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RESEARCH ARTICLE

MULTI-PURPOSE TUGBOAT/AHT SELECTION FOR NORTHERN CASPIAN SEA WITH TOPSIS AND MOORA METHODS

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ABSTRACT

A large part of the world energy requirement is provided from offshore oil and gas fields. The Kashagan site in the Northern Caspian Sea has one of the largest known reserves and marine operations are important for the continuation of activities regarding oil and gas production in area. However, the geographical features of the region make the maritime-related activities difficult. There are different types of marine equipment in operation within the scope of the Kashagan project and one of the most widely used vessel is Multi-Purpose Tugboat / AHT (Anchor Handling Tug). As far as the requirements of the task are concerned, the geographic challenges of the region (especially low water depth) should be taken into consideration when selecting the AHT by the management. In this study, the optimum AHT vessel will be selected to operate in the North Caspian Sea by utilizing MOORA (Ratio and Reference Point approaches) and TOPSIS methods and the concordonce among three methods will be tested by Kendall's Coefficient of Concordonce (Kendall's W).

Keywords: *Offshore Oil and Gas Industry, Offshore Supply Vessels, MOORA, TOPSIS, Kendall's Coefficient of Concordonce (W).*

MOORA VE TOPSIS YÖNTEMLERİ KULLANILARAK KUZEY HAZAR DENİZİNDE KULLANILACAK ÇOK AMAÇLI RÖMORKÖR SEÇİMİ YAPILMASI

ÖZ

Dünya enerji ihtiyacının önemli bir bölümü açık deniz petrol ve gaz sahalarından temin edilmektedir. Kuzey Hazar Denizinde yer alan Kashagan petrol sahası bilinen en büyük rezervlerden birine sahip olup, denizcilik operasyonları bölgedeki petrol üretimi ile ilgili faaliyetlerin devamlılığı açısından büyük öneme sahiptir. Nitekim, bölgenin coğrafik özellikleri genel olarak bölgede denizcilik ile ilgili faaliyetlerin yapılmasını zorlaştırmaktadır. Kashagan projesi kapsamında bölgede farklı tipte deniz taşıtları ve ekipmanları kullanılmaktadır ve bunlar içerisinde en çok yaygın olarak kullanılanlardan bir tanesi Çok Amaçlı Römorkör / Demir Zinciri Elleçyebilen Römorkör (AHT)'dir. Görevin gereklilikleri dikkate alındığında AHT seçiminde bölgenin coğrafi özellikleri de (özellikle düşük su derinliği) yöneticiler tarafından dikkate alınmalıdır. Bu çalışmada MOORA (oran yöntemi ve referans nokta yaklaşımı) ve TOPSIS yöntemleri kullanılarak Kuzey Hazar Denizinde kullanılacak optimum AHT seçimi yapılacak, ve üç yöntem arasındaki uyum Kendall'ın uyum katsayısı (Kendall's W) ile test edilecektir.

Anahtar Kelimeler: *Açık Deniz Petrol ve Gaz Endüstrisi, Açık Deniz Destek Gemileri, MOORA, TOPSIS, Kendall'ın Uyum Katsayısı*

1. INTRODUCTION

The offshore industry is of great importance for meeting the world's energy needs. Today, approximately 30% of the oil and 27% of the gas production are realized through offshore projects [1]. The interest in offshore oil and gas fields leads to a high amount of investment in these areas. One of the largest oil reserves in the world is located in the Kashagan region of the Caspian Sea. Kashagan region is reported to have approximately 1-2 billion tons of oil reserves [2] and this capacity makes it the 5th largest oil field in the world [3]. Kashagan region differs from other regions of the world in terms of its geographical characteristics. While the region is important for the oil and gas industry, the natural conditions of the region is also brings some difficulties for maritime activities in the region. These are especially low water depth, ice surface coating caused by harsh winter conditions and H2S gas (sour gas) release. The mentioned geographic difficulties caused the production in the oil field discovered in 2000 to start in 2013 [4].

Oil reserves in the northern Caspian Sea also contain about 15% H_2S gas [5]. The most important factor that complicates the maritime operations in the region is undoubtedly that the water depth in the region is very low and this makes it impossible to operate in the region with ships of high draught. The water depth, which is usually around 5-6 meters [6], can decrease to 0.5 meters during certain periods of the year [7]. Therefore, ships serving in the region should have a very low draft value. The low water depth, salinity and extreme weather conditions freeze the North Caspian Sea during the winter [8].

The Kashagan region consists of five artificial islands, one of which is the central production hub (D-island or D-block), the others being the drilling islands connected to this center. Marine operations are carried out in the D-block and on other drilling islands for different purposes. Multi-Purpose Tug Boat (MPT) or Anchor Handling Tug (AHT) vessels are one of the most widely used equipment. The AHTs carry out vital operations for offshore activities such as the proper positioning of special purpose pipe / cable laying vessels and supply of materials. Therefore, AHT selection should be made by taking into account the correct planning, geographical conditions and operational requirements.

