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A SURVEY on MCDM APPROACHES for MARITIME PROBLEMS

Devran YAZIR[1]

ABSTRACT

The maritime industry is a worldwide area of work where critical decisions are made in critical situations. The fact that decision-making is based on a scientific and mathematical basis has been in academic authorities' attendance area for the last five decades. In this study, a literature review has been conducted on the use of decision-making techniques in maritime practices. In the literature survey, Multi-Criteria Decision-Making (MCDM) methods have been examined, studies in Turkey and the International area carded; weights, distributions, usage reasons, advantages, and disadvantages of methods determined based on studies have been comparatively studied. The main aim of this paper is to statistically compare the quality and quantity of the papers published on the decision-making techniques used in maritime in Turkey and the International area. In addition to MCDM techniques, other mathematical methods used in shipping are also included in the study. The evaluation of other mathematical methods and their comparison with the commonly used methods have been made under a subtitle in this paper.

Anahtar Kelimeler: *MCDM, MADM, Fuzzy, Maritime Decision-Making, Mathematical Decision-Making Methods*

[1]Dr. Öğr. Üyesi, Karadeniz Teknik Üniversitesi, Sürmene Deniz Bilimleri Fakültesi, Deniz Ulaştırma İşletme Mühendisliği Bölümü, Trabzon, Türkiye https://orcid.org/0000-0002-6825-8142, dyazir@ktu.edu.tr

1. INTRODUCTION

Decision analysis is a process that provides a systematic order to explain decision-making situations better. During this period, many authors made different opinions. But systematic decision analysis is lying down to Benjamin Franklin (1706-1790). Writing positive effects of decisions on one side of a white paper and writing adverse effects of decisions on the other side of the paper is fundamental of Benjamin's procedure.

On the other hand, the multi-criteria decision-making method examines more than one criterion and tries to reveal the issue solution most transparently with many concrete and abstract factors. Also, it is accepted that the academic field of Multi-Criteria Decision Making (MCDM) started with a paper which belongs to Stan Ziont named 'MCDM- If Not a Roman Numeral, then What?' (Zionts, 1979). Definitely, some papers such as ELECTRE Method (Roy, 1968), Choquet Integral (Choquet, 1954), AHP Method (Saaty, 1972), and Fuzzy Set (Zadeh, 1965), underpin the MCDM by providing it to be grown but the paper of Stan Zionts can be defined as a touchstone which is accepted MCDM compilation by most of the academists. Multi-Criteria Decision-Making (MCDM) method has been preferred in the maritime industry in recent years. MCDM was chosen because it is a massive factor in the transparent handling of events in the maritime sector. Besides, while the MCDM method is preferred in the maritime sector, it has also made significant progress in the last 45-50 years (Koksalan et al., 2011). In this case, it caused the organizations affiliated with the maritime sector to make fast and correct decisions. If it is necessary to give some examples of the use of MCDM applications in the maritime sector, these can be given as follows; MCDM (Multi-Criteria Decision-Making) procedure on cargo type selection (Ozdemir and Guneroglu, 2018), the Hybrid MCDM method to determine service quality factors in a port (Tsai et al., 2018), MCDM approach to decide dry port location (Nguyen et al., 2016), etc. Many studies focused on MCDM methods in maritime, and they will be considered in this working, detail. From a general perspective; port performance evaluation and related topics have been focused recent years and mostly used techniques can be given as AHP (Analytic Hierarchy Process), TOPSIS (Technique for Order Preference by Similarity to Ideal Solution), PROMETHEE (The Preference Ranking Organization Method for Enrichment Evaluation) and their combinations with their fuzzy versions. However, studies that

have been done after the year 2016 are analyzed in this research. This work aims to compare up to date MCDM workings on maritime in Turkey with international workings.

For the literature survey, 19 national papers and 73 international papers have been investigated and analyzed carefully. It is aimed to look at the event globally through both national and international literature research. According to analyses, workings have been classified into eight categories for clear understanding and comparison, which are human resources, ship machine, and equipment selection, port/facility location decision, route selection, port performance/efficiency/risk analysis, ship selection, port/facility, and management selection and others. This classifying was created carefully for workings to be non-grouped as much as possible. In this way, it provided the opportunity to make understandable, simple, and wide-ranging research without getting things too complicated. This study comprehensive compared the quality and quantity of the papers published on the decision-making techniques used in maritime in Turkey and the International area. Often a lot of research is done to create a general perspective on a topic. These are, respectively, obtaining data from the internet, scanning current articles on the subject, reports, books, encyclopedias, etc. use of resources. However, presenting that subject in a scientific form and, most simply, examining a lot of data about that subject in an article will enable a more objective look at the events. Therefore, this study is to serve as a resource to create an overview of the topic.

2. METHODOLOGY

The introduction to a topic is vital in the subject, as much as the topic be fluent. The national and international papers discussed in this article can be a reference for the author. However, a start must demonstrate how understandable and fluent this work is. This paper is a point for the past, but a reference for the years to come. First of all, the study on the mathematical methods used in Turkey's maritime activities are correct, precise, concrete evidence and our systematic approach to the subject effective decision-making situations are investigated. Taking the events after 2016, it should obtain information with the available data, develop ideas effectively, and evaluate the research results by minimizing the margin of error. Therefore, decision analysis of mathematical methods applied in maritime, taken up separately for Turkey and the international arena, all the literature published after 2016 were screened. After the incident's findings were handled meticulously, they were noted independently, and the subject was continued with interpretation.

Subsequently, the studies were divided into eight subgroups determined by us, and the articles published were classified according to these groups. With this grouping, when the events were gathered under eight subtitles, it was possible to view the events from specific to general. Thus, the findings were fed with enough evidence. Studies that stand out in the specified subgroups are briefly explained, and the studies are presented not only in terms of quantity but also in terms of quality. The reason for this criterion is to add comments to the subject and to conclude with opinions. Studies using similar methods have been analyzed in this paper. However, the advantages, disadvantages and superior aspects of these studies over other studies have been emphasized. Subsequently, sub-fields that have been studied more in national and international publications were determined. Compared with Turkey's efforts focus on the issues to which the global study. Turkey's position in comparison with the results it has been detected. Then, the usage weights of the methods were determined, and the method usage orientations of the Turkish researchers were compared with the average orientation of the international studies. This comparison with researchers in other countries who have researched Turkey's pros and cons gave rise to reveal aspects. In this context, this study has been created an environment critically. Also, the number of studies is weighted by years, and the performance of mathematical decision-making techniques in maritime studies is compared. Then, it looks for an answer to 'how should be mathematical decision performances which are exhibited?' Then, studies other than MCDM used in maritime were examined, featured studies were mentioned and the reasons for using MCDM techniques more than other methods were interpreted based on the studies. Finally, the methods used were compared based on studies, and their advantages and disadvantages were revealed in the quotations from the publications that were examined.

