these steps included 157 articles published in different databases; 89 studies were collected from the *Science Direct* database, 24 articles from the ISI *Web of Knowledge* database, 05 articles from Brazilian journals (in Portuguese language), and 39 articles were obtained through Google Scholar.

5.1. Main authors and institutions

After collecting data from the articles, the most prolific authors in the area addressed in this study were identified and are presented in Table 1. The results obtained from the analysis of the data identified Maarten J. IJzerman, J. M. Hummel, James G. Dolan, J. A. van Til, and R. Baltussen as the main authors in the area of health management.

Table 1. Most prolific authors in the health management area.

Author	Number of publications	Percentage of sample
IJzerman, M. J.	18	11.46%
Hummel, J. M.	13	8.28%
Dolan, J. G.	11	7.00%
van Til, J. A.	8	5.09%
Baltussen, R.	7	4.45%
Groothuis-Oudshoorn, K.	5	3.18%
Thokala, P.	5	3.18%
Ensslin, L.	4	2.55%
Reddy, B.	4	2.55%
Steuten, L	4	2.55%
Authors with less than 4 publications	78	49.71%

Next, we identified the main institutions linked to the production of these scientific papers. After analysis of the data (Table 2), the most prolific institutions in the area were the *University of Twente* (20 publications), the *University of Rochester* (11 publications), the *Erasmus University Hotterdam* (7 publications) and the *University of Groningen* and the *University of Sheffield* (5 publications) each.

Table 2. Most prolific institutions in the health management area.

Institution	Number of publications	Percentage of sample
University of Twente	20	12.73%
University of Rochester	11	7.00%
Erasmus University Hotterdam	7	4.45%
University of Groningen	5	3.18%
University of Sheffield	5	3.18%
Galatasaray University	4	2.55%
Institute for Quality and Efficiency in Health Care	4	2.55%
Johns Hopkins School of Public Health	4	2.55%
National Centre for Pharmacoeconomics	4	2.55%
Universidade Federal de Santa Catarina	4	2.55%
Institutions with less than 4 publications	89	56.71%

5.2. Main countries where the articles were developed

Another aspect considered in the classification of the selected articles was the country where the studies were conducted and the results are presented in Table 3.

Table 3. Main countries where the studies were conducted.

Country of origin	Number of publications	Percentage of sample
Netherlands	34	21.66%
United States	31	19.75%
United Kingdom	22	14.02%
Germany	12	7.64%
Brazil	12	7.64%
China	10	6.36%
Canada	9	5.73%
Turkey	6	3.82%
Ireland	5	3.18%
Australia	4	2.55%
South Korea	4	2.55%
Iran	4	2.55%
Switzerland	4	2.55%

The results indicate that the predominance of scientific study in this area by the authors was conducted in the Netherlands with 34 publications, followed by the United States with 31 publications, the UK with 22 publications, and Germany and Brazil with 12 publications each.

5.3. Main journals with articles on the subject

Another construct addressed in this study is related to the main journals where the scientific papers were indexed. From this analysis, it was possible to identify which journals are most focused on health management, thus demonstrating the most relevant journals in this field. The results obtained are presented in Table 4.

Table 4. Main journals focused on the area of study.

Journals	Number of publications	Percentage of sample
Value in Health	52	33.12%
Medical Decision Making	10	6.37%
Expert Systems with Applications	8	5.09%
European Journal of Operational Research	5	3.18%
Journal of Medical Systems	4	2.55%
Health Policy	4	2.55%
Journals with less than 4 publications	74	47.14%

The results obtained from the analysis (Table 4) indicate a disparity in the distribution of articles by journal. *Value in Health* was the main scientific journal with 52 publications indexed in its database. The *Medical Decision Making* journal followed, with 10 publications in its database.

5.4. Production over time

Under this topic, we present the publication of papers on the multicriteria methods in health management over time, taking into account the sample used when conducting the bibliometric analysis (Figure 1). From the results of Fig. 1, we can determine that the topic is relatively new, considering that DSS emerged decades before their application in the health management area. The development of the area in recent years can also be noted, with the largest number of publications in 2014, totalling 26. It is noteworthy that the collection of the study sample was carried out between the months of September and October 2015, and 2015 may be the most prolific time period presented in the study.

