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ARTICLES

BIBLIOMETRIC STUDIES ON MULTI-CRITERIA DECISION ANALYSIS (MCDA) METHODS APPLIED IN MILITARY PROBLEMS

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ABSTRACT. Military issues have great relevance worldwide since they affect the security and sovereignty of nations. In this context, the application of Multicriteria Decision Analysis (MCDA) methods is important because accurate decision-making is the deciding factor for success, which can reduce expenses and increase defense capacity. This paper aims to present a literature review on the main applications of MCDA in the military area, considering the tactical, operational and strategic spheres. The methodology includes a bibliometric study and literature review of documents from the Scopus and Web of Science databases. The bibliometric study identified the document type, language, year of publication, authors, author network, author's publications, affiliation, keyword clusters, the field of knowledge, country and the main applied MCDA methods in military problems. The literature review allows us to verify that, as well as in other areas of knowledge, the Analytic Hierarchy Process (AHP) is the most applied MCDA method in the military area.

Keywords: multicriteria decision analysis, bibliometric studies, military.

1 INTRODUCTION

Complex environments, conflicting criteria, uncertainties and inaccurate information are characteristic of many decision problems that are present in the real world. The Multicriteria Deci-

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sion Analysis (MCDA) methodology contributes to making the decision-making process more rational and efficient (Hatami-Marbini & Tavana, 2011; Pereira et al., 2017).

In this context, the expression Multiple Criteria Decision Analysis (MCDA) is used to describe a set of formal approaches which seek to take explicit account of multiple criteria in helping stakeholders and groups explore decisions that matter (Belton & Stewart, 2002). These decisions almost universally involve multiple conflicting objectives, nebulous types of nonrepeatable uncertainties, costs and benefits accruing to various individuals, businesses, groups and other organizations (Keeney et al., 1993).

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) (Greco et al., 2016).

Considering a finite set of alternatives, the DM may face three main types of problem: choice problems imply the selection of a subset containing the best alternatives; ranking problems provide the alternatives from the best to the worst; sorting problems distribute the alternatives into pre-defined and ordered categories (Corrente et al., 2016).

An important feature to emphasize is that MCDA methods are not designed to search for the best alternative concerning all criteria. The difficulty of the problem originates from the presence of more than one criterion (Martins et al., 2020).

Increasingly, the methods of support for decision-making, including the MCDA, have been used in the military sphere, because of the sensitivity of these issues, which greatly affect the security and sovereignty of nations (Hamurcu & Eren, 2020). This requires the analysis of conflicting factors, and, in this context, MCDA may be of great relevance in supporting decision-making (Sánchez-Lozano & Rodríguez, 2020).

According to Van Hoan and Ha (2020), the application of MCDA methods in the Armed Forces is important because accurate decision-making is the deciding factor for success and can reduce spending and increase defense capacity. These methods are systematic scientific models to help DMs make accurate decisions (Van Hoan & Ha, 2020).

In this context, this research presents a literature review on the main applications of MCDA in the military area, considering tactical, operational and strategic spheres, seeking to answer the following questions:

- Who are the main authors and how are they connected?
- Which major journals publish the research topic?
- How many articles are published per year?
- What are the main keywords used in the articles and how do they connect?
- Which countries have articles on the topic?

- What are the fields of knowledge that publish articles on the topic?
- Which are the most applied MCDA methods in military problems?

This paper presents the results of bibliographic research on MCDA and military applications, providing a descriptive overview of the scientific production of both themes. A bibliometric study was performed on the Scopus and Web of Science databases to answer the research questions.

The paper is organized as follows. Section 2 presents the literature review with some examples of proposals and approaches of MCDA methods in military problems. Section 3 explains the methodology. Section 4 analyzes the results of the bibliometric study on MCDA in the military sector. Section 5 concludes this study.

2 LITERATURE REVIEW

The academic literature contains many examples of the application of MCDA in the military field. Among the main MCDA methods, according to Santos et al. (2021), the Analytic Hierarchy Process (AHP) is the most applied method in military problems, such as in ordering and evaluating weapon systems (Mon et al., 1994; C. Zhang et al., 2005); selecting rough terrain cargo handlers for the U.S. Army (Bard & Sousk, 1990); scoring and classification of military network sensors (Bisdikian et al., 2013); selecting the best location for the installation of a military naval base (Suharyo et al., 2017), sizing the US destroyer fleet (Crary et al., 2002), firing position of a guided anti-tank missile battery (Bojanic et al., 2018); resource allocation for anti-terrorism in protecting overpass bridge (Li et al., 2016); selecting and evaluating a subcontractor firm for a company in defense industry (Can & Arikan, 2014); positioning of the surveillance system within a national security project in Turkey (Çarman & Tuncer Şakar, 2019); selecting ground vehicles for the provision of military units intended for multinational operations (Starčević et al., 2019); evaluating naval tactical missile systems (Cheng, 1997), defense simulation packages (Alomair et al., 2016) and attack helicopters (Cheng et al., 1999); selection of the location for deep wading as a technique of crossing the river by tanks (Bozanic et al., 2018); determining strategy of the Indonesian air force military cargo aircraft in supporting the Global Maritime Fulcrum (Mulia et al., 2018); and selecting the best advanced military training aircraft for the Spanish Air Force (Sánchez-Lozano & Rodríguez, 2020).