There is a limited number of studies regarding AHT selection in the literature. In particular, there is a significant gap regarding AHT's with low draught. In this study, in order to fill this gap in the literature, optimum AHT selected according to the predetermined criteria among 18 low-draught AHTs, produced by different shipyards. In the study using MOORA and TOPSIS methods draught, bollard pull, ship's propulsion power, and fuel capacity are considered as the selection criteria. As a result of the study, it is planned to select AHT equipment which has a low water draft in accordance with the North Caspian Sea conditions but which can also provide an operationally effective solution such as a considerable propulsion power.

Practical results of the study will be guiding the vessel management companies operating in the Kashagan region and in other areas with similar geographic features as well as the study will make a significant contribution to the literature regarding low-draught AHTs.

The next sections are planned as follows: Chapter 2 presents the literature review. The methodology of the study is given in Chapter 3. In Chapter 4, results of the application are presented. Chapter 5 is devoted to discussion of the research.

2. LITERATURE REVIEW

2.1. Oil and Gas Production in Kashagan Oilfield

Kashagan oil field which is located 80 km southwest of Atyrau City, was discovered in 2000 and has one of the largest known oil and gas reserves. It is one of the five offshore oil and gas projects of Kazakhstan. Others are Kalamkas-Sea, Kairan, Aktoty, and Kashagan South West [2]. In the region, NCOC (North Caspian Operating Company Consortium) is operating, including Shell, ExxonMobil, KMG, Total, Eni, CNPC, and INPEX [9]. Due to the geographic features of the Kashagan site, jacket type oil platforms are not in use; instead, artificial islands have been built for oil and gas extraction and processing with the necessary facilities [10]. The total cost of the Kashagan project is estimated at US $ 116 billion [3].

Providing the necessary material supply to Kashagan oilfield contains many technical challenges in terms of logistics. The most important of these is low water depth and ice. Water depth in the Kashagan East-1 (KE-1) region is approximately 10 feet - 3.048 m [11]. The fill material used in the project was carried from Bautino village, 180 nautical miles away [12]. Another factor that makes the project difficult is the high amount of sour gas (16%

H_2S, 4% CO_2) [13]. This leads to a serious Health, Safety and Environment (HSE) investment. IBEEVs (Ice Breaking Emergency Evacuation Vessels), designed and manufactured specifically for the Kashagan project, are examples of these investments [14]. The Kashagan project is considered to be one of the most challenging industrial projects ever undertaken in terms of engineering, safety and logistics due to the difficulty of environmental conditions [9].

2.2. Oil Offshore Marine Operations

In the offshore oil and gas industry there are ships used for different purposes. They can be grouped as follows [15]:

- Oil Exploration and Drilling Vessels
- Offshore Support Vessels (OSV)
- Offshore Production Vessels
- Special Purpose Vessels
- Construction Vessels

Offshore Support Vessels (OSV) undertakes different tasks. They can be used for sheltering purposes (accommodation vessels), for personnel transfer (crew boats), for relocating oil platforms, for supply of various materials and even for performing seismic tasks (seismic vessels) [16]. AHT vessels need to be considered seriously because of their benefits in the offshore oil and gas industry. AHT ships are used for various purposes. The first of these is to carry out anchor handling operations of the oil platforms, construction platforms, and pipe laying barges [17]. AHT ships have the necessary equipment (winches, wire, etc.) to perform anchor handling operations [18]. They are also used for the supply of various materials and personnel transportation [16]. AHT ships must be equipped with machines capable of generating sufficient capacity to perform tasks such as anchor handling, towing, and pushing support.

In a similar study on the selection of Multi-Purpose Tugboat - AHT, 14 criteria and 4 alternatives are evaluated. Azimuth Stern Drive Tug is the best option among four alternatives, where work safety, bollard pull and price factors emerge as the most important criteria [19]. However, there is no restriction on draft limitation in the aforementioned study. In another study on offshore fleet selection, CTV (crew transfer vessel) alternatives to take part in offshore wind farm maintenance works are discussed [20]. In another study, optimization and sensitivity analysis are performed in the selection of O&M (operation and maintenance) fleet for offshore wind farms [21]. Yang, et al. [22] used Approximate TOPSIS method with four criteria (integrity, pollution prevention, vessel running cost, restrictions on vessel) and 19 sub criteria. Aas, et al. [23] mentioned supply vessels in offshore logistics and examined supply vessels in terms of reliability, operational capability, sailing capability, and loading/unloading capability.