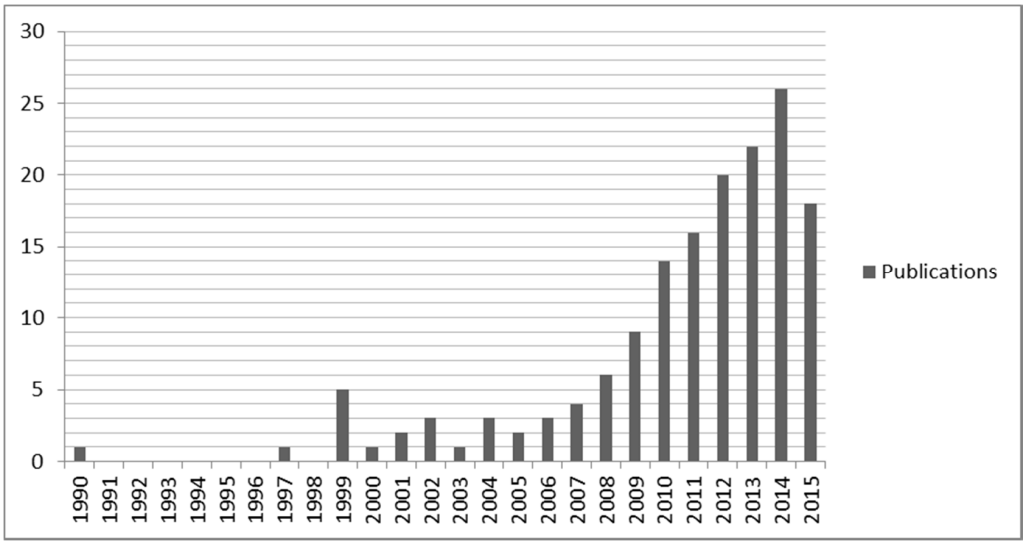

Fig. 1. Demonstration of production on the multicriteria methods in health management over time.

5.5. Keywords

This subsection presents the keywords from all articles in the sample used in this study that provided keywords in their text.

Based on Table 5, the term AHP was cited as a keyword most often, with 32 occurrences in the articles studied. Next, the term MCDA occurred 12 times. The terms MCDM and *priority setting* had 9 mentions each. The term *health care* was mentioned six times.

This analysis identified the lack of standardization in the use of keywords, with several variations being observed for the same information.

Table 5. Most-frequent keywords in the articles.

Keyword	Number of occurrences
AHP and variants	32
MCDA and variants	12
MCDM and variants	9
Priority setting	9
Health care	6
Decision making	5
Health technology assessment	4
Decision aid	3
TOPSIS	3

5.6. Methods used

Here we present the multicriteria methods used in the articles included in the study, identifying the methods most frequently applied by the authors of the articles (Table 6).

Table 6. Most frequently used multicriteria methods.

Method applied	Number of applications	Percentage of sample
AHP	87	55.41%
MCDA	25	15.92%
Fuzzy AHP	9	5.73%
ANP	5	3.18%
Conjunct Analysis	5	3.18%
TOPSIS	5	3.18%
BSC	4	2.55%
Markov method	4	2.55%
Other methods	13	8.30%

The analysis of the results indicates the apparent preference for the use of the AHP multicriteria method, which was the method most frequently used in the health management area, with 87 published articles.

Most of the articles that cited the generic term, MCDA as the method, used only criteria ranking logic in its application to the frameworks developed by the authors. In some cases, the authors did not mention which method was applied.

5.7. Area of application

This section deals with the areas of health management in which the multicriteria methods were applied, thus demonstrating the main research *foci* in the sample of articles evaluated (Table 7).

The analysis of the obtained data revealed that multicriteria methods were applied most often in the strategy area, with 37 published articles addressing this topic, representing 23.57% of the total sample.

Performance evaluation was the next most common area, with 26 articles published in the databases used, representing 16.57% of the article sample.

Following these, 22 articles were identified in two subjects, clinical decision support and information technology, with each representing 14.02% of the sample.

Table 7. Health management areas applying multicriteria methods.

Area applied	Number of papers	Percentage of sample
Strategy	37	23.57%
Performance evaluation	26	16.57%
Clinical decision support	22	14.02%
IT	22	14.02%
Decision shared with the patient	16	10.19%
Finances	10	6.37%
Bibliographic review	9	5.73%
Logistics	8	5.09%
Performance optimization	5	3.18%
Method evaluation	1	0.63%
Equipment maintenance	1	0.63%

5.8. Most-cited authors

The most rigorous analysis that could be performed was the verification of the papers cited most often in the articles selected for this study; all references obtained within these articles were considered and tabulated (Table 8).

According to Table 8, we can see that the author with the highest number of citations in the analysed papers and books is T. L. Saaty[3], with 28 citations in the sample for his article published in 1990. Next, with 19 citations, was M. J. Liberatore and R. L. Nydick's[16] article from 2008. The third most cited work was the article published in 2006 by R. Baltussen and L. Niessen[17] with 14 citations in the articles analysed. The article by T. L. Saaty[18] published in 1977 had 13 mentions in the study sample. Several authors had more than one article among the most cited works: T. L. Saaty[3,18,24], R. Baltussen[10,17], and J. G. Dolan[19,20,22,30].

