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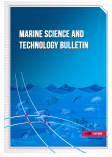

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RESEARCH ARTICLE

Investigation of the use of multi-criteria decision-making techniques in maritime studies with PRISMA method

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ABSTRACT

Multi-criteria decision-making (MCDM) techniques make it possible to reach the optimal solution among different criteria and priorities with their dynamic processes. The ability to analyse big data, use integrated techniques, respond to complex problems in terms of quantitative and qualitative criteria, and structure the result as a repeatable process for different decision makers makes these techniques an increasingly attractive source of reference. MCDM techniques are used in many different fields of science today. One of them is maritime studies. In the current maritime curriculum, the fact that decision-making is among the minimum requirements at both operational and management levels in deck and engine departments draws attention to the importance of the subject in maritime terms. At this point, investigating the use of multi-criteria decision-making techniques in the maritime field on a global scale will contribute to the literature. In this study, the use of MCDM techniques in maritime has been investigated with the PRISMA method. The findings contribute to the scientific literature by revealing the use of multi-criteria decision-making techniques in maritime, their change over time and their main fields of study. With the results obtained, it is aimed to reveal the profile of a methodological concept used globally in maritime studies and to serve as a reference for future studies. Given the evolving landscape of maritime publications utilizing the MCDM technique, the study results will be an incentive to explore potential avenues for future methodological advances.

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Introduction

Decision-making is first and foremost the result of a selection process. This process consists of awareness of the problem, defining the problem, developing solutions, and determining the best alternative. When the best alternative is put into practice, the decision-making process is theoretically completed and the decision is practically realized. In the scientific literature, new methods and approaches to the decision-making process are gaining importance day by day. MCDM techniques, which aim to reach the optimal solution among different criteria and priorities, find application in many different disciplines today.

MCDM addresses the research question in two stages. The first one is the selection of alternatives suitable for the decision makers' objectives and the second one is the ranking of these alternatives (Altın, 2020). At this point, the concepts of multi-objective decision-making and multi-attribute decision making come into play. While multi-objective decision-making searches for the best alternative among different conflicting objectives, multi-attribute decision-making approaches the ideal solution by assigning numerical values to the specific characteristics of the problem (Phua & Minowa, 2005; Dalbudak & Rençber, 2022). The research questions subject to MCDM are essentially based on choosing between certain alternatives by considering criteria appropriate to the dynamics of the problem. In other words, a syllogistic mechanism is inherent in decision-making. However, the alternatives that are subject to syllogism are not always sharply delineated and may be subject to some uncertainty. Decision-making science commonly uses fuzzy logic to deal with uncertainty. Fuzzy logic can be defined as a generalized version of classical two-valued logic based on [0-1] (Baykal & Beyan, 2004). According to another definition, it constitutes the intersection set of multi-valued logic system that assumes that propositions can take more than 2 values with reasoning in case of uncertainty (Özkan, 2003). The concepts of fuzzy logic, fuzzy set and fuzzy system were first introduced by L. A. Zadeh in 1965 (Zadeh, 1965; Yavuz & Deveci, 2014; Uludağ & Doğan, 2016). This theory, which was not accepted much at first, started to gain importance in the literature with the modelling of a steam engine control with a fuzzy logic system in 1975 in England (Şen, 2009; Yıldırım et al., 2016).

MCDM problems can use different methods simultaneously to reach the ideal outcome regardless of the uncertainty (Öztel, 2021). The critical distinction here is the decision maker's process of determining the most appropriate technique or techniques for the nature of the problem. Problems subject to MCDM are essentially categorized according to selection, classification and ranking. While selection problems are based on the selection of the ideal alternative among different options, classification techniques focus on the grouping of alternatives and ranking techniques focus on the priorities among alternatives (Dalbudak & Rençber, 2022). In the literature review, 26 multi-criteria decision-making techniques mainly used in the maritime literature were obtained. These are AHP (Analytic Hierarchy Process), AHP & QFD (Quality function deployment) & DEMATEL (Decision-making Trial and Evaluation Laboratory), AHP & TOPSIS (Technique for Order Preference by Similarity to Ideal Solutions), ANP (Analytic Network Process), BWM (Best Worst Method), CODAS (COmbinative Distance-based ASsessment), DECISION TREE, DELPHI, DEMATEL, FDM & PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluation), Fuzzy AHP, Fuzzy AHP & PRAT Proportional Risk Assessment Technique, Fuzzy AHP & TOPSIS, Fuzzy AHP & VIKOR, Fuzzy ANP, Fuzzy BWM, Fuzzy, DEMATEL, Fuzzy FMEA (Failure Mode and Effect Analysis), Fuzzy TOPSIS, PRAT, PROMETHEE, QFD, SMMA (Stochastic Multicriteria Acceptability Analysis) & TOPSIS, VIKOR (VIseKriterijumsa Optimizacija I Kompromisno Resenje), WASPAS (Weighted Aggregated Sum Product Assessment). Within the scope of the study, these techniques were examined according to their frequency of use and the most commonly used ones are examined below.