3. NATIONAL STUDIES

According to research, 19 papers have been published on MCDM applications in maritime since 2016 in Turkey. The most focused subject is seen as port performance and risk analysis. Ozdemir, (2016) has studied the causes of work accidents in ports. In this study, fuzzy DEMATEL (The Decision-Making Trial and Evaluation Laboratory), and fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution) approaches were used to prevent or reduce accidents. According to the study results, the causes of the accident are listed as follows; Accidents due to human error, accidents due to administrative reasons, accidents due to defective equipment and improper use of equipment, and accidents due to working environment and conditions

(Ozdemir, 2016). Acer and Yangınlar, (2017) investigated the performance of container ports in Turkey. Their work included 20 ports and they have examined selected ports according to 7 criteria with the TOPSIS method. Mersin port appeared as the most performance port (Acer and Yangınlar, 2017). In another study that belongs to Temiz et al. (2018) Samsun Port has analyzed for gaining a point of view about the future performance and opportunities of Samsun Port in the Transcaucasia project. According to analyses, the dock length and port depth's current situation is not enough to respond to the future demands of the industry. They have used a hybrid method that included the DEMATEL technique for their work (Temiz et al., 2018). Another study for port performance and risk analysis has been published by Senel et al. (2018), who worked on risk and accident analysis of ports. Accident risks have been prioritized, and recommendations have been proposed to reduce ports' accidents (Senel et al., 2018). Ship collision has caused the loss of life and property. Besides, marine pollution can occur because of ship accidents. For this, TCPA (Time to Closest Point of Approach) and DCPA (Distance to Closest Point of Approach) values were applied most appropriately according to COLREGs rules. This study tried to be concluded by using AHP and TOPSIS (Inan and Baba, 2020).

The second most focused topic in national studies is human resources. Four papers have been published since 2016. Situations that make shipmen must be taken administrative penalty have carried by Ozdemir. These situations have prioritized the FAHP method to foresee the problems and to increase efficiency in the maritime industry (Ozdemir, 2018). Another study by Efe and Kurt (2018), on human resources is selecting personnel for a port facility. Criteria that should exist in the port personnel have been prioritized with a hybrid AHP-FTOPIS method, and recommendations have been proposed. The study has done with 8 criteria and ten candidates (Efe, and Kurt, 2018). The third most focused topic is ship selection. Three papers focused on ship selection which is, decision analyzing determining ship type that will be built in the shipyard by Balbas and Turan (2019), criteria determination on ship selection in sea transport by Sener (2016), and criteria determination on cargo type selection by Ozdemir and Guneroglu, (2018).

Other study subject weights are port/facility location decision, route selection, ship machine and equipment selection, and port/facility and management selection. In the port/facility selection topic, a port selection analysis for the Western Black Sea was carried out by Pekkaya and Bucak in 2018. They have used PROMETHEE, TOPSIS, and VIKOR techniques to select the best local port location (Pekkaya and Bucak,

2018). Another study on this subject is fishery facility location selection with the AHP method has been published by Arslan et al. (2019). They have investigated the location of Mauritania's fishery facilities and found that the best option is Nauadhibu. Outputs have been matched up with the real data (Arslan et al., 2019).

2 studies have been completed since 2016 for ship machine and equipment selection. Some studies can be summarized as:

Uzun and Kazan (2016) have proposed a decision-making system to select primary machine selection in shipbuilding. 7 machines have been evaluated according to 12 criteria with separately AHP, TOPSIS, and PROMETHEE. An exact conclusion cannot be taken in this study, every method showed differences. Uzun and Kazan, remark that approximate selection can be done with this system because the system is created only for one case (Uzun and Kazan, 2016). Last of all, one studies per other subjects are determining route selection criteria by (Polat and Merdivenci, 2019), evaluating criteria for selectin of broker in sea transportation by (Ozturkoglu and Calıskan, 2016), and a study on future of the maritime education in Turkey by (Ozdemir et al., 2017).

3.1. Evaluation Frequencies of Classified Topics of National Studies

As explained before, studying has been classified into 8 sub-topics. These are human resources, ship machine, and equipment selection, port/facility location decision, route selection, port performance/efficiency/risk analysis, ship selection, port/facility, and management selection and others. There are 4 studies for human resources, 2 studies for ship machine and equipment selection, 2 studies for port/facility location decision, 5 studies for port performance/efficiency/risk analysis, 3 studies for ship selection, 1 study for route selection, 1 study for ship selection, and 1 study for other subject topics out of the 19 studies. The distribution of papers can be seen in Figure 1. And the percentage of the topics can be seen in Table 1.

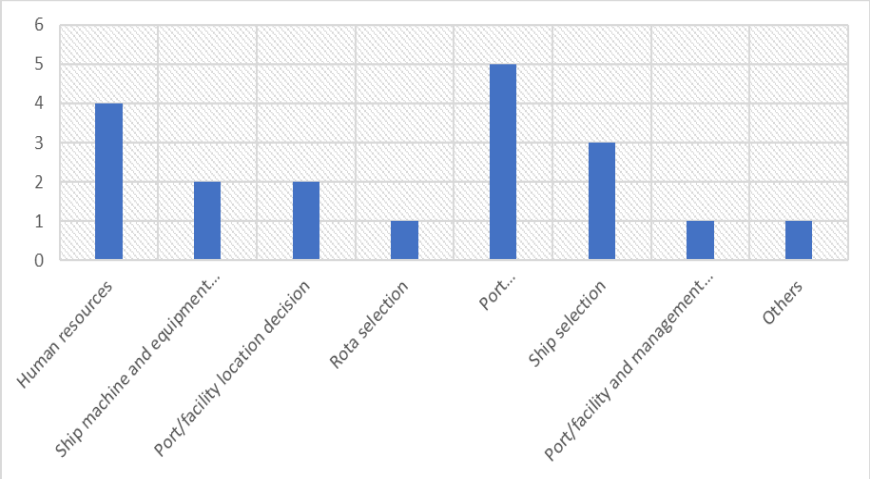

Figure 1. Distribution of national papers by organised sub-areas.

The numerical expressions and percentage rates of organized sub-areas in national studies are given in Table 1.

Table 1. Percentages of organized sub-areas.

	Number of Study	**Percentage (%)**
Human resources	4	21,05
Ship machine and equipment selection	2	10,53
Port/facility location decision	2	10,53
Route selection	1	5,26
Port performance/efficiency/risk analysis	5	26,32
Ship selection	3	15,79
Port/facility and management selection	1	5,26
Others	1	5,26

3.2. Evaluation of Exercised Techniques

According to analyses, the most used method was TOPSIS in Maritime MCDM studies in Turkey as 12 times (Sigle usage 5, hybrid

usage 7). AHP follows TOPSIS with the number of 10 times (Sigle usage 5, hybrid usage 5) and the third one is VIKOR with the number of 4 (Sigle usage 3, hybrid usage 1). The general distribution can be seen in Figure 2. And the percentage of the methods can be seen in Table 2.