Table 8. Most-cited articles in the study sample.

Title	Author	Number of citations
How to make a decision: the analytic hierarchy process	Saaty, T. L., (1990).[3]	28
The analytic hierarchy process in medical and health care decision making: A literature review.	Liberatore, M. J., & Nydick R. L., (2008).[16]	19
Priority setting of health interventions: The need for multi-criteria decision analysis.	Baltussen, R., & Niessen, L., (2006).[17]	14
A scaling method for priorities in hierarchical structures.	Saaty, T. L., (1977).[18]	13
Fuzzy sets.	Zadeh, L. A., (1965).[23]	11
The analytic hierarchy process in medical decision making: A tutorial.	Dolan, J. G., Isselhardt, B. J. Jr., & Cappuccio, J. D., (1989).[19]	11
Multi-criteria clinical decision support: A primer on the use of multiple criteria decision making methods to promote evidence-based	Dolan, J. G., (2010).[20]	8
Multiple attribute decision making: Methods and applications.	Hwang, C., & Yoon, K. (1981).[21]	8
Decisions with multiple objectives: Preferences and value trade-offs.	Keeney, R. L., & Raiffa, H., (1976).[24]	7
Involving patients in decisions regarding preventative health interventions using the analytic hierarchy process.	Dolan, J. G., (2000).[22]	7
The analytic network process: Decision making with dependence and feedback.	Saaty, T. L., (1996).[25]	7
Towards a multicriteria approach for priority setting: An application to Ghana.	Baltussen, R., Stolk, E., Chisholm, D., & Aikins, M., (2006).[10]	7

6. Results Discussion

The results obtained from the performed analysis indicate that the most prolific author in the health management area was Maarten J. IJzerman[26,27,28,29,30,31], with the largest number of MCDA articles published in the health management area, a total of 18, making up 11.46% of the sample. Professor IJzerman produced most of his studies in conjunction with J. M. Hummel[27,29,31] and J. A. van Til[26,30,31]. It is noteworthy that these authors also have studies identified in the area without connection to Professor IJzerman. The American professor, James G. Dolan[19,20,22,30],

also appears in the sample as one of the most prolific authors, with 11 studies identified, the equivalent of 7% of the sample, highlighting studies in support of decisions by patients and physicians regarding approaches to disease treatment. Rob Baltussen[10,17], a PhD in economics whose research focus is economic evaluation in health, also appears among the most prolific authors, having 7 articles in the analysed sample, representing 4.45% of the total.

The institutions affiliated with these studies were found to be directly related to the most prolific authors. Institutions with the most citations in the sample of analysed articles were the *University of Twente*, located in the Netherlands, with 20 articles listed, representing 12.73% of the sample; the *University of Rochester*, based in the United States, with 11 articles linked to it, corresponding to 7% of the total sample; and *Erasmus University Hotterdam*, located in the Netherlands, with a sample of seven associated articles, representing 4.45% of the study sample.

Regarding the country of origin of the studies, the Netherlands was the most representative country within the sample, with 34 published articles, comprising 21.66% of the analysed articles. According to the Table 3, it is notable that publication on MCDA for the healthcare sector is dominated by studies originated from developed countries. Only one in developing country, Brazil, it is among the five countries that generated more publications. This somehow reflects what is observed in other areas. We believed that more studies in this area could help countries in development to soften somewhat the critical situation that the health sector lies in these locations.

In terms of the journals with the highest number of publications, we highlight the journal, *Value in Health*, with 52 articles, corresponding to 33.12% of the articles analysed. The journal with the second largest share of the sample was *Medical Decision Making*, with 10 publications, totalling 6.37% of the sample. The third most represented journal was *Expert Systems with Applications*, with 8 published articles and 5.09% of the sample. The rest of the publications were dispersed among several different journals with little representation in the research sample.

With regard to the keywords, we obtained a total of 266 different keywords. For the purpose of this study, those that were correlated and had only a difference in spelling were considered as the same construct. Thus, the most representative keyword was AHP and its variants, with 32 citations within the analysed articles. The second most repeated keyword within the sample was MCDA and its variants, with 12 occurrences in these articles. In third place, MCDM and its variants occurred nine times, along with priority setting, within the analysed articles. We observed a wide variation within the keywords that represented the same desired term, thus posing a difficulty for studies in this area.

Having this data as a reference, we may highlight a preference of researchers in the context of the health sector by methods, since the five most frequent keywords, three of them regard to methods.

The analysis of the years of article publication revealed that interest in applying multicriteria methods in health management is relatively new, with the first study published in 1990. The first year with more than five publications in the area was 2008, with six articles identified. Since 2008, the production of articles has been showing annual growth, with 2014 being the year with the highest number of publications in the sample, with 26 articles representing 16.56% of the sample. Up to the time of the present study, 18 articles from the year 2015 were obtained, representing 11.46% of the sample.