AHP divides the problem subject to MCDM into sub-problems by making pairwise comparisons and ranks them hierarchically. Thus, the ranking obtained makes it possible to solve the best alternative (Haliloğlu & Odabaş, 2018).

ANP can be defined as a generalized version of AHP. ANP refers to a more complex process for finding the weights of interacting components of problems that cannot be defined by a hierarchical structure (Üstün et al., 2005; Ömürbek et al., 2013). While AHP is based on a one-way hierarchy, ANP makes it possible to include more complex relationships in the decision-making process. Thus, it becomes possible to model complex problems that cannot be modelled with hierarchical structures due to decision levels and characteristics at the AHP level (Dağdeviren et al., 2006; Dalbudak & Rençber, 2022).

TOPSIS is a MCDM technique developed by Hwang and Yoon in 1981, which represents a multi-objective decision-making problem with "m" number of alternatives and "n" number of criteria with m points in n-dimensional space. TOPSIS, which is based on the concept of a compromise

solution, is based on the shortest distance to the positive-ideal solution and the farthest distance to the negative-ideal solution for the selection of the solution alternative. This idea was introduced by Hwang & Yoon (1981) and later developed by Zeleny (1982), Yoon (1987), Hall (1989) and Hwang et al. (1993) (Yoon & Hwang, 1995; Ömürbek et al., 2013). Fuzzy TOPSIS technique is the application of fuzzy logic integrated into TOPSIS technique.

VIKOR is a MCDM technique developed by Opricovic in 1998 for solving complex problems. VIKOR is based on the selection of the most appropriate alternative by including multiple criteria in the decision-making process and performing a ranking process that will provide maximum group benefit (majority rule) and minimum individual regret among different alternatives (Opricovic & Tzeng, 2004; Yıldırım et al., 2016, Dalbudak & Rençber, 2022). In other words, VIKOR is a useful technique when more than one criterion must be included in the selection process for the final decision. The VIKOR method operates on the assumption that the criteria weights are known. However, multi-criteria decision problems, by their very nature, do not always provide the researcher with a complete data set, which makes it difficult to quantify the criteria. Uncertain situations in reality and the existence of conflicting criteria emphasize the fuzzy VIKOR concept. Fuzzy VIKOR, which emerged by applying fuzzy logic to the VIKOR method, fuzzifiers both criteria and criteria weights in the decision-making process (Opricovic, 2011; Yıldırım et al., 2016).

WASPAS is a widely used technique in the decision-making process of multi-criteria problems. Developed in 2012 by Zavadskas et al. (2012), the WASPAS technique is essentially a synthesis of the Weighted Sum Model (WSM) and Weighted Product Model (WPM) methods (Adalı & Işık, 2017; Çakır et al., 2018; Dalbudak & Rençber, 2022).

PROMETHEE, developed by Brans in 1982, is essentially based on a ranking system and is a useful technique when it comes to ranking for solving multi-criteria decision-making problems. The technique is divided into partial ranking (PROMETHEE I) and full ranking (PROMETHEE II) (Brans et al., 1986; Ekin & Okutan, 2021). PROMETHEE enables the pairwise comparison of available alternatives according to 6 types of preference functions by means of specified criteria (Brans & Vincke, 1985; Ekin & Okutan, 2021).

DEMATEL, which stands for Decision-Making Trial and Evaluation Laboratory, focuses on the analysis of factors affecting the decision-making process and the relationship between these factors (Nilashi et al., 2015; Akın, 2017). Developed between 1972 and 1976 in Geneva, DEMATEL is based on graph theory to enable the analysis and hierarchical explanation of nested complex problem groups (Li & Tzeng, 2009; Aksakal & Dağdeviren, 2010). With the advantage of visualization, DEMATEL facilitates the solution of the problem by dividing the factors affecting the process into cause-and-effect groups (Li & Tzeng, 2009; Aksakal & Dağdeviren, 2010; Tzeng & Huang, 2011; Akın, 2017).

The concept of MCDM with its dynamic techniques and analysis methods is becoming increasingly important in many different fields of science. One of these is maritime studies. According to current maritime curriculum, learning and applying decision-making techniques are among the minimum requirements for both operational and management levels of deck and engine departments (Anonymous, 2018). At this point, it is a critical need for the literature to investigate the applications of MCDM techniques in the maritime studies on a global scale. In order to meet this need, this study seeks to answer the following research questions and aims to contribute to the literature with the results obtained.