Another MCDA method widely used in military problems is the Technique for Order Preferences by Similarity To Ideal Solution (TOPSIS), as noted in the classification of the threat of military targets (Zhang et al., 2012); risk management for obsolescence in the U.S. Armed Forces (Adetunji et al., 2018); target-tracked prioritization to surveille ballistic missiles (Luo & Li, 2009); evaluating initial training aircraft (Wang & Chang, 2007), abrasive Water Jet machining of military-grade armor steel (Rammohan et al., 2021), method of air force attack airline (Chen & Zhang, 2016); scheduling algorithm based on heterogeneity and confidence for mimic defense (Zhang et al., 2020); resource allocation to military countermeasures versus probabilistic threat (Wan et al., 2018); supplier selection and evaluation in military supply chain and order allocation (Nazeri et al., 2019).

The Borda method was applied by Du et al. (2015) to evaluate military research institutes' core competence; Etesamipour and Hammell II (2020) made a Value of Information (VoI) research and demonstrated outcomes from a military-related experiment using Borda and Condorcet methods; Lee (2018) compared cases of bilateral trade conflicts between the US and China and the US and Japan using the Copeland method. This author stated that the increase in bilateral economic interdependence also increased the frequency of conflicts in the two cases.

The Multiattribute Utility Theory (MAUT) method was applied to evaluate modern combat aircrafts (Sundararajan, 2020), based on a decision model for canceling navy ship maintenance availabilities (Williams & Hester, 2017), anti-terrorism decision aid (Dillon et al., 2009) and a problem in defense systems acquisition (Dewispelare & Sage, 1980).

The Analytic Network Process (ANP) was applied to analyze military training security risk assessment (Pan et al., 2021); evaluation of Unmanned Aerial Vehicles (UAV) contribution degree to an Army aviation combat system (Duan et al., 2020) and airworthiness criteria for military aircraft (Şenol, 2020).

De Leeneer and Pastijn (2002) applied the *Organísation, rangement et synthèse de données relationnelles* (ORESTE) method to the selection process of the best combination of landmine detection sensors on an airborne platform. Aloini et al. (2018) presented fuzzy intuitionistic modeling with the TOPSIS method (IF-TOPSIS), applying the model in a case study of a company operating in the military sector (Advanced Underwater System).

Roussat et al. (2009) conducted a case study on the demolition of 25 buildings of a former military camp by applying the *ELimination Et Choix Traduisant la REalité* (ELECTRE) III method in the context of the choice of a sustainable demolition waste management strategy in the city of Lyon, France. The method was also applied to select an anti-submarine sensor of a helicopter (Ahmadi et al., 2017).

Gazibey et al. (2015) applied the Decision Making Trial and Evaluation Laboratory (DEMATEL) method to understand the cause-and-effect relationships between the criteria for the selection of main battle tanks. The method was applied in the primary and secondary criteria separately.

Bahadori et al. (2020) conducted a descriptive study for the selection of the best supplier in a military hospital, using a combination of artificial neural networks and fuzzy *VIseKriterijumska Optimizacija I KOmpromisno Resenje* (VIKOR) methods.

The adoption of a combination of methodologies enables the identification of the variables and a rational analysis of the information. The AHP method is also widely used in conjunction with other MCDA methods. Wang et al. (2008), for instance, combined the techniques AHP fuzzy and TOPSIS to evaluate the effectiveness of air combat of military aircraft. In the study, the Fuzzy AHP method was used to determine the relative weights of multiple evaluation criteria and to synthesize the classifications of candidate aircraft. TOPSIS was employed to get a crisp overall performance value for each alternative to make a final decision.

Altunok et al. (2010) compared the performance of the AHP, Weighted Product (WP) and TOPSIS methods to select graduate students from the Defense Science Institute of the Turkish Military Academy. According to the study, the AHP presented the best performance in the proposed analysis. Genc (2015) conducted a study to support decision-making in the acquisition of military tanks, through the application of the ELECTRE III and PROMETHEE II methods.

Sánchez-Lozano et al. (2015) selected military training aircraft for the Spanish Air Force, through hybrid modeling composed of AHP, TOPSIS and Fuzzy Logic. Sánchez-Lozano et al. (2020) conducted a study to prioritize obsolete military coastal batteries, to transform them into places of tourist interest in Spain, through the application of the GIS, AHP and TOPSIS methods.

To meet the need for military and commercial approaches, Di Bona and Forcina (2017) implemented the reliability allocation method called Analytic Critical Flow Method (ACFM), a reliability allocation model for parallel configurations in series, based on the failure analysis of each unit of the system. The approach is based on the critical flow method and its results were combined with the AHP method.

Kiracı and Akan (2020) applied the Interval Type-2 Fuzzy AHP (IT2FAHP) and Interval Type-2 Fuzzy (IT2FTOPSIS) methods to choose the most suitable aircraft to be acquired. Hamurcu and Eren (2020) applied an integrated methodology based on AHP and TOPSIS methods to evaluate Unmanned Aerial Vehicles (UAV) alternatives in the selection process. First, the AHP was used to determine the weights of the criteria, while the TOPSIS was applied to classify vehicle alternatives in the decision problem.

Van Hoan and Ha (2020) evaluated and selected an appropriate combat aircraft for the Vietnam People's Air Force, using the Full Consistency Method (FUCOM) to obtain the criteria weights and Additive Ratio Assessment (ARAS) to obtain the final classification of alternatives in light of the criteria.