Regarding the multicriteria method used by the articles, we noticed a wide range of methods employed by the various authors, but a preference for AHP was noted, having been used in 87 articles, corresponding to 55.41% of the analysed sample. In addition to these 87 articles, another nine articles applied the AHP method in conjunction with the fuzzy sets theory, thus demonstrating the authors' preference for AHP. In the 25 articles that mentioned only the generic term, MCDA, as the method (15.92% of the sample), the use of hierarchical theory for criteria evaluation was observed. Besides these, another three methods were identified with five publications each: ANP, TOPSIS, and Conjunct Analysis, each representing 3.18% of the total sample.

Thus, we can point out that there is a direction, in a remarkable way, of the researchers in the context of the health sector by AHP method. It is central highlight that this predilection can already be observed when analyzing the data of the most frequent keywords. AHP is in the top of the list.

In terms of the areas of health management in which the methods were applied, a greater interest was identified in the strategic segment, with a total of 37 articles, representing 23.57% of the sample. Another segment with a high number of publications was the application of multicriteria methods for performance evaluation, with 26 articles, representing 16.57% of the sample. In a third trend, support for clinical decision and information technology appeared, with the same number of publications and representation for both: 22 articles and 14.02% of the sample.

Accordingly, we can highlight that these two frequently related areas, strategy and performance, show that the management of health sector is central in this context.

Among the most-cited articles, the study by Saaty[3] takes first place, published in 1990 on the AHP method, with 28 citations. Liberatore and Nydick's[16] (2008) article with 19 citations is the second most-cited, comprising a bibliographic review on the application of the AHP method in health management. Baltussen and Niessen's[17] (2006) paper had 14 citations and refers to the need for multicriteria methods in health interventions. Saaty's[18] (1977) article describing hierarchy structuring comes next with 13 citations. Following these are Zadeh's[23] (1965) and Dolan et al's[19] (1989) articles, both with 11 citations. Again, we can see a greater interest in the AHP method over other methods, which is clear from the figures for the most-cited articles given above referring to AHP.

From the analysis of all the parameters described above, we have concluded that the application of multicriteria methods for developing DSS in the health management area is an expanding field of study, being relatively new compared to the use of these methods in other areas of society. We observed a preference for the use of the MCDA variant, AHP, by the authors who develop DSS in the health management area. This is also reflected in the analysis of article references, where those most cited were related to this multicriteria method.

When assessing the aspect of the most prolific authors, the main researchers in the field of multicriteria methods focused on health management were identified: Professors Maarten J. IJzerman, J. M. Hummel, James G. Dolan, J. A. van Til, and R. Baltussen. The analysis comparing the institutions linked to the studies and the country of origin provides us with an understanding of the development of this area of study, showing that there is a greater interest in this area in the Netherlands, the United States, and the United Kingdom.

A difficulty was identified in the use of keywords. It was necessary to use different spellings to refer to the same term, thus achieving a representative sample of the studied area.

By analysing the areas of application of multicriteria methods, a greater interest in the use of the methods in strategic areas was observed, but other areas also showed high interest, such as performance evaluation, clinical decision support, and information technology. With regard to information technology, a large number of articles published in recent years can be noted, which is reflected in current studies addressing a representative study area of Health Technology Assessment (HTA) in healthcare facilities around the world.

It is noteworthy that this study considered the study by Diaby et al[6], thus seeking to analyse some aspects not addressed by the authors. The present study sought to identify institutions with greater involvement in the use of multicriteria methods in health management, also rating the multicriteria methods used most often by the authors and analysing all the references used in the sample of 157 articles. Therefore, this work builds upon the study by Diaby et al[6], envisaging a greater understanding and characterization of the area as a whole.

7. Final considerations

The proposal of this work was to analyse the scientific literature dealing with the development of DSS based on multicriteria methods in health management, in order to support managers and researchers in this area.

As such, the bibliometric method was used for the collection of health management articles and their subsequent analysis.

The databases used in this study were Google Scholar, the ISI *Web of Knowledge* system, and the *Web of Science*, CAPES, and *Science Direct* portals. When data collection was complete, we obtained a total of 157 articles from these databases.

A variant of the MCDA methods, termed AHP, was identified as the most frequently used method in the health management area, encompassing the authors with more publications in this area, as well as the institutions and countries where the studies were conducted.

Our results indicate that MCDA methods were applied strategically in performance evaluation, clinical decision support, and information technology. The area of information technology was identified as the most currently representative area, given its high number of publications in recent years.

One limitation of this study is the restriction of access to some international databases, which prevented the analysis of all publications in the field. We suggest applying the same search while adding an even greater number of databases as a way to expand the accuracy of the bibliometric indicators outlined and measured.

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