- What are the main MCDM techniques used in maritime studies?
- What are the main areas of use of MCDM techniques in maritime studies?
- What is the time-dependent change of the studies carried out with MCDM techniques in maritime?
- What is the share of research articles using MCDM techniques in the maritime field in total studies?
- What is the distribution of research articles using MCDM in maritime studies according to journals and years?

This study aims to investigate the use of MCDM techniques in the maritime studies. For this purpose, a literature review covering the last 15 years was conducted through Scopus and Science Direct databases, focusing only on peer-reviewed research articles. Accordingly, both databases were first filtered with the keywords “multi-criteria decision making” and “maritime transportation” and review articles, book/book chapters, editorials, short communications and conference abstracts were extracted from the dataset. Within the scope of the study, only articles written in English were evaluated. The lower temporal limit was set as 2009, since this is the date of publication of the oldest article accessed with the relevant keywords. The literature review was conducted as of August 9, 2023 and the PRISMA method was used as the methodology. As a result of the first stage, 159 articles were found that used

MCDM techniques in maritime studies. The main distribution of the obtained studies according to their subjects was obtained as Engineering, Environmental Science, Social Sciences, Decision Sciences, Energy, Business, Management & Accounting, Mathematics, Computer Science, Earth and Planetary Sciences and Materials Science. Within these fields, maritime studies are focused on Maritime Economy, Maritime Education, Maritime Management, Maritime Policy, Maritime Safety, Maritime Transportation, Port Sustainability, Ship Energy Efficiency, Shipbuilding, Maritime Tourism. The results revealed the profile of the research articles that utilize the MCDM techniques of the maritime literature. Accordingly, using MCDM techniques have generally shown a steady upward trend, although they have shown small fluctuations in some years. Furthermore, the study profiles the most frequently used decision-making techniques using in maritime literature 15 years of literature and categorizes them according to topics. Obtained results showed that the main decision-making techniques used in the maritime studies are AHP, Fuzzy AHP, TOPSIS, Fuzzy TOPSIS, DEMATEL, ANP and VIKOR.

MCDM techniques are used in many different disciplines of science today. The main advantages of MCDM are that it makes big data analysis possible, techniques can be used in an integrated manner, complex problems can be answered in terms of quantitative and qualitative criteria, and the result is structured as a repeatable process for different decision makers. Accordingly, the use of MCDM in the academic literature is gaining more importance day by day and the number of studies conducted with MCDM is increasing in parallel. This study is the first to address the use of MCDM, which is gaining momentum on a global scale, in the maritime field from a holistic perspective. The obtained results aim contribute to the scientific literature by revealing the use of multi-criteria decision-making techniques in maritime, their time dependent change and their main fields of study.

Material and Method

In this study, the dataset obtained by filtering the studies using MCDM as a method in the maritime studies between 2009 and 2023 using Scopus and Science Direct databases. The mentioned databases were selected because they contain over 19 million peer-reviewed and accessible full-text articles in their portal and were considered to constitute a highly representative sample group on the subject. This data obtained through systematic literature search was then analysed using the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols) method.

PRISMA method, especially used in evidence-based medicine and health sciences, is one of the most common methods used to standardize meta-analysis reports. The PRISMA method, which proceeds with a dynamic checklist, provides an ideal roadmap for setting study boundaries, making it easier to focus on the research question. Because of these advantages, the method is used today in many different fields of science. In the Science Direct database, the mainly scientific disciplines using PRISMA systematic review are medicine and dentistry, neuroscience, psychology, nursing and health professions, biochemistry, genetics and molecular biology, agriculture and biological sciences, environmental sciences, social sciences, computer science, pharmacology, toxicology and pharmaceutical sciences.

In the PRISMA method, the data set that will form the basis for the screening emerges by selecting the inclusion criteria and removing duplicate publications that do not meet the criteria from the data set. The keywords, the year of the search and the date of the search constitute the most critical stages of the method. The fact that PRISMA can be replicated/tested by different researchers for further studies makes it attractive for use as a scientific method in different disciplines. Aşık & Özen (2019) defined the PRISMA process with the stages of detection, screening, eligibility and inclusion. The identification phase includes the characteristics of the databases, keywords and selected studies. By isolating duplicate studies, the number of studies subject to screening, i.e., the new "n" value, is obtained. These studies expressed with the new "n" value and the studies included/excluded in the research after screening are explained by stating their justifications. In this way, the studies included in the research are clearly revealed. In this study, the PRISMA method is adapted to maritime studies for the first time in the literature to the authors' knowledge, focusing on the use of MCDM techniques in maritime studies. Thus, it is aimed both to create an infrastructure for new studies in maritime studies and to make a methodological contribution to the maritime literature by using a new technique. The implementation of the PRISMA method to the study is given in Figure 1.