Sennaroglu and Varlik Celebi (2018) carried out a study to select a military airport location by AHP integrated PROMETHEE and VIKOR methods. Dağdeviren et al. (2009) analyzed weapon systems by applying the AHP and TOPSIS methods under fuzzy environment. A hybrid approach using the AHP and integer programming to screen weapon systems projects was developed by Greiner et al (2003).

Some papers also present military applications of new MCDA methods/approaches and hybrid methodologies, as presented by Di Bona et al. (2016), who proposed an approach based on the Integrated Factors Method (IFM), whose values are adjusted using the AHP method, depending on the importance of each factor and each unit of the system. The reasons that led to the development of IFM-based AHP are the result of a careful analysis of current military and commercial approaches. According to the authors, the result is a dynamic model, which combines the advantages of the allocation method and the multicriteria decision-making technique.

Gigović et al. (2016) presented a new MCDA technique - MAIRCA (Multi-tax Ideal-Real Comparative Analysis), based on the combined use of Geographic Information Systems (GIS) and

multicriteria techniques. The authors applied the DEMATEL-ANP model for the selection of suitable locations for the installation of ammunition deposits.

Costa et al. (2020) proposed and applied the THOR 2 method to select the Brazilian Navy's most suitable hospital care vessel (NAsH) to support the fight against the COVID-19 pandemic. Moreira et al. (2021) proposed and applied the PROMETHEE-SAPEVO-M1 method to select a Remotely Piloted Aircraft System to be acquired for use in naval warfare by the Brazilian Navy. Costa et al. (2021) proposed and applied the ELECTRE-MOr method to classify aircrafts to be acquired by the Brazilian Air Force and employed in the fight against the COVID-19 pandemic.

The literature review revealed several applications combining MCDA methods to support the decision-making process in military 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.

Regarding the main themes related to military applications, Khalifa (2021) presents the common hierarchy in the Armed Forces, consisting of three levels: strategic, operational and tactical. Clausewitz defines strategy as "the use of engagements for the object of war". Tactics in the military literature are actions on the battlefield, executed to defeat the enemy (Clausewitz, 2008; Friedman, 2017; Liddell Hart, 2008). The operational level can be considered as the link between strategy and tactics, being a sequence of tactical actions connected by a unifying idea in service of strategy (Kelly & Brennan, 2009).

The analysis carried out in this research allowed us to verify that most applications of MCDA methods in the military field refer to the strategic level (about 60% of documents), mainly dealing with logistical, personnel and acquisition problems (Bastian et al., 2016; De Almeida et al., 2021; Jou et al., 2016; Koban & MacDonald Gibson, 2017; Maêda; et al., 2021; K. Wang & Zheng, 2012). Operational/tactical levels can be represented by threat assessment, military operations planning, war tactics, among others (Frini et al., 2017; Han et al., 2014; Weir et al., 2014).

3 METHODOLOGY

According to the classification proposed by Creswell and Creswell (2017), this research can be characterized as qualitative-quantitative research, combining both to map the state of the art on applications of MCDA methods in military problems.

The research was carried out in the Scopus and Web of Science databases in August 2021. There were no limits of date, document type, or access type. Figure 1 illustrates the steps used to choose the most relevant documents for the topic, analysis and results obtained with the bibliometric analysis.

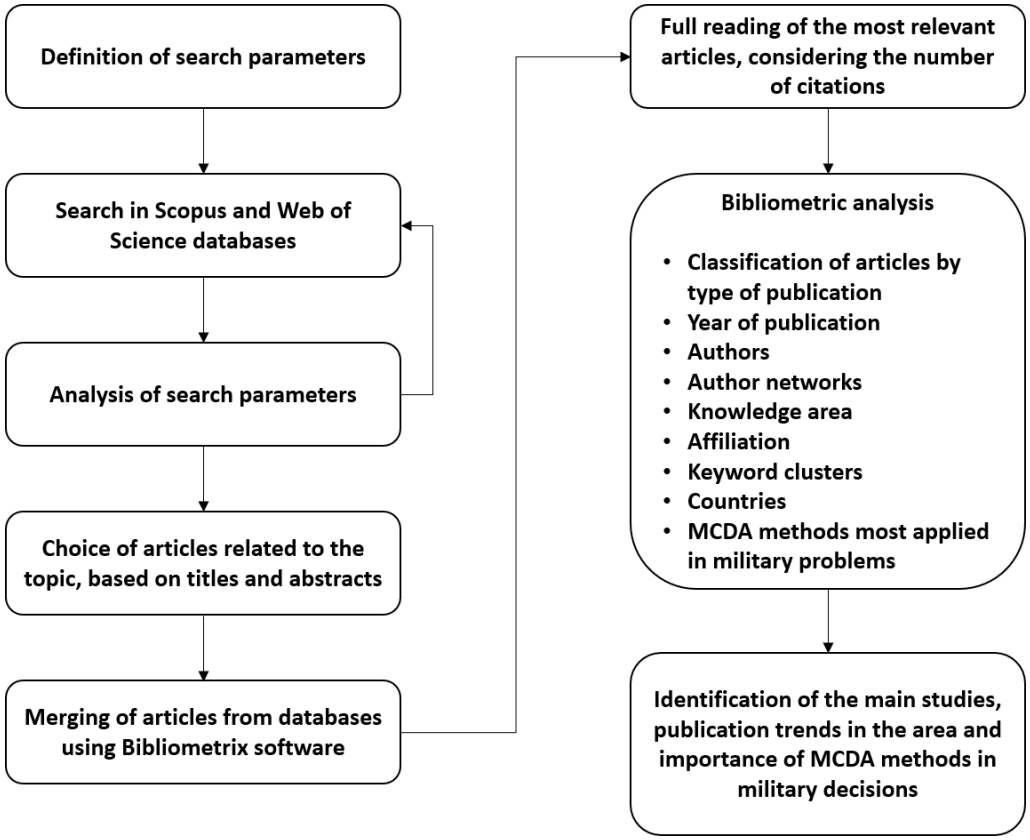

Figure 1 – Steps of the methodology.