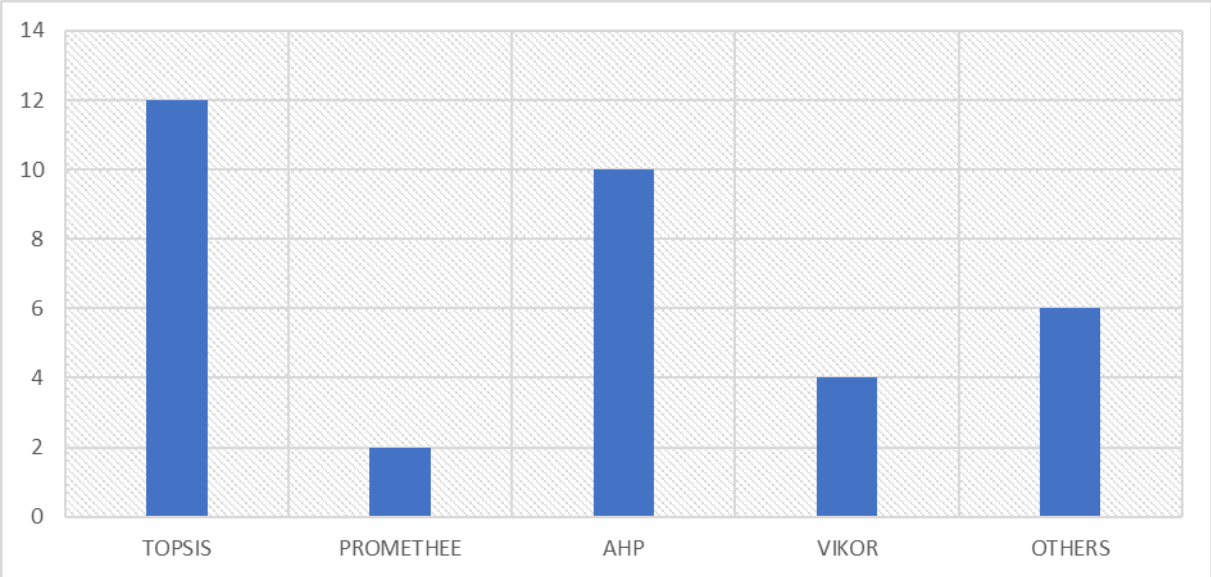

Figure 2. Distribution of MCDM methods in national studies.

The numerical expressions and percentage rates of methods in national studies are given in Table 2.

Table 2. Percentages of methods in national studies.

	Number of Usage	**Percentage (%)**
TOPSIS	12	35,30
PROMETHEE	2	5,88
AHP	10	29,41
VIKOR	4	11,76
OTHERS	6	17,65

3.3. Number of Paper Evaluation by Years

Another investigation has been done to determine studying numbers according to years. As explained before, papers that were only published after the 2016 year have considered to make up to date comparison. 2018 was the most efficient year for MCDM studies on maritime in Turkey with a study number of 7. The year 2016 is following 2018 with the paper number of 5. Other paper scores, according to years, can be seen in Figure 3.

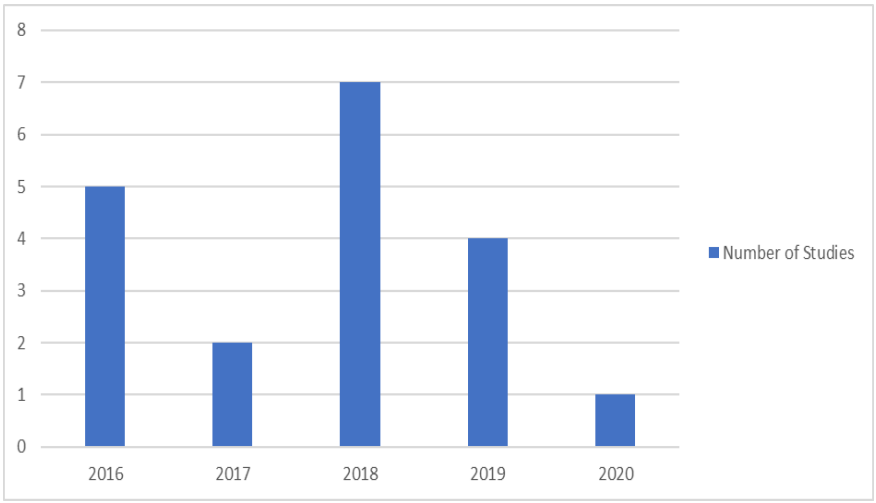

Figure 3. Distribution of national studies by years.

4. INTERNATIOANAL STUDIES

For the international investigation, 73 papers have been determined according to the literature survey criteria. These workings are based on MCDM techniques because MCDM methods are generally not used in the maritime field. The usage of MCDM techniques is rare for the maritime industry. However, selected studies have been analyzed carefully, and a general comparison between national and international studies will be executed according to outputs. Determined 8 sub-areas are used in this part of the work, too.

From a general perspective, the most focused sub-area in international studies is port performance/efficiency/risk analysis. Global logistics hub port evaluation criteria can be compared with the AHP method (Yang and Chen, 2016). In another article about security, MCDM, AHP, and

FTOPSIS models were used to conclude. This article has also modeled what can be done in the selection of operational security strategies and risk assessment at container terminals (Yami et al., 2017). Moreover, FTOPSIS and AHP methods were used to prioritize port performance improvement strategies (Ha et al., 2017). Kim has made a port competition analysis on Korea and China ports with entropy weighed TOPSIS method and tested it with real data. He has seen that outputs are matched up with accurate data (Kim, 2016). In another study, Mladineo et al. (2017) have created a decision support system using the PROMETHEE method in the case of maritime accidents. They have indicated that the system can be developed with AI and can be strongly supportive of the maritime industry (Mladineo et al., 2017). Tsai et al. (2018) have analyzed solutions for increasing port service quality with a hybrid method, a combination of AHP-ANP-DEMATEL methods (Tsai et al., 2018). On the other hand, Gao et al. (2018) have made a competition analysis for Quanzhou Port with the ELECTRE III-FAHP hybrid method and have seen that Quanzhou Port is weaker than other ports (Gao et al., 2018).