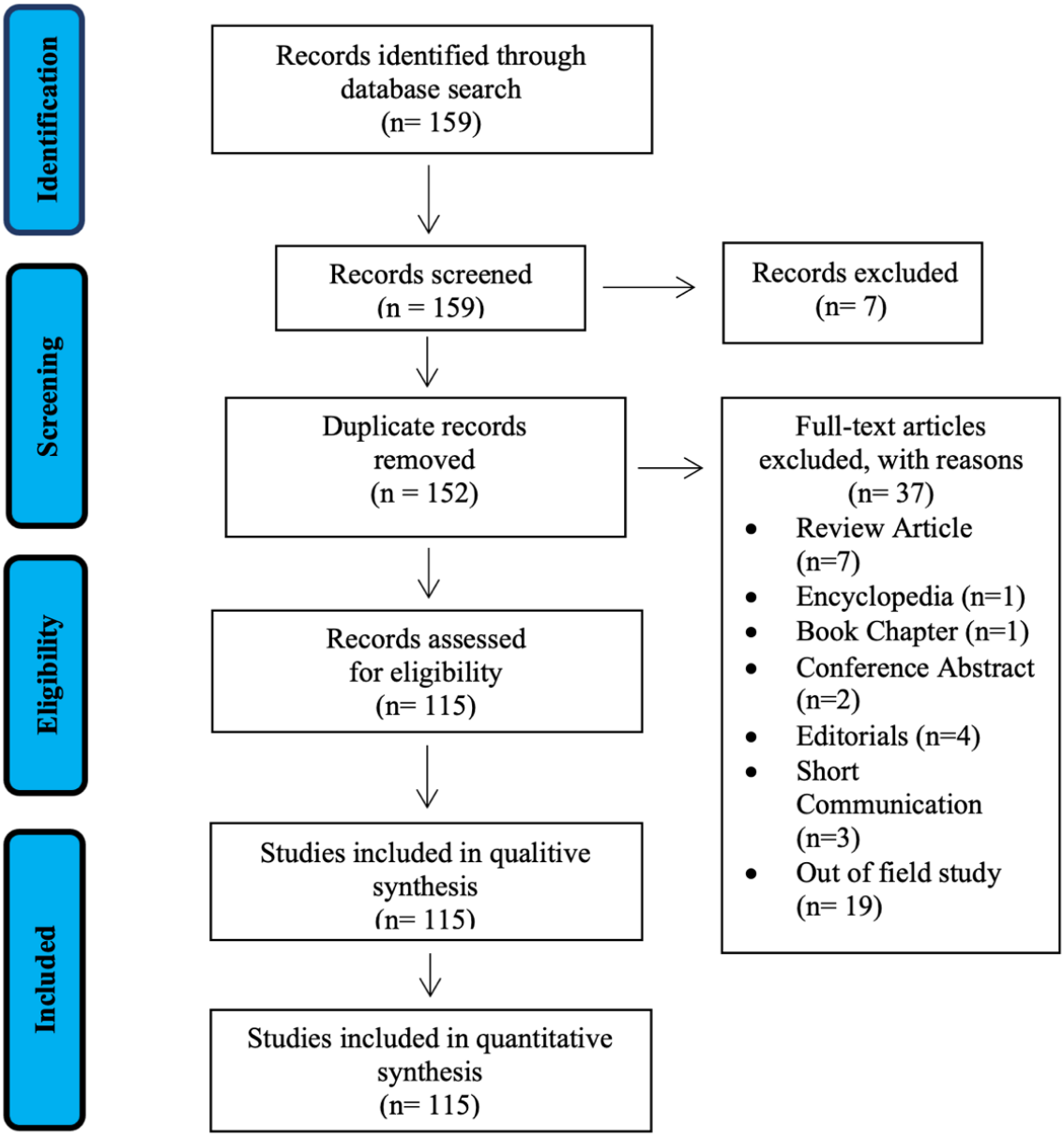

Figure 1. Implementation of the PRISMA method to the study

This investigation focuses only on English-language research articles that have been peer-reviewed and whose full text is available. The search was conducted on August 9, 2023 through Science Direct and Scopus databases with the keywords "multi criteria decision making" and "maritime transportation" and 159 articles were found. 7 of these articles were eliminated from the data set due to duplication. When the remaining 152 articles were scanned, a total of 37 studies, including 7 review articles, 1 encyclopaedia, 1 book chapter, 2 abstracts, 4 editorials, 3 short communications and 19 out-of-field articles, were excluded from the research because they did not meet the eligibility criteria. Thus, 115 articles that met the necessary criteria for the study were included in the qualitative and quantitative study.