This study considered the Webibliomining model proposed by Costa (2010). The following strategy was tested in the Scopus and Web of Science databases to find documents on applications of MCDA methods in military problems, linking both research themes via the following search parameters:

- TITLE-ABS-KEY ((”multicriteria” OR ”multiple criteria” OR ”MCDA” OR ”MCDM” OR ”AHP” OR ”ANP” OR ”ELECTRE” OR ”TOPSIS” OR ”MACBETH” OR ”PROMETHEE” OR ”DEMATEL”) AND (”military” OR ”navy” OR ”army” OR ”air force” OR ”war”)).

After a preliminary analysis of titles and abstracts, we selected the relevant articles for this study and merged articles from the Scopus and Web of Science databases, excluding duplicate documents. After these procedures, we found 685 studies with the themes analyzed (Table 1).

A bibliometric study was developed to identify the year of publication, journals, clusters of keywords, authors, affiliation, country/territory, fields of knowledge and language. VOSviewer and

Table 1 – Search results in the SCOPUS and Web of Science databases.

Document type	Number of articles (%)	
Journal article	383	55.9%
Conference article	261	38.1%
Book chapter	26	3.8%
Review	15	2.2%
Total	685	100.00%

bibliometrix softwares were used to analyze keyword clusters and the author network. They are tools for creating maps, viewing and exploring (Van Eck & Waltman, 2018). According to Aria and Cuccurullo (2017), increasing publication rates and fragmented research streams make the use of bibliometry essential for scientific mapping.

Figure 2 shows the distribution of articles by year of publication.

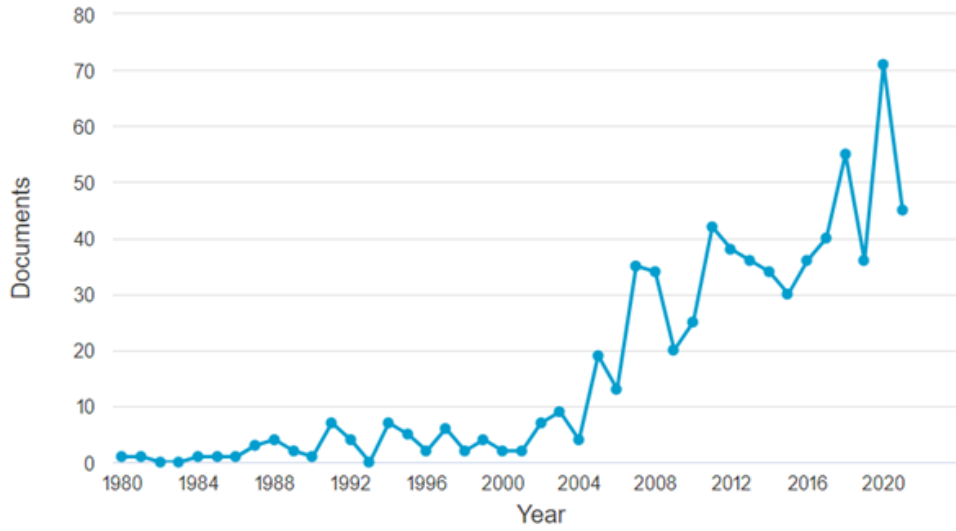

Figure 2 – Distribution of articles by year.

Distribution began in 1980 with one paper. The number of documents per year did not follow a pattern. Although, from 2004 to 2019, there was a significant increase in the number of articles published with fluctuations from 5 to 71 articles per year. In 2020, there was the highest number of publications (71 articles), which represents an increasing trend of applications of MCDA methods in military problems.

4 RESULTS AND ANALYSIS

To identify the main studies in the area, we analyzed the 20 papers with the greatest impact. For this, we analyzed the absolute number of citations and the average of citations per year (Table 2).

We observed that the most relevant works deal with the evaluation for the acquisition or choice of high-tech and high-value military assets, such as aircraft, battle tanks, missiles and ammunition. In general, this result corroborates the fact that most applications of MCDA methods in military problems are related to the strategic sphere, as seen in section 2.

This fact illustrates the importance of multicriteria methods in military issues, as these tools support the decision-making process in real problems that directly affect the security and sovereignty of nations. Besides, the costs involved in military technologies are very high, and a wrong decision can lead countries to significant losses, which is why MCDA methods are increasingly being applied in military problems.

The analyzed articles were published in different journals. Table 3 shows the distribution of articles by journal, considering 4 or more works. The European Journal of Operational Research stands out with 11 published articles, followed by Advances in Intelligent Systems and Computing, with 10. Journal of Military Medicine and Applied Mechanics and Materials published 9 papers each. Therefore, it is noted that the articles are distributed by a wide variety of journals.