2.3. Studies Regarding Equipment Selection Using TOPSIS and MOORA Methods

In literature, there are vast number of studies conducted with TOPSIS and MOORA methods. These studies are regarding system and equipment selection, supplier selection, as well as selection of optimum location and evaluation of firm performance.

Pelorus [24] studied the ballast water treatment system (BWTS) selection using combination of AHP and TOPSIS methods. As an example of the optimum location selection, AHP and TOPSIS are used to select the most suitable site for the oil spill center to be established in Marmara Sea [25]. Aktepe and Ersöz [26] used MOORA and AHP-VIKOR methods in their studies for choosing a storage location for a foundry factory. As a result, Samsun is selected as the most suitable location among 11 alternatives. Vatansever and Ulukoy [27] apply Fuzzy MOORA and Fuzzy AHP methods on the selection of enterprise resource planning system (ERP), a total of six criteria are taken into account.

There are also studies using TOPSIS and MOORA methods together. One of these studies is related to the selection of supplier in the tourism sector. Five main criteria and 20 sub-criteria are determined and six suppliers are selected according to these criteria [28]. In another study using these two methods, the financial performance of 11 energy companies is compared [29].

3. METHODOLOGY

In this study, it is planned to select AHT, which can be used in Northern Caspian Sea - Kashagan Oilfield region. The decision criteria are determined as follows with respect to author's own experience in marine operations in the region:

- **Bollard Pull** and **Propulsion Power:** It affects the ship's barge backup, towing, anchor handling performance.
- **Draft:** Low draft is gaining importance, as the region to be operated is shallow water zone.
- **Fuel Oil Capacity:** Determines the ability of the vessel to operate without supply.

AHT plays an important role in maritime industry such as escorting dangerous good vessels, help maneuvering ships, etc. Therefore, selection of AHT among numerous alternatives poses a great issue. In this part of the study, Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) and Technique for Ordering Preference by Similarity to Ideal Solution (TOPSIS) methods will be utilized in light of the determined criteria and results will be compared.

3.1. Multi-Objective Optimization on the basis of Ratio Analysis (MOORA)

MOORA method developed by Brauers and Zavadskas [30], is a multi-criteria decision making method that can be used in a wide range of areas. It takes into account the maximization and minimization of criteria and makes a simple calculation algorithm for users. MOORA method is a new method compared to other MCDM methods and find uses in areas such as material selection [31], project manager selection [32], bank branch location selection [33], supplier selection [34], etc. In this study, MOORA-Ratio Analysis and MOORA Reference Point approaches will be utilized to rank alternatives. MOORA method calculation procedures and detailed calculations will not be discussed in this research, since it is not considered the objective of this study. All calculations and procedures are followed as in literature [30, 35, 36].

3.2. Technique for Ordering Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS method is developed by Hwang and Yoon [37] to evaluate a set of alternatives. This method is based on selecting the alternative closest to the positive ideal solution (PIS) or farthest to the negative ideal solution (NIR). PIS aims to maximize the benefit criteria whereas NIS aims to minimize the cost criteria [38]. Therefore, alternatives are sorted according to the closeness to the PIS. TOPSIS method is also used in numerous research such as solution construction process safety [39], ship main engine selection [40], staff appointment problem [41], etc. Calculation details are not given explicitly, however detailed explanations are given by Hwang and Yoon [37]. Therefore, decision matrix for MOORA and TOPSIS methods is shown as Table 1.

Table 1. MOORA and TOPSIS Methods Decision Matrix

Criteria / Alternatives	**Bollard Pull (tons)**	**Propulsion Power (kW)**	**Draught (m)**	**Fuel Capacity (m3)**
MOORA	Maximization	Maximization	Minimization	Maximization
TOPSIS	Benefit	Benefit	Cost	Benefit
A-1	27.8	2028.0	2.5	105.0
A-2	23.5	1074.0	2.2	140.0
A-3	32.0	1640.0	3.2	126.0
A-4	49.5	2460.0	3.0	72.1
A-5	16.0	1148.0	1.6	160.0
A-6	28.0	1642.0	2.7	126.0
A-7	27.6	1492.0	2.6	62.2
A-8	40.0	2238.0	2.6	122.0
A-9	21.0	1268.0	2.3	45.5
A-10	50.7	2460.0	3.2	174.9
A-11	46.1	2610.0	3.2	220.0
A-12	51.0	2910.0	3.1	220.0
A-13	50.0	3000.0	3.3	180.0
A-14	14.0	714.0	2.7	50.0
A-15	32.0	2910.0	1.5	170.0
A-16	48.0	2850.0	2.6	155.0
A-17	40.0	2388.0	2.6	125.0
A-18	48.0	2850.0	3.0	177.0

In literature, MOORA and TOPSIS methods found a few application to compare. However, some studies give important clues about the strength and simplicity of these methods. While Sevgin and Kundakcı [42] are assessing European Union countries and Turkey in terms of economic indicators with both MOORA and TOPSIS, Şimşek, et al. [28] makes supplier selection in tourism sector.