Results and Discussion

The obtained results made it possible to reach more than one judgment. The results of the study firstly reveal the main using areas of MCDM techniques in maritime. Accordingly, the main areas where MCDM techniques have been used in the last 15 years of literature are maritime transportation, maritime safety, ship energy efficiency and sustainability. These areas are followed by maritime management, maritime economics, maritime education, maritime policy and shipbuilding. The results obtained are given in Figure 2.

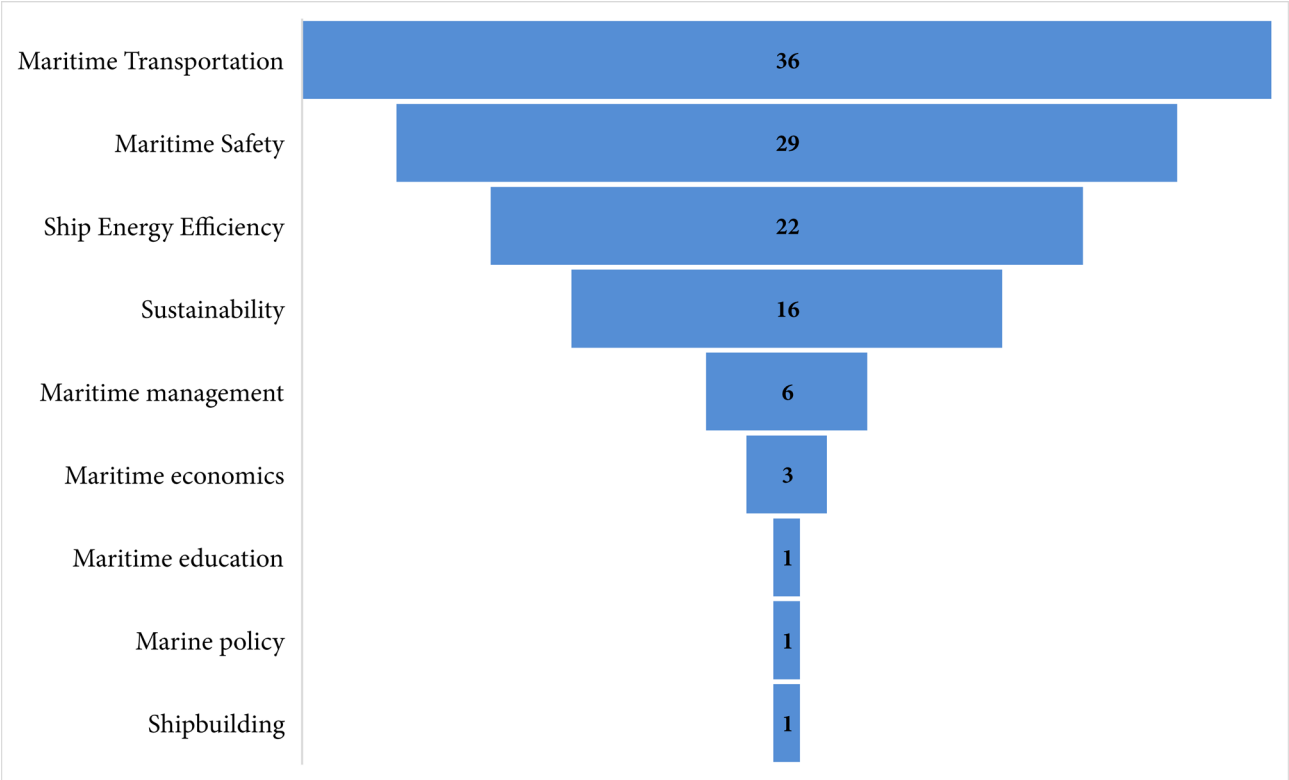

Figure 2. Application areas of MCDM techniques in maritime studies (2009-2023)