Analyzing the words can bring information and knowledge about a certain subject (Ishikiriyama et al., 2015). This research used VOSviewer software to analyze keywords, including author keywords and index keywords. The fractional counting method (the weight of a link is fractionated) and the linglog/modularity normalization method were used. The minimum number of occurrences of a keyword was 10, and 81 of 5,291 keywords reached this threshold. Figure 3 shows the clusters of keywords.

The keyword ”decision making” has the highest number of occurrences (o = 169) and the highest total binding force (s = 600), followed by ”analytic hierarchy process” (o = 94, s = 354). The most related military problems are ”risk management”, “location” and “logistics”. Next, we analyzed publishing trends over the last 20 years (Figure 4).

Analyzing the temporal distribution, we observed that the first applications dealt with problems related to military operations and logistical issues. Over time, the issues began to address artificial intelligence and risk assessment. The latest applications seem to indicate a trend in issues of locating and acquiring military vehicles. In addition, the AHP and TOPSIS methods stand out as the most applied in the area. This leads us to believe that the compensatory mentality is present in this type of problem.

Table 4 shows the distribution of articles per author, in descending order according to the number of published articles, considering 5 or more papers. Linkov, I. has the largest number of works published in the area, with 12, followed by Cheng, C.H. (9 papers) and Bahadori, M. (8 articles).

This research also used the VOSviewer software to obtain the authors' relationship network, considering 4 as the minimum number of articles per author, without limiting the number of

Table 2 – Main studies in the area.

Authors	Title	Total Citations (TC)	TC per Year
(T.-C. Wang & Chang, 2007)	Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment	431	269.3
(Cheng, 1997)	Evaluating naval tactical missile systems by fuzzy AHP based on the grade value of membership function	367	141.1
(Cheng & Lin, 2002)	Evaluating the best main battle tank using fuzzy decision theory with linguistic criteria evaluation	342	162.8
(Cheng et al., 1999)	Evaluating attack helicopters by AHP based on linguistic variable weight	279	116.2
(Mon et al., 1994)	Evaluating weapon system using fuzzy analytic hierarchy process based on entropy weight	227	78.2
(Cheng & Mon, 1994)	Evaluating weapon system by Analytical Hierarchy Process based on fuzzy scales	174	60.0
(Cheng, 1999)	Evaluating weapon systems using ranking fuzzy numbers	158	65.8
(Sennaroglu & Varlik Celebi, 2018)	A military airport location selection by AHP integrated PROMETHEE and VIKOR methods	105	210.0
(Bisdikian et al., 2013)	On the quality and value of information in sensor networks	97	97.0
(Roussat et al., 2009)	Choosing a sustainable demolition waste management strategy using multicriteria decision analysis	92	65.7
(Farahani & Asgari, 2007)	Combination of MCDM and covering techniques in a hierarchical model for facility location: A case study	77	48.1
(Gigović et al., 2016)	The Combination of Expert Judgment and GIS-MAIRCA Analysis for the Selection of Sites for Ammunition Depots	73	104.3
(Greiner et al., 2003)	A hybrid approach using the analytic hierarchy process and integer programming to screen weapon systems projects	69	34.5
(J. Lee et al., 2010)	A hybrid approach of goal programming for weapon systems selection	66	50.7
(Jiang et al., 2011)	Weapon System Capability Assessment under uncertainty based on the evidential reasoning approach	60	50.0
(Deng, 2015)	A Threat Assessment Model under Uncertain Environment	53	66.2
(Qu & He, 2002)	A method of threat assessment using multiple attribute decision making	53	25.2
(Rose-Pehrsson et al., 2000)	Multi-criteria fire detection systems using a probabilistic neural network	52	22.6
(Pamučar et al., 2018)	Normalized weighted geometric Bonferroni mean operator of interval rough numbers – Application in interval rough DEMATEL-COPRAS model	51	102.0
(Goossens & Basten, 2015)	Exploring maintenance policy selection using the Analytic Hierarchy Process; An application for naval ships	51	6.3

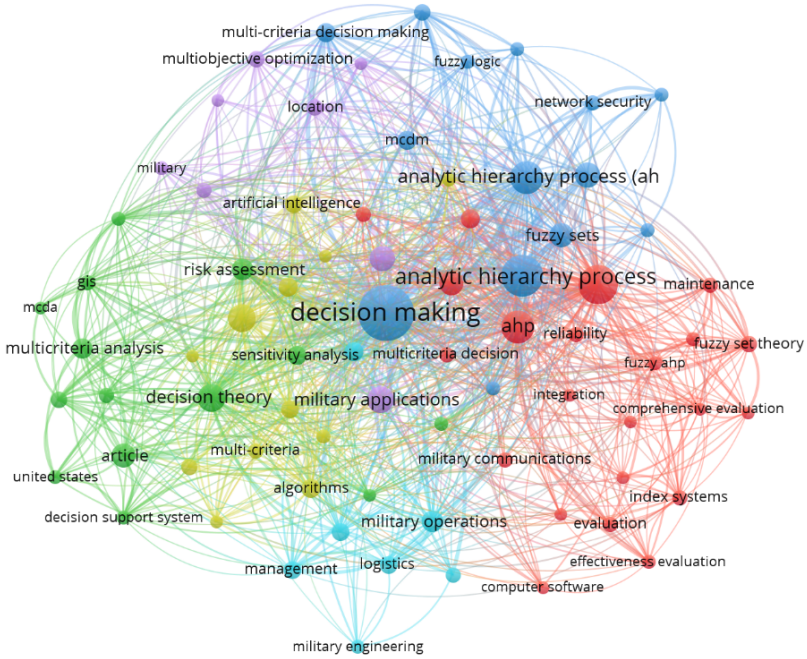

Figure 3 – Keyword clusters.