AHP model was used instead of VFT and AFT models. With the continuous expansion of the ports, the ships' location should be dispatched may confuse recently. For this, the pilotage dispatch operation is required in the port. However, there is little international study on how to use or evaluate effectively for a port. Therefore, the AHP model should be established to evaluate and effectively use port pilotage dispatch operations (Du et al., 2017). In another similar article, there are many ports around the world. With the development of technology, the capacity of these ports is also increasing. Icaza and Parnell (2018) have wanted to evaluate the region's economic potential due to the expansion of port capacity, especially in West Africa, using multi-criteria decision analysis. With this analysis, they have analyzed the strengths, weaknesses, and aspects of the ports in West Africa with VFT (Value-focused thinking) and AFT (Alternative-focused thinking) models (Icaza and Parnell, 2018). Globalization has led to the effective use of ports. There has been an increase in containers, especially at ports. In this case, Alyami et al. (2019) have used the FRBN (Fuzzy Based Bayes Network) method instead of the AHP method to evaluate the security performance of the Container Operating System (CTOS) and improve its functionality (Alyami et al., 2019).

Maritime transport has increased in recent years with the development of technology. In this case, it has triggered congestion in the river, strait, and canals. Moreover, maritime transport has caused the deterioration of

marine ecology and an increase in greenhouse gas emissions. TOS (Terminal Operating Systems) operating the terminals is used to reduce this greenhouse gas emission and marine ecology degradation. However, Terminal Operating Systems should be developed based on technological development. Therefore, the AHP method can be used to improve TOS functions and make them hierarchical (Hervás-Peralta et al., 2019). After the 2015 Tianjin Port explosion, international measures were taken against port disasters. Together with these measures, the TOPSIS method was used to measure the ex-post port vulnerability (Cao and Lam, 2019). In another TOPSIS method, Kim and Lu (2016) compared the port competitiveness of Busan and Shanghai ports (Kim and Lu, 2016). Othman et al. (2020) have used the FAHP method to find the causes of the imbalance in cargo flows in Malaysian ports. Thanks to this modeling, factors that cause cargo flow imbalance have emerged. As a result, it is understood that economic factors are the leading cause of cargo flow imbalance (Othman et al., 2020). For the port/facility and management selection, some studies can be summarized as; shipping registry selection decision-making system with the ANP method (Chou, 2018), selecting a ship management company with a hybrid AHP-FTOPSIS method (Seo et al., 2018). Sumner and Rudan have tried to choose a transshipment port in pairwise compassion with Best Worst Method. They have preferred BWS instead of AHP (Sumner and Rudan, 2018). These and similar papers tried to decide the most efficient management or company in the maritime industry. TOPSIS method was used instead of the AHP method to measure the service quality of container terminal operators. It is understood that the proposed method is consistent with the results obtained (Hemalatha et al., 2018). In another similar article, the Consistent Fuzzy Preference Relation (CFPR) method was used to create an idea about competitive factors and risk factors and their overall service quality for container terminals (Pham and Yeo, 2019).

AHP, CFPR MCDM techniques can facilitate hub port selection by a feeder port (Wang and Yeo, 2019). The MCDM technique was used to select a mid-level manager with managerial competency and capabilities. This technique, it has enabled international shipping service providers to effectively select the best middle manager (Ding et al., 2019). Another article examines the key competencies that influence mid-level managers' selection for global transport logistics service providers (GSLSPs). Besides, middle-level managers' capabilities were investigated experimentally using the AHP method (Ding et al., 2019). Using the Kano model, one can create a different perspective on Port selection factors (Min and Park, 2019). Port performance and Port selections are

considered separately as research topics. This situation will affect the port performance when there are any changes in the ports in the coming years, and the performance of the selected port will change. A solution can be found for this complex situation using the MCDM technique (Rezai et al., 2018). An evaluation can be made in another article on the Port selection of linear carriers for ship calls with the MCDM technique. Besides, a model based on the MCDM technique can be suggested to improve ort management of port companies. Moreover, MCDM can provide theoretical information and reference for methodological research (Hsu et al., 2020).

People are always planning to achieve success, goals, and ideals in professional life. This planning is a valid concept for people working in the maritime industry. Also, when seafarers are planning, they look at the ship type, salary status, occupational health, and work intensity criteria. The AHP can be used to correlate seafarers taking these criteria. Besides, a solution can be found with the most preferred Fuzzy TOPSIS methodology (Kaya et al., 2018). The F-AHP method can be used to compare the human factor affecting the management of container terminals, the facility's strengths and weaknesses, and the systems used in the port (Adenso-Diaz et al., 2019). Various services are provided to the ships by the ports. These services are essential for the operation between the ship and the port. Besides, the port service should be economical, high quality, reliable and with them the operation should be fast. F-AHP is also preferred in these port services (Longaray et al., 2019). Fan et al. (2020) have proposed the maritime accident prevention strategy formulation from a human factor perspective using Bayesian Networks (BN) and TOPSIS. They also showed the characteristics of multiple criteria and the relationships between strategies. As a result, they emphasized what should be done to minimize the accident rates at sea and to minimize human errors (Fan et al., 2020). The human factor has always been the most effective in ship collisions. Also, analyzing the human factor is hard to understand because it has a complex socio-technical structure. Yildiz et al. (2020) have demonstrated the feasibility of the modified Human Factor Analysis and Classification System for Passenger Vessel Ship collisions (HFACS-PV) for other types of accidents. Based on the results of this study, it can be said that the HFACS-PV structure is compatible with collisions as well as contact, grounding and sinking accidents (Yildiz et al., 2020). Song et al., (2020) have proposed the Dynamic hesitant fuzzy Bayesian network and its application in the optimal investment port decision making problem of "twenty-first-century maritime silk road" using BN (Bayesian Network), DHFBN (Dynamic Hesitant Fuzzy Bayesian Network), EM (Expectation-

Maximization) and PSO (Particle Swarm Optimization). They have also had the opportunity to compare the validity and positive aspects of the method with an experiment by using these techniques together. Moreover, with their research, they have offered opportunities to examine humanity's new trade initiatives, socio-cultural interactions, and exchange opportunities that may occur in the 21st century. Finally, they have sought an answer to the question of how economically countries are affected by this (Song et al.,2020).

Pressing and receiving ballast water on the ship is important for the stability of the ship. However, IMO has made the ballast water treatment system mandatory due to the increase in environmental problems. Therefore, it is important to predict the malfunction of the ballast water treatment system or make an effective repair. The MCDM method was used for this fault solution (Bakalar and Beatriz Baggini, 2016). In the ship machine and equipment selection sub-area, Agarwal, and Chand a made decision analysis system is based on the AHP method for selecting IT tools in shipping. It was revealed that the Internet is the most critical IT tool (Agarwal and Chand, 2018). In another study, Jiang et al. (2019), proposed a 'fuzzy MCDM if than rule' system to select a submarine power cable (Jiang et al., 2019). Also, Sahin and Yip (2017) have offered a Gaussian FAHP method for selecting shipping technology and found that energy efficiency systems are more suitable in the long term (Sahin and Yip, 2017). The Fuzzy TOPSIS model was used to find the root cause of the engines' failure in the ships using the opinions of experts. Thanks to this model, it has been observed that although engine fault detection is difficult, faults can be diagnosed (Aikhuele et al., 2017). Again, the Fuzzy TOPSIS model was used in another article. In this article, expert opinions were taken to find the root cause of offshore boat engine malfunctions. Besides, it was seen that the Fuzzy TOPSIS model was used in the solution (Aikhuele et al., 2017). When looking at both articles briefly, it is clearly seen that the Fuzzy TOPSIS model can be used in the solution of ship engine malfunctions.