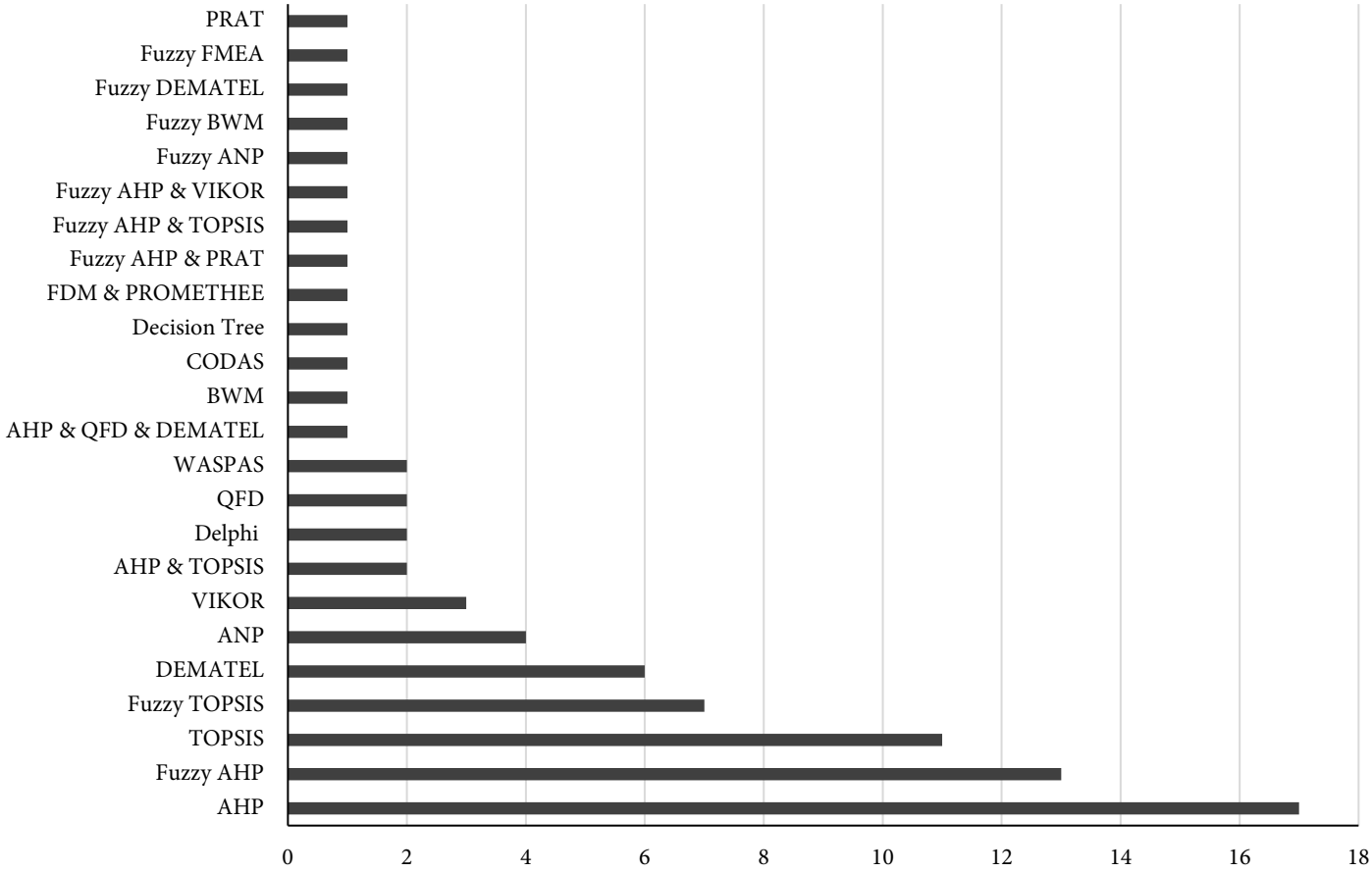

Figure 3. The frequency of use of MCDM techniques in maritime studies (2009-2023)

Table 1. Classification of studies with MCDM techniques according to keywords

Technique	Area
AHP	Maritime tourism, maritime transportation, sustainability, maritime safety, shipbuilding, shipyard, smart ports, ship energy efficiency
AHP & QFD & DEMATEL	Maritime Transportation
AHP & TOPSIS	Maritime Transportation
ANP	Maritime transportation, sustainability
BWM	Port sustainability
CODAS	Sustainability
DECISION TREE	Maritime safety
DELPHI	Sustainability
DEMATEL	Maritime safety, maritime transportation, sustainability, smart ports
FDM & PROMETHEE	-
Fuzzy AHP	Maritime education, maritime economics, maritime transportation, maritime management, ship energy efficiency, maritime safety
Fuzzy AHP & PRAT	Maritime Safety
Fuzzy AHP & TOPSIS	Ship energy efficiency
Fuzzy AHP & VIKOR	Maritime Transportation
Fuzzy ANP	-
Fuzzy BWM	Maritime Safety
Fuzzy DEMATEL	Maritime management
Fuzzy FMEA	Maritime safety
Fuzzy TOPSIS	Maritime transportation, maritime education, maritime safety
PRAT	-
PROMETHEE	Ship energy efficiency
QFD	Shipbuilding
SMMA & TOPSIS	Maritime transportation
TOPSIS	Maritime transportation, maritime safety, ship energy efficiency
VIKOR	Shipbuilding
WASPAS	Maritime economics, sustainability

The results also answered the question of which MCDM techniques are widely used in maritime. As a result of the literature review, 115 studies were analysed according to keywords and evaluated in terms of the technique used. Thus, the studies in the maritime with MCDM techniques were classified according to keywords. The findings are given in Table 1.