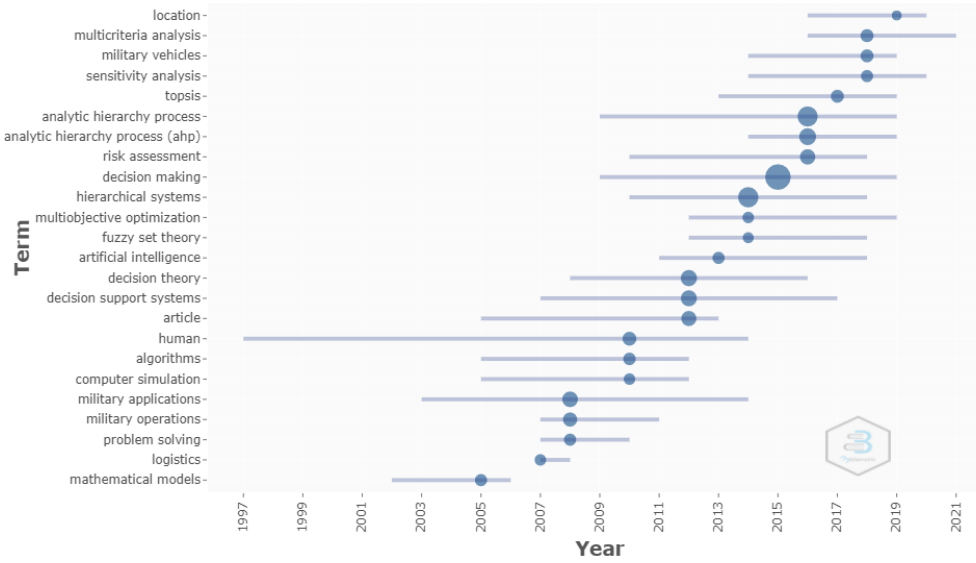

Figure 4 – Trend Topics in the area.

Table 3 – Distribution of articles by journals with at least 4 papers.

Journal	Number of articles
European Journal of Operational Research	11
Advances In Intelligent Systems and Computing	10
Applied Mechanics and Materials	9
Journal of Military Medicine	9
Expert Systems with Applications	6
Interfaces	6
IEEE Transactions on Engineering Management	5
Sustainability Switzerland	5
Journal of the Operational Research Society	5
Journal of Defense Modeling and Simulation	4
Defence Science Journal	4

Table 4 – Distribution of articles by author.

Author	Articles
Linkov, I.	12
Cheng, C.H.	9
Bahadori, M.	8
Karvetski, C.W.	6
Lambert, J.H.	6
Gomes, C.F.S.	5
Teymourzadeh, E.	5

authors per article. To create the map, we did not select the author with zero total link strength, and we applied the full counting method and the association strength normalization method. Figure 5 shows the author's network with 14 clusters.

The largest set of connected items consists of 5 authors: Liu, B.; Liu, H.; Wang, Y.; Zhang, X. and Zhao, J. This cluster is linked to another one, with 2 authors: Yang, Y. and Wang, J., which is the only relationship between clusters. The largest total relationship strength (s = 11) belongs to 3 authors: Linkov, I.; Lambert, J.H. and Karvetski, C.W. The remaining 11 clusters are not connected.

Table 5 presents the distribution of documents by affiliation, with 9 or more papers. Northwestern Polytechnical University ranks first with 13 documents. Beijing Institute of Technology, United States Air Force Institute of Technology and the National University of Defense Technology have 11 articles each. Also, there are 3 institutions with 10 and 3 universities with 9 documents each.

Table 6 presents the distribution of documents by country or territory. China ranks first with 182 documents, followed by the United States, with 148 published articles. These two countries account for approximately 50% of all published documents on MCDA applications in military