There are adverse environmental problems associated with high sulfur dioxide emissions from ship machinery. Besides, health problems have occurred. IMO has established rules following regulation 14 of MARPOL Annex VI. However, it has been observed that the ship operators around the Gulf of Guinea have difficulty in complying with the IMO regulation. To identify these main obstacles, MCDM, AHP, TOPSIS, and FAHP methods were used together. The findings have proved to be the most effective obstacles to the lack of infrastructure, lack of maritime air pollution laws and the need for high capital to reduce sulfur (Animah et

al., 2018). In another article, the engine rooms of ships are critical for sudden maneuvers and operations. Therefore, a model has been created about how the ship's main engine rooms should be maintained. AHP and PROMETHEE were used in this model, and a cost-benefit analysis was made (Animah and Shafiee, 2019). Nowadays, choosing the appropriate location for transshipment has become very important. Therefore, Zabihi et al. (2016) have used the MCDM model to evaluate and select the marine container transfer port. This model has been used in Iran's main ports to offer a practical solution together with the technical solution. As a result, it is understood that the MCDM model can be used in the assessment and selection of the marine container hub location selection (Zabihi et al., 2016).

In the developing world, people have started to turn to sea tourism in recent years. In this case, it has caused countries to choose and plan suitable places for sea tourism. The most convenient location can be selected with the MCDM technique and VISUAL PROMETHEE (Badurina Tomic et al., 2016). In another article, the AHP model was used to determine the potential of RO-RO Short Sea Transport operations (Arof, 2018). The tugboat to be used in the ports is selected according to the procedures to be performed. Besides, many criteria are evaluated for the tugboat required in the port and a conclusion is reached. However, there are technical knowledge, experience, and many other issues that need to be evaluated for tugboat selection in this process. Therefore, Cakıroglu et al. (2018) for selecting tugs have made a numerical analysis with the fuzzy AHP method within the framework of design, operational and financial criteria (Cakıroglu et al., 2018). Suhario and Suharyo (2019) have made the port evaluation by looking at the ports' technical, political, and economic conditions using the Fuzzy MCDM technique. In this way, they have provided ease of selection between ports by looking at the current port or the various characteristics of the important ports to be built (Suhario and Suharyo, 2019). As in other ports, it is vital to choose an ideal location for the dry port. However, choosing a location for a dry harbor is a complex decision. Because evaluating more than one criterion creates decision problems in location selection. The fuzzy-AHP method is used to minimize these uncertainties (Goncalves et al., 2019). Another study is the CFPR method of LNG selection by Lu et al. (2019). According to calculations, the Busan port has been stood as the best option for LNG (Lu et al., 2019).

One of the most focused other sub-area in the MCDM maritime applications is route selection applications. Bellsolà Olba et al. (2019) executed a SAW method on vessel traffic determination for Rotterdam

Port. They provide a selection of scenarios according to five important criteria (Bellsolà Olba et al., 2019). Another study was carried out on determining suitable routes that have environmentally friendly behavior. Jugovic et al. (2017) have evaluated Croatia ports according to decided criteria with PROMETHEE and found that none of the ports in Croatia are suitable for environmental development (Jugovic et al., 2017). The PROMETHEE method was used to direct an alternative route to cargo transportation over the Adriatic Sea. With this model, issues that need to be discussed in a new route are tested and evaluated (Vilke et al., 2017). Due to the increase in trade in Asian countries, it is imperative to have an efficient intermodal route for cargo transportation. FUZZY DELPHI and ELECTRE I models were used for this intermodal route. As a result, it is understood that the most important factor in route selection for logistics companies is the total cost (Wang and Yeo, 2018). The fuel consumption of the ships disrupts the ecological order. Therefore, studies have been started in the maritime sector to protect the ecological balance of nature. Accordingly, a different field has emerged in the maritime sector where the MCDM method is used. For example, new low-fuel ship designs can be given as examples. Within this, the Ship Energy Efficiency Management Plan (SEEMP) adopted by IMO is of great importance for the ecological balance (Besikci et al., 2016). MCA, PROMETHEE and GAIA models can be used for the type of vessel and size that will connect the mainland and island and island each other connections (Kovacic and Mrvica, 2017). In another article, it was reported that various factors affect ship maneuvering decisions. Xue et al. (2019) focused on factors affecting decision-making in autonomous ship maneuvering. As a result, the ship maneuver has allowed evaluating the factors affecting decision making theoretically and practically. It has also demonstrated that autonomous ship maneuvers can be used to make better maritime safety decisions and that transportation can be safer (Xue et al., 2019). Recently, ship selection has become a very complex affair. Because determining the most suitable ship for maritime trade means having a say in the maritime market. Therefore, the investor and the shipowner need to compare the ships to solve this problem. For example, the EVAMIX (EVAluation of MIXed Data) method was used for the first time in the articles of Yazir et al. (2020), for comparison and the solution was tried to be reached (Yazir et al., 2020). Safety at sea is paramount. Because if security is provided at sea, the risk of collision of ships is reduced. Besides, the work that needs to be done and delivered is done on time. For this, Wu et al. (2016) have decided to use the TOPSIS technique to facilitate ship safety control on uncontrolled ships. As a result of this decision, they have revealed that ship security control can provide uncontrolled ships' practical decisions (Wu et al., 2016).

Another issue where the MCDM technique is discussed in the maritime sector is the design of the holds of bulk carriers. Hatch cover design selection is very important to prevent water ingress in bulk carriers' structure and protect the transported cargo from damage caused by external factors. For this design, a solution was tried to be found by using AHP and VIKOR methods. In this way, a practical contribution has been made to ship engineers, class societies and ship owners to facilitate the selection of hatch covers (Soner et al., 2017). Celik and Akyuz (2018) have proposed a hybrid FAHP-TOPSIS method for deciding ship loader. They have recommended a parallel (traveling) ship loader for bulk material loadings (Celik, and Akyuz, 2018). There are many reasons for marine pollution. A few of them can be listed as follows; there may be spills from ship collisions and oil spills during oil extraction and oil tanker activities. Within the scope of this subject, Zafirakou et al. (2018), what can be done to prevent oil spills with the PROMETHEE method was theoretically evaluated (Zafirakou et al., 2018). Emergency response is vital in the onshore sector as well as in the maritime sector. Wu et al. (2018) have proposed the TOPSIS technique for managing ships without command. As a result of the use of this technique, it is useful in handling ships that are not under control (Wu et al., 2018). The maritime sector has an impact on the development of world trade and the growth of the logistics network. This growth has enormous implications for marine safety, human health, and marine ecology. To reduce ship accidents, which are the primary source of these factors, a solution can be made with the TOPSIS technique (Chen et al., 2019). Maritime safety policy is affected by many things. These are respectively: technological developments, new political arrangements, infrastructure, socio-cultural and the like. Hozairi et al. (2019) have tried to find solutions to what needs to be done to develop the Indonesian maritime security policy using AHP and TOPSIS techniques (Hozairi et al., 2019).