Table 1 shows that in the last 15 years, some techniques have been more widely used in maritime than others. These are AHP/Fuzzy AHP, ANP, BWM, CODAS, DECISION TREE, DELPHI, DEMATEL, Fuzzy FMEA, PRAT, PROMETHEE, QFD, SMMA, TOPSIS/Fuzzy TOPSIS, VIKOR and WASPAS. One of the main advantages of MCDM is that the techniques can be used integrated with each other according to the research question and data structure. The results obtained in this context show that the prominent techniques in terms of joint use are AHP & QFD & DEMATEL, AHP & TOPSIS, FDM & PROMETHEE, Fuzzy AHP & PRAT, Fuzzy AHP & TOPSIS, Fuzzy AHP & VIKOR and SMMA & TOPSIS.

Table 2. Share of maritime studies in total studies achieve

Years	All Studies	Research Articles	The share of research articles in total
2023	24	19	0.79
2022	31	26	0.84
2021	22	16	0.73
2020	16	13	0.81
2019	10	7	0.70
2018	12	7	0.58
2017	4	2	0.50
2016	10	7	0.70
2015	10	9	0.90
2014	2	2	1.00
2013	3	2	0.67
2012	4	2	0.50
2011	0	0	0.00
2010	1	0	0.00
2009	3	3	1.00

Obtaining the main MCDM techniques used in the maritime literature in the last 15 years has raised the question of their frequency of use. At this point, the number of times each technique was used independently of the keywords was investigated and the findings are presented in Figure 3.

Table 3. Distribution of studies examined by PRISMA method according to journals and years

Journal	Years														
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Applied Mathematics and Computation												1			
Applied Ocean Research								1			1				
Applied Soft Computing											1				
Case Studies on Transport Policy														1	
Computers & Industrial Engineering														3	2
Computers & Operations Research							1								
Decision Analytics Journal															1
Electronic Commerce Research and Applications												1			
Energy											1				
Energy Conversion and Management: X													1		
Engineering Applications of Artificial Intelligence														1	1
European Journal of Operational Research								1							
Expert Systems with Applications	2			1			1				1	1	1		1
Fuel														1	
Information Sciences													1	2	
Innovation and Green Development															1
International Journal of Disaster Risk Reduction					1										
International Journal of e-Navigation and Maritime Economy							1								
International Journal of Hydrogen Energy				1										1	
International Journal of Industrial Ergonomics							1								
Journal of Air Transport Management										1		1		1	
Journal of Cleaner Production									1				2	1	1
Journal of Industrial Information Integration															1
Journal of Loss Prevention in the Process Industries								1							
Journal of Space Safety Engineering										1					
Marine Policy												1	1	1	
Marine Pollution Bulletin															1

Table 3 (continued)

Journal	Years														
	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Nuclear Engineering and Technology															1
Ocean & Coastal Management													1		1
Ocean Engineering	1							1		1	1	3	4	5	3
Procedia - Social and Behavioral Sciences							1								
Procedia Engineering							1								
Process Safety and Environmental Protection															1
Progress in Nuclear Energy														1	
Reliability Engineering & System Safety								1				1	2	1	1
Renewable Energy															1
Research in Transportation Business & Management												1		3	1
Safety Science							1	1	1	2				1	
Sustainable Energy Technologies and Assessments														1	
Sustainable Production and Consumption															1
The Asian Journal of Shipping and Logistics										1			1		
Tourism Management						1									
Transport Policy							1								
Transportation Research Part A: Policy and Practice					1			1				1			
Transportation Research Part B: Methodological												1			
Transportation Research Part D: Transport and Environment						1						1	1	2	
Transportation Research Part E: Logistics and Transportation Review							1			1	1		1		
Transportmetrica A: Transport Science											1				

Figure 3 shows that the most frequently used techniques in the maritime studies are AHP (17), Fuzzy AHP (13), TOPSIS (11), Fuzzy TOPSIS (7) and DEMATEL (6). This was followed by ANP and VIKOR techniques with a frequency of use of 4 and 3 respectively within 15 years. AHP & TOPSIS, DELPHI, QFD and WASPAS techniques have been repeated twice each in the 15-year period, while the other techniques have been used only once in the literature.