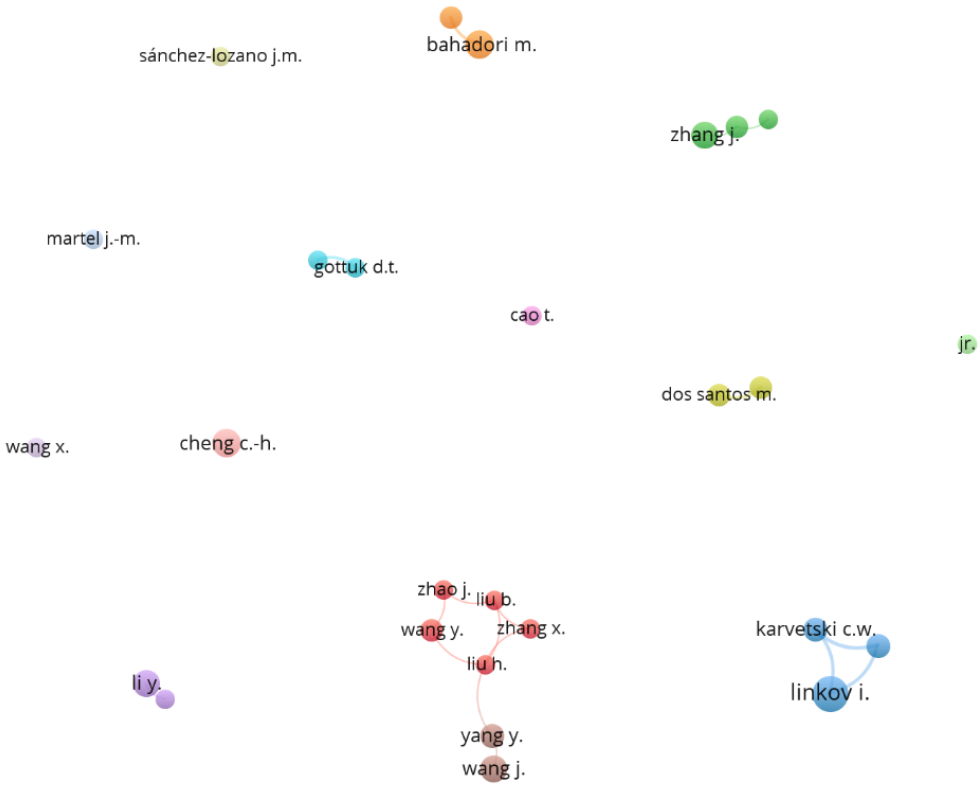

Figure 5 – Clusters of relationships between authors.

Table 5 – Distribution of articles by institutions with at least 9 works.

Institution	Articles
Northwestern Polytechnical University	13
Beijing Institute of Technology	11
United States Air Force Institute of Technology	11
National University of Defense Technology	11
Baqiyatallah University of Medical Sciences	10
Academy of Armored Force Engineering China	10
National Defense University Taiwan	10
Chinese Military Academy Taiwan	9
Air Force Engineering University China	9
Naval University of Engineering	9

problems. This result is probably justified by the fact that they are recognized as the greatest military powers in the world, with more investment in research and military resources. This result corroborates the findings of Pessôa and Costa (2020), but with a greater number of articles analyzed, as we included more military terms in the searches in the Scopus and Web of Science databases. Besides, we considered all types of documents, not just journal articles.

Table 6 – Distribution of articles by country or territory.

Country/territory	Articles
China	182
United States	148
Turkey	38
Taiwan	34
United Kingdom	27
Iran	23
Canada	19
India	19
South Korea	15
Brazil	14
Indonesia	10
Serbia	10

Figure 6 shows the countries that have scientific articles published in the area (highlighted in blue). We emphasize that most of the developed countries have scientific production in the area, but two of them with great war power – Russia and North Korea – do not have published papers in the area. Probably, this fact is due to the secrecy of military operations maintained by those countries.

Regarding publication by continents, Africa and South America have few countries with publications in the area, probably due to the low investment in research and military equipment when compared to more developed countries. Overall, only 58 of the 193 countries (30%) in the world have work in the area. This result indicates a certain inequality generated by the economic and technological disparity. It could be discussed since almost all countries have Armed Forces, and the use of MCDA techniques would certainly improve decision-making in this field.

Figure 7 shows the distribution of articles by field of knowledge: Engineering (26.4%), Computer science (18.0%), Mathematics (9.5%), Decision Sciences (6.6%), Social Sciences (6.6%) and Business Management (5.8%) are the areas that most attract publications, with approximately 74% of documents.

The English language stands out concerning the other ones, representing 91.4% of the total articles (Table 7).

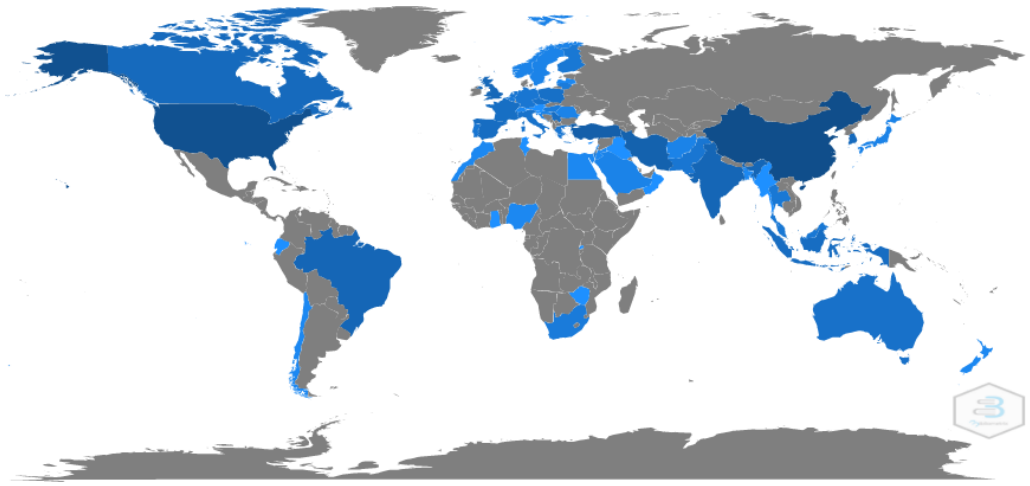

Figure 6 – Country Scientific Production.