4.1. Evaluation Frequencies of Classified Topics of International Studies

Studies have been analyzed according to created sub-areas. Eight studies can be classified into our sub-areas. The reason for this situation is being considered studies much more than national studies with the number of 73. However, port performance/efficiency/risk analysis is the most focused topic in international studies with a number of 18. It means nearly a quarter of all studies. Port/ facility and management selection follow the first rank with the study number of 13 and the third rank are ship machine and equipment selection and port/facility location decision

topics with 8 studies. Other distributions of their percentage can be seen in Figure 4 and Table 3.

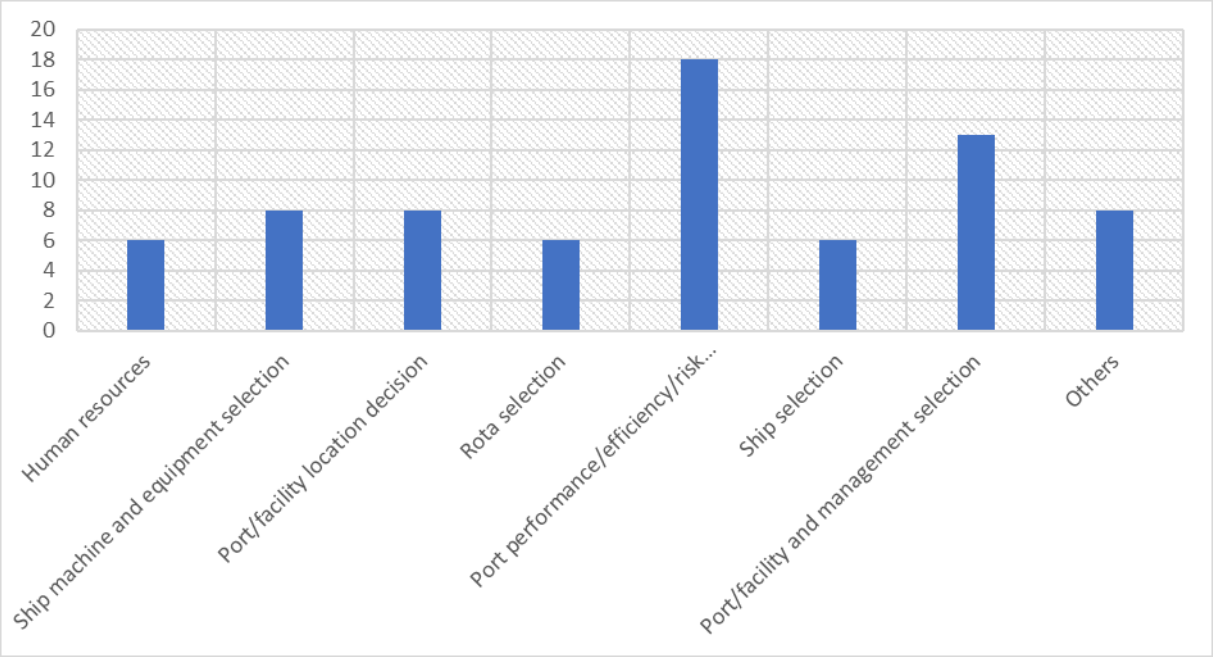

Figure 4. Distribution of international papers by organized sub-areas.

The numerical expressions and percentage rates of organized sub-areas in international studies are given in Table 3.

Table 3. Percentages of organized sub-areas in international studies.

	Number of Study	**Percentage (%)**
Human resources	6	8.22
Ship machine and equipment selection	8	10,96
Port/facility location decision	8	10,96
Route selection	6	8,22
Port performance/efficiency/risk analysis	18	24,66
Ship selection	6	8,22
Port/facility and management selection	13	17,80
Others	8	10,96

4.2. Evaluation of Exercised Techniques

In the studies, the AHP method was the most used. AHP is used 34 times and takes place as the first rank. In 20 studies AHP was used alone and in 14 studies it was used hybrid type. The second rank is the TOPSIS method, which was used 19 times in the distribution of 11 single, 8 hybrid ways. At third rank, there is PROMETHEE with the number of 7, which separated as 5 single and 2 hybrid types. A however interesting thing in the international studies is that there is 35 MCDM method usage in others' class. Almost all the 23 methods are different, and they have used some hybrid types. Some of these methods are: Saw Method, ANP, BN, GRP, ER, ELECTRE, DEMATEL, and DELPHI. Totally, MCDM techniques were used 96 times and 33 of them were the hybrid type. Distributions and their percentages can be seen in Figure 5 and Table 4.

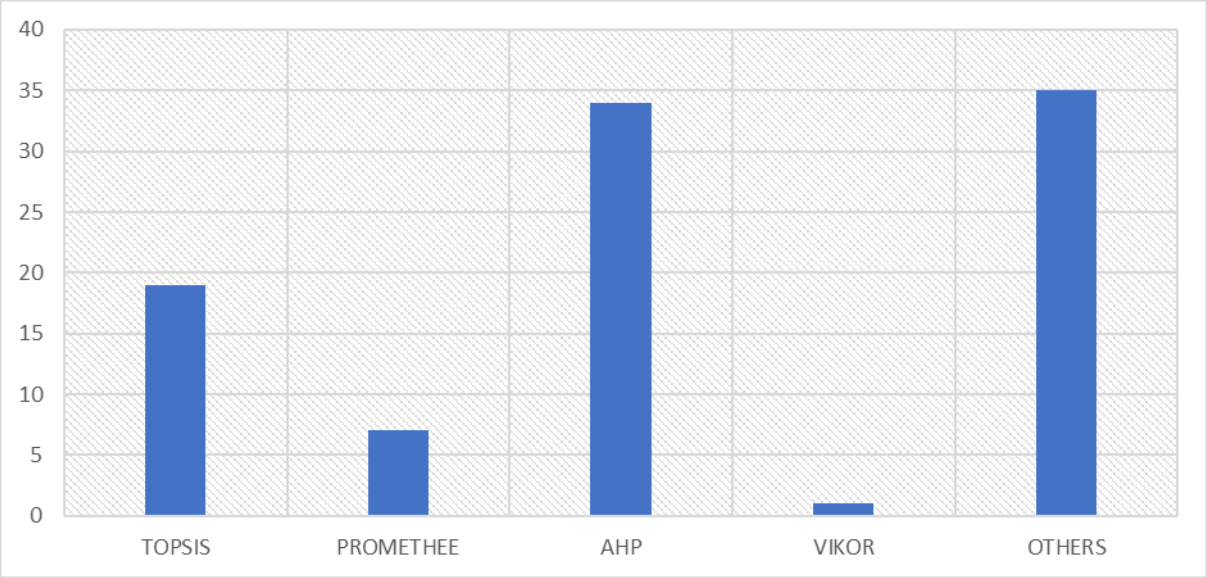

Figure 5. Distribution of MCDM methods in international studies.