With the findings obtained, the temporal change in the use of MCDM techniques in the maritime studies has also been revealed. The decisive distinction here is to obtain profile of research articles. For this reason, review articles, conference abstracts, short communication, book chapters, encyclopaedias and editorials have isolated from the investigation. Thus, profile of research articles in total studies was observed. The results are presented in Table 2 and Figure 4.

The findings revealed that the studies in the data set followed a fluctuating course between 2009 and 2019. Between 2019 and 2022, it was observed that both the number of studies accessed and the number of research articles conducted in the maritime studies showed a steady upward trend. The relative downward trend in 2023 is explained by the fact that the study was conducted as of August 2023. The distribution of the studies examined by PRISMA method according to journals and years is given in Table 3.

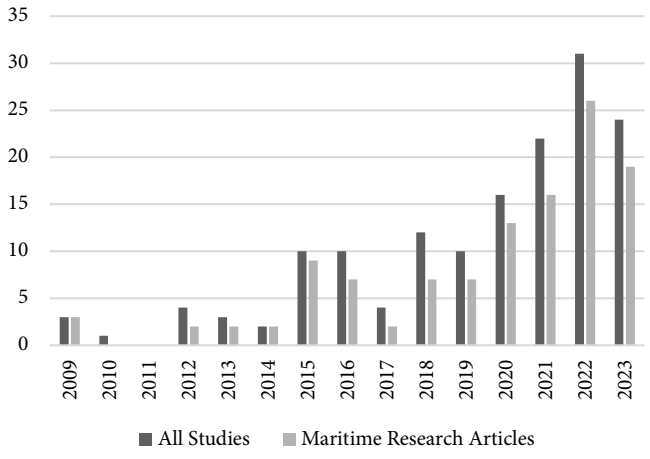

Figure 4. Time-dependent change in the use of MCDM techniques in the maritime studies

Conclusion

Today, MCDM techniques are gaining importance in every field of science. This study focuses on the implementations of these techniques in maritime studies in the literature and answers more than one research question with the results obtained. These results are presented below.

- Although the use of MCDM techniques in the maritime studies exhibited an unbalanced behaviour in the 15-year period, it generally showed an upward trend. Especially it has exhibited a steady upward trend between 2019 and 2022. By the end of 2023, this upward trend is expected to continue.
- In terms of MCDM, when the time-dependent change in the share of maritime research articles in the total number of studies accessed is examined, no steady upward or downward trend is observed.
- A review of 15 years of literature shows that the most commonly used MCDM techniques in maritime studies are AHP, Fuzzy AHP, TOPSIS, Fuzzy TOPSIS and DEMATEL.
- PRISMA, which is used as a study method, contributes to the maritime literature in terms of methodology and provides an alternative method for future studies.
- Obtained results show that the main areas of use of MCDM techniques in maritime transportation, maritime safety, ship energy efficiency, sustainability, maritime management and maritime economics in 15 years of maritime literature. When examined in terms of the technique used and the field of study, the results obtained are as follows.
  - The most used techniques in maritime transportation are AHP, AHP & QFD & DEMATEL, AHP & TOPSIS, ANP, DEMATEL, Fuzzy AHP, Fuzzy AHP & VIKOR, Fuzzy TOPSIS, SMMA & TOPSIS and TOPSIS.
  - The most used techniques in maritime safety are AHP, DECISION TREE, DEMATEL, FUZZY AHP & PRAT, FUZZY BWM, Fuzzy FMEA, Fuzzy TOPSIS & TOPSIS.
  - The most used techniques in ship energy efficiency are FUZZY AHP, FUZZY AHP & TOPSIS, PROMETHEE and TOPSIS.
  - The most used techniques in sustainability are AHP, ANP, BWM, CODAS, DELPHI, DEMATEL.
  - The most used techniques in maritime management are Fuzzy AHP, Fuzzy DEMATEL.
  - The most commonly used techniques in maritime economics are Fuzzy AHP and WASPAS.

Since full-text accessibility is the main criterion in this study, the databases scanned were limited to Scopus and

Science Direct and a basic framework was drawn with the results obtained. This research, which will form an infrastructure for future studies, suggests new researchers to reach micro-scale results by adding different databases to the dataset. In this way, the applications of the ever-renewing and developing analysis techniques of the scientific world in the maritime studies will constitute a reference source for future research.

Compliance With Ethical Standards

Conflict of Interest

The author declares that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Data Availability Statement

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

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