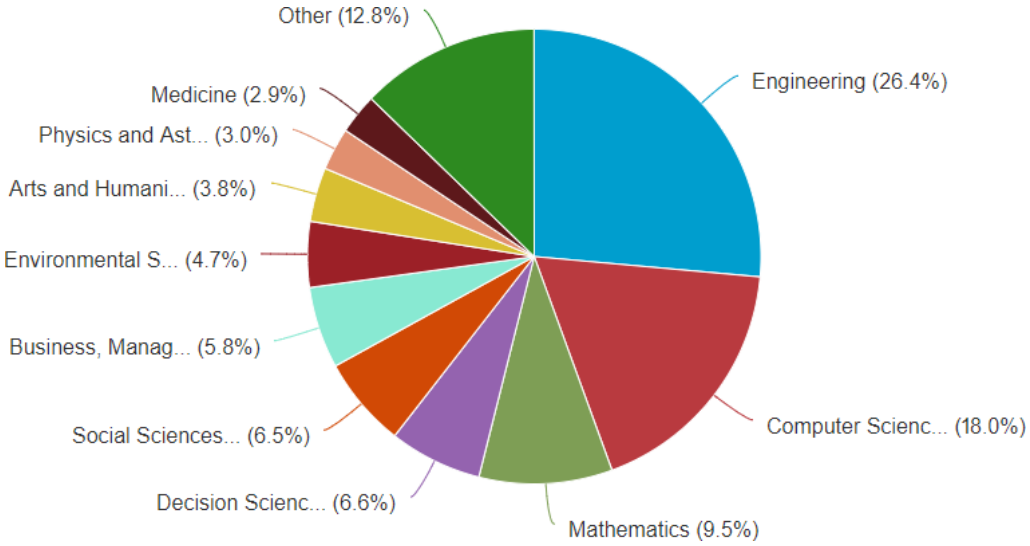

Figure 7 – Distribution of articles by area of knowledge.

Table 7 – Distribution of articles by language.

Language	Articles	Percentage
English	626	91.4%
Chinese	40	5.8%
Persian	10	1.5%
Spanish	4	0.6%
Portuguese	3	0.4%

5 ANALYSIS OF THE APPLIED MCDA METHODS IN MILITARY PROBLEMS

In this article, we analyzed the most applied MCDA methods in military problems (Table 8).

Table 8 – Distribution of MCDA methods.

MCDA method	Percentage
AHP	43.80%
TOPSIS	22.17%
ANP	6.30%
Condorcet	3.56%
PROMETHEE	3.56%
ELECTRE	3.56%
DEMATEL	3.01%
ORESTE	3.00%
VIKOR	2.44%
Borda	2.06%
Verbal Decision Analysis (VDA)	1.13%
MAUT	1.10%
THOR	0.94%
Reference Ideal Method (RIM)	0.56%
Full Consistency Method (FUCOM)	0.56%
Simple Multi Attribute Rating Technique (SMART)	0.56%
REGIME	0.56%
TODIM	0.38%
Utility Additive (UTA)	0.38%
FITradeoff	0.38%
Copeland	0.38%

Analyzing the results, we observed that AHP is the most used MCDA method in military problems, corroborating the findings of Vaidya and Kumar (2006). The authors state that the AHP is considered one of the most well-known and widely disseminated decision-making tools, having the greatest number of applications reported in the literature.

Santos et al. (2021) state that another important factor that justifies the preponderance of the AHP method in military problems is the modeling that involves concepts of hierarchy and compensatory decision rules, which are in accord with military culture. These features facilitate the analysis by the military experts.

More than 72% of applications use compensatory methods (AHP, TOPSIS and ANP), confirming the priority use of compensatory modeling. According to our findings, the AHP is followed and used in most cases in conjunction with the TOPSIS, widely applied to selection/choice problems, which are the most common in military issues. We emphasize that other MCDA outranking

methods widely used in the literature, such as ELECTRE and PROMETHEE, do not have a large number of applications in the themes analyzed in this research.

6 CONCLUSIONS

The bibliometric study provided a descriptive overview of scientific production on applications of MCDA methods in military problems. The research in the Scopus and Web of Science databases showed results with several tactical, operational and strategic applications, presenting many hybrid models, combining the characteristics of different MCDA methods.

The literature review, although not exhaustive, showed several methods and approaches, their concepts, paradigms, steps and applications in different military problems, presenting a strong dual characteristic in the proposed methodologies, as these can also be used to support the decision-making of typically civil problems. It was verified that, in general, the papers are divided by several journals, and there is not one that can be pointed out as the greatest reference in military applications with MCDA.

China and the United States stand out as the countries with the most publications in the area, reflecting their military hegemony, with the highest war power and investments in military technologies worldwide. On the other hand, we found that only 30% of the countries have articles in the area. These applications seem to be directly influenced by economic factors. Among the continents, Africa and South America have the lowest proportions of countries with applications in the area.

The distribution by field of knowledge showed that the articles are spread over several areas. However, Engineering, Computer science and Mathematics concentrate about 50% of the analyzed articles.

The number of articles analyzed is quite large, but it was possible to verify that most applications of MCDA in the military environment refer to the strategic level, notably logistical aspects and acquisitions of military equipment. Regarding the multicriteria methods, there is a considerable dominance of the AHP method, probably because it is the most known worldwide and works with the concept of hierarchy, typical of military culture.

Regarding the importance of decision-making support provided by MCDA methods, it is observed that they are very useful for the success of military operations, in the tactical, operational and strategic spheres, with several applications in the literature. The growing number of applications in recent years seems to indicate that most countries already use these techniques in real military problems, going beyond purely academic applications.

Finally, future works can explore more specifically the tactical and operational levels, since they are the least explored, aiming to verify trends and gaps that can be filled concerning the application of multicriteria applications in the military context.

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