The numerical expressions and percentage rates of methods international studies are given in Table 4.

Table 4. Percentages of methods in international studies.

	Number of Usage	Percentage (%)
TOPSIS	19	19,79
PROMETHEE	7	7,29
AHP	34	35,42
VIKOR	1	1,04
OTHERS	35	36,46

4.3. Number of Paper Evaluation by Years

After the year 2016, 73 papers have published in the international area for MCDM techniques in maritime. 2018 and 2019 were the most effective year for the MCDM workings in maritime with a study number of 20. And 2017 is following the years 2018 and 2019 with a study number of 17. In 2016 and 2020, the number of papers is 9 and 7, respectively. The number of articles in 2018 and 2019 exceeded half of the total articles written. That is why 2018 and 2019 are milestones for MCDM techniques in maritime. The distribution of the number of published papers per year can be seen in Figure 6.

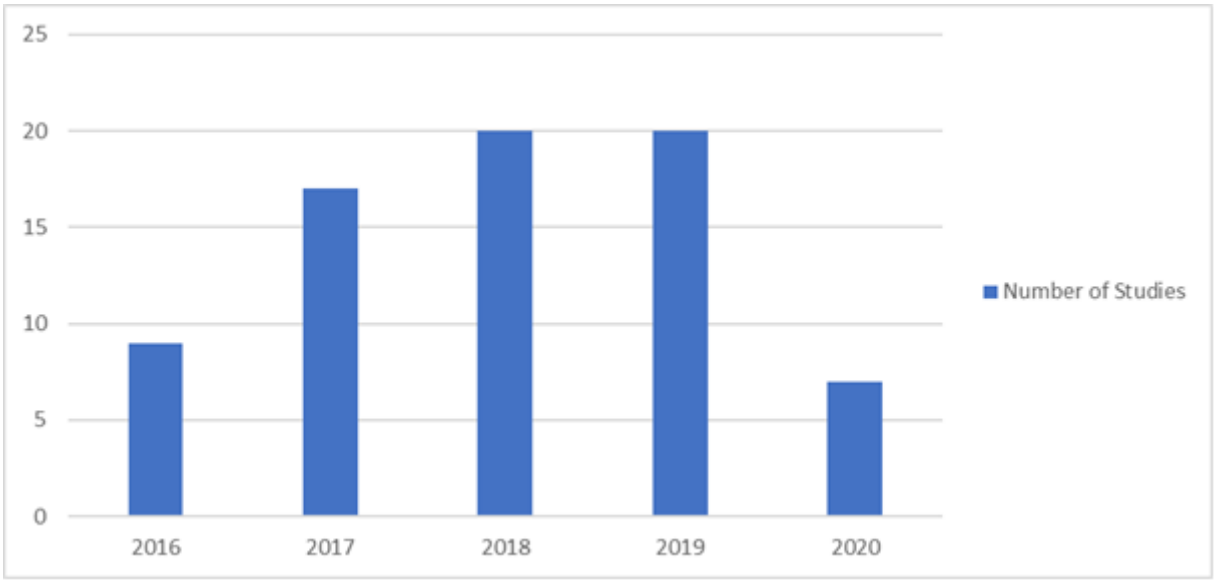

Figure 6. Distribution of national studies by years.

5. OTHER METHODS AND MATHEMATICAL MODELS USED IN THE MARITIME INDUSTRY

Besides MCDM methods, there are other decision making or analysis methods used in the shipping Industry. These methods can be grouped generally as regression and forecasting. The regression methods used frequently in shipping are as follows:

- Support Vector Regression (SVR)
- Linear Regression
- Vector Autoregression (VAR)

Forecasting methods do not have a general classification, but prediction methods such as ARIMA and Markov Chain are used in maritime studies. Wang et al. (2018) in the Target Direction of Arrival Estimation paper, have evaluated possible routes to estimate arrival time using the Support Vector Regression (SVR) method (Wang et al., 2018). Also, Kawan et al. (2007) have done a ship motion prediction study with the SVR method (Kawan et al., 2017).

Mobbing Examination in Maritime Sector article can be given as an example for linear regression studies in recent years. In that work, factors affected the mobbing were determined with Multiple Linear Regression Analysis (MLRA) (Tavacioglu et al., 2018). Weng et al. (2018) made a predicting shipping accident mortality study with MLRA, too. Twenty-three thousand twenty-nine accidents between 2001 and 2011 were examined, and a damage prediction method was created in ship accidents (Weng et al., 2018). On the other hand, there are maritime studies where forecasting methods have been used in recent years. Articles such as De Girolamo et al. (2017), Stavroulakis and Papadimitriou, (2017), and Xiao et al., (2017); have completed studies on such as Maritime activities, Maritime traffic prediction, European cluster prediction.

During the investigations, it was seen that regression, forecasting, or any type of decision supportive method have used much less than MCDM techniques in the maritime industry. In MCDM techniques, dispersed and multifarious data, criteria or alternatives are worked but in regression or forecasting studies definite data is used to compare MCDM studies. To be clearer, forecasting and regression analyses can be applied when their previous data reservoir has a single or limited dimension. However, in the

MCDM studies, much more data with infinite dimensions can be analyzed according to the method's strength.

6. COMPARISON OF NATIONAL AND INTERNATIONAL STUDIES

In national studies, port performance/efficiency/risk analysis is the most studied subject with 26.32%. The second most focused subject is human resources, with 21.4%, and the third rank is ship selection with a nearly equal percentage of 16%.