In addition, it is evaluated whether the rankings obtained by three methods are concordant with each other. For this purpose, Kendall's coefficient of concordance (W) is used. Kendall's W evaluates the agreement among variables. Here, we aim to test the level of agreement among three methods. Kendall's W finds a wide range of uses. For example, Gearhart, et al. [43] utilize this method in aerial imagery to test the concordance among assessor group. Nisel and Nisel [44] use Kendall's W to test the concordance between two university rankings. Kendall's W is a value between 0-1.0. As it is closer to 1.0, it yields to a stronger concordance among raters. However, this test result is also required to be tested by Chi-square statistics.

4. RESULTS

In this study, the selection of AHT vessel for use in Kashagan oil field is done by using TOPSIS and MOORA (Ratio and Reference Point) methods. The results of these three methods are shown in Table 2.

Table 2. Results of MOORA and TOPSIS Methods

Alternative	TOPSIS	MOORA-Ratio	MOORA-Reference Point
	Rankings		
A-12	1	1	4
A-11	2	3	6
A-15	3	2	2
A-18	4	5	3
A-16	5	6	1
A-13	6	4	10
A-10	7	7	5
A-17	8	8	9

A-8	9	9	11
A-4	10	10	15
A-5	11	11	14
A-1	12	12	12
A-6	13	13	8
A-3	14	14	7
A-2	15	15	13
A-7	16	16	16
A-9	17	17	18
A-14	18	18	17

When the results are evaluated, Alternatives 12,11,15,18 and 16 are in the first five options. There is so little deviation among ranking since this comes from the difference in solution algorithms. Although TOPSIS and MOORA uses the same normalization formula, they differ from each other in terms of distance calculation from optimal solution. TOPSIS uses the Euclidean distance to optimal solution where, MOORA uses the linear distance between normalized value and the max/min value of the each criterion. Alternative 12 shows superior characteristics in terms of bollard pull, power and oil capacity criteria, yet draught value is a bit higher than the others. Alternative 11 is distinguished only by the fuel capacity criterion. However, the superiority of oil capacity difference for Alternative 11 dominates other criteria among other alternatives. Alternative 15 is superior than others in terms of draught value and oil capacity. These two criteria dominate others. As seen from the ranking, especially TOPSIS and MOORA ratio methods show a good concordance in whole assessment. However, MOORA-Reference Point approach yields to the same concordance with a holistic evaluation. The concordance of the results of three methods are assessed by Kendall's coefficient of concordance (W) and chi-square statistics tests are also done to test Kendall's W. Therefore, the results are shown in Table 3.

Table 3. Kendall's Coefficient of Concordance (W) for the Methods

Methods	Kendall's W	Chi-Square	Significance
TOPSIS and Ratio and Reference Point	0.909	46.368	0.000
TOPSIS and Ratio	0.996	33.86	0.000
TOPSIS and Reference Point	0.906	30.807	0.021
Ratio and Reference Point	0.894	30.386	0.024

Concordance of each method is determined by Kendall's W and is statistically tested. Three methods show a good concordance since it is greater than 0.90 and this concordance is statistically significant. Concordance of TOPSIS and MOORA Ratio methods is so close to a perfect degree with a 0.996. In the results obtained from other comparisons, Kendall's W values are so high and concordances are statistically meaningful.

5. CONCLUSION

Considering the criteria of bollard pull, propulsion power, draught, and fuel capacity, AHT vessel is selected to operate in the Northern Caspian Region by utilizing MOORA (Ratio and Reference Point approaches) and TOPSIS methods which are multi-criteria decision making tools. Besides, concordance of three methods are demonstrated by Kendall's coefficient of concordance (W) and statistically tested by chi-square test. Results show a great concordance among methods. As a result of the analysis, it is seen that Alternative-12 (A-12) stands out among the others. The A-12 has the most bollard pull and the second most propulsion power among alternatives. These features are advantageous for challenging marine operations such as towing heavy tonnage barges to the selected vessel. While the arithmetic mean of the draught values of all alternatives is approximately 2.66 m., the draft value of the selected vessel is above this average. However, it is still within the acceptable limits for the region. Finally, A-12 is the second regarding fuel capacity and it is important in terms of being operational for longer than other alternatives without fuel supply. The study is expected to provide convenience to the maritime companies operating in oil and gas industry in the North Caspian Sea in terms of the ideal AHT selection. In addition, both MOORA-Ratio and TOPSIS methods can be used for selection problems for such reasons that both methods use the same normalization formula. Also, the distance calculation from optimal solution show similarity which yields to nearly a complete concordance in between two methods.

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