In international studies, port performance/efficiency/risk analysis is the most studied subject with a percentage of 24.66%, too. The second rank is port/facility and management selection with 17.8% and the third rank is shared by port/facility location decision and ship machine and equipment selection with 10.96%. Port performance/efficiency/risk analysis is the most studied sub-area according to our analyses. The reason for this situation can be included other sub-areas such as human resources, port/facility location decision, and route selection by port performance/efficiency/risk analysis. It can be said that other sub-areas are criteria for port performance/efficiency/risk analysis field. On the other hand, AHP was the most used MADM technique in international studies with 35.42%. Also, the second rank is TOPSIS, with 19.79% for international studies. For national studies, this percentage is the opposite. So, TOPSIS was the most used in national studies with 35.30%. Moreover, the second rank is AHP, with 29.41% for national studies. The third ranks are different, the VIKOR method is the third one for national studies and the PROMETHEE method is for the international area. All in all, it can be said that percentage of methods used in the studies in the national area is matched up with the international area. Another analysis is the usage of fuzzy methods. 38.24% of the methods are hybrid in national papers and this percentage for the international area is 34.38%. It is seen that hybrid method usage is better than the international level in Turkey. Also, it shows that Turkey is willing to consider fuzzy and uncertain data more than international colleagues. In other respects, MCDM studies for maritime in Turkey have been rising and falling from 2016 to 2018. However, MCDM papers have been decreasing since 2018. This situation, it can be problematic for future developments. And while it can be said that MCDM studies have increased in the international

arena from 2016 to 2018, it is clearly seen that it has decreased since 2019. Additionally, in the next few years, especially for 2020, the number of studies might be decreased because of the coronavirus epidemic.

7. Advantages and Disadvantages of Methods

There are so many studies for different cases that are done with different methods. Every method has advantages and disadvantages. Every researcher finds some methods good or bad for their workings. Some inferences have been determined due to evaluated papers for both national and international studies. In national studies, it is seen that hybrid methods will become more common in future works. 38.24% of the papers included hybrid methods in the national area. Efe and Kurt (2018), claim in their personnel selection for a port facility analysis that hybrid methods are more beneficial for the maritime area (Efe and Kurt, 2018). Also, Gul (2019), supports this remark in the determination of health and occupation risk analysis in the maritime industry (Gul, 2019). In another remark, when a decision analysis system is created for only one project, it can weaken performance. In Uzun and Kazan's study, general evidence cannot be taken with AHP, TOPSIS, and PROMETHEE methods for equipment selection in shipbuilding (Uzun and Kazan, 2016). Uzun and Yıldırım also support this proposition with another paper (Uzun and Yıldırım, 2016). In the international area, the AHP method is the most commented on and criticized one in the MADM methods. It makes sense because it is the most common method with a 35.42% percentage. Othman et al. (2019), present AHP as complex but net output given method in their Dry Bulk Cargo Application Analysis (Othman et al., 2019). Also, Sahin and Yip remark that they chose the AHP method because it is the most consistent method (Sahin and Yip, 2017). Sahin et al. (2020) also made another suggestion that AHP should be used in purchase analyses in maritime (Sahin et al., 2020). AHP also be used as a hybrid form with other methods and gives satisfactory outputs in limited criteria and alternatives tried on Ballast Water System Decision Analysis (Karahalios, 2017). On the other hand, the AHP method has some disadvantages, according to some studies. Lu et al. (2019) have not preferred to use the AHP method in their Location Decision Analysis for LNG. They found the AHP method is less consistent while increasing the number of criteria. Also, it is not possible to do a pairwise comparison with the analytical hierarchy process (Lu et

al., 2019). Sumner and Rudan (2018) support this remark in the Transshipment Port Selection study and defends that the Best Worst Method is much better than AHP in a pairwise comparison (Sumner and Rudan, 2018). Tsai et al. (2018) propose that the AHP method has low performance in the analyses in which dependent variables and feedback mechanisms are used. ANP method would be more useful for this type of analysis (Tsai et al., 2018). In several situations, PROMETHEE could be more effective in the comparison of the AHP method. Gagatsi et al. (2017) remark this inference in the Port Policy Comparison study and claims that AHP has not performed well although the number of criteria was limited (Gagatsi et al., 2017). The PROMETHEE method is another MADM method that is favored in maritime studies internationally. Mladineo et al. (2017) indicate that especially for the PROMETHEE II that the PROMETHEE method is simple and can be understood by non-professionals (Mladineo et al., 2017). PROMETHEE II also has accepted better than PROMETHEE I for the studies that worked with fuzzy data. This type of problem is generally solved by developing current methods or has adopted them with fuzzy data. However, another common technique to overcome this problem is working with hybrid methods. Chen and Zheng (2018), state that hybrid methods give more objective results in the Ship Targeting Method Analysis study (Chen and Zheng, 2018).

8. Results and Discussion

Looking at the national field studies, human resources, and port performance/ efficiency/risk analysis studies are almost half of the total studies as a ratio. From this result, the importance of human resources, and port performance studies in national studies is clearly seen. When looking at international studies, it is seen that port performance/efficiency/risk analysis and port/ facility and management studies have the highest two rates of comprehensive studies. Also, when compared to national and international studies, a common point of them is port performance. In both studies, the Port performance stands out as the most common paper. The weights of the methods used in the analyzes differ except for AHP. The reason for this may be differences in periodic needs or maritime policies.

If other methods are excluded from the research, when national and international studies are examined, it has been determined that AHP constitutes the basis of approximately half of the studies. This is because AHP is a building block in determining criteria, and it can quickly adapt to hybrid methods. On the other hand, when looking at international studies, it is seen that the 'others' part in the method distribution is high in MCDM techniques. It seems that the international arena is one step ahead in trying different techniques and looking for new solutions to problems.

Among the techniques used by adapting to common MCDM techniques, there are methods such as ANP, BN, GRP, ER, ELECTRE, DEMATEL, and DELPHI. To give an example, BN is a useful and indefinite causal inference model in the field of uncertain reasoning. Unlike other decision-making models, the BN model, which graphically visualizes multiple information, is ideal for predicting probabilistic situations in any study. Further, BN more conveniently includes causation and a conditional correlation between network node variables. In this case, even if the BN method is not used as much as the AHP method, it may be the method that will stand out in the coming years. The use of hybrid methods is quite common because the problems are wide and comprehensive, and the methods are relatively limited in singlev use. Analysis and hybrid usage rates show that hybrid methods are much more efficient than using single methods. It is understood from the course of studies that these methods and combinations should be improved and will be so for the future position of decision-making techniques, especially for maritime applications. An example of this is developing the AHP method as ANP and the PROMETHEE method as PROMETHEE II, III. From a general perspective, the AHP method loses its consistency when the number of criteria increases and methods such as VIKOR and TOPSIS are better than AHP in this regard. According to the literature search, especially the TOPSIS method performs well in complex analyzes. Although some shortcomings, the studies in Turkey and the international arena continue apace and will be concluded in a decision given in a purely mathematical base of the not too distant future of most of both management and application areas. For this study to be better, the studies should be examined in a broader time range, and the methods should be

scanned in a broader range. In other words, the limitations of this paper are that the studies didn't be examined in a wider range of time and methods didn't be scanned in a wider range.

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