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BARBAROS DENİZ BİLİMLERİ
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NATIONAL DEFENSE UNIVERSITY
BARBAROS NAVAL SCIENCES AND ENGINEERING INSTITUTE
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Açık erişimli yayın politikası izleyen Deniz Bilimleri ve Mühendisliği Dergisi değişik bilimsel bakış açılarını okuyucularına sunmaktadır. Dergide yayınlanan makalelerin bilim, içerik ve dil bakımından sorumluluğu yazarlarına aittir. Doğrudan veya dolaylı olarak ifade edilen görüşler kurumun resmi görüşleri olarak görülmemelidir.

Dergimiz, makale değerlendirme sürecinde çift-kör hakemlik sistemini kullanmaktadır. DBMD'ye yayımlanmak üzere gönderilen makaleler; makale gönderim, işlem ve yayın ücretinden muaftır. Kabul edilen makaleler, ücretsiz olarak basılı şekilde ve dergi web sayfasından çevrimiçi olarak yayınlanmaktadır.

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RESEARCH ARTICLE

DEVELOPING THE REFERENCE ENERGY SYSTEM OF A GENERIC FRIGATE

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ABSTRACT

Referring 3rd IMO GHG study maritime transport is responsible for about 2.5% of global greenhouse gas (GHG) emissions emitting around 940 million tons of CO2 annually. This emission figure is projected to increase significantly if serious mitigation measures are not put in place. Thanks to the studies conducted by IMO GHG emissions from international shipping to be reduced, actually the projection of the reduction amount is 50% achieved by 2050 compared to 2008. Today, navy vessels are not responsible for the IMO emission regulations as commercial vessels, but special regulations may appear in the future. Therefore energy analysis can be needed also for the naval vessels in the future. In this paper, the initial step for performing a ship energy system analysis, which is called "Reference Energy System", has been developed for a generic frigate. The aim of this work is to provide to open a window for energy analysis of naval platforms.

Keywords: *Ship Energy System Analysis, Reference Energy System, Frigate, Emission Control Areas, Greenhouse Gases.*

GENEL BİR FIRKATEYNİN REFERANS ENERJİ SİSTEMİNİN GELİŞTİRİLMESİ

ÖZ

IMO'nun 3. sera gazı emisyonu çalışmasına göre deniz taşımacılığı yılda yaklaşık 940 milyon ton CO2 gazı salmakta ve bu da küresel sera gazı salımının (emisyon) yaklaşık %2.5'u kadardır. Ciddi önemler alınmadığı takdirde bu rakamların önemli ölçüde artacağı tahmin edilmektedir. IMO'nun yaptığı çalışmalarda, 2008 yılına kıyasla 2050 yılında deniz taşımacılığı kaynaklı sera gazı salımlarının %50 azalması hedeflenmektedir. Günümüzde donanma gemileri ticari gemiler gibi IMO'nun kısıtlamalarından sorumlu tutulmasa da gelecekte bu gemilere özel kısıtlamalar getirilebileceği değerlendirilebilir. Bu çerçevede donanma gemilerine yönelik enerji analizinin yapılması faydalı olacaktır. Bu çalışmada genel bir fırkateyn için gemi enerji analizinin gerçekleştirilmesinde ilk basamak olan Referans Enerji Sistemi çalışması yapılmıştır. Çalışmanın amacı askeri deniz platformlarının enerji analizi için bir pencere açılmasını sağlamaktır.

Anahtar Kelimeler: *Gemi Enerji Sistemi Analizi, Referans Enerji Sistemi, Fırkateyn, Emisyon Kontrol Alanları, Sera Gazları.*

1. INTRODUCTION

Population rise and technological advances have increased the energy demand enormously following the industrial revolution. Energy consumption per capita is a significant indicator in terms of the country's development level.

Fossil fuels are the primary source for the world's energy demand and used to power many vehicles including the naval vessels. However, fossil fuels are limited in nature, and diminishing day by day, while they cause harmful emissions during combustion processes, bringing the greenhouse emissions (GHG) associated with huge disadvantages.

Energy system analysis approach basically starts with providing a balance between energy leaving and entering the system with all the interactions of energy carriers including respective technologies; mainly aiming to detect and minimize the inefficiencies in a complex and detailed structure. In this way, analyzing the energy system of a ship may address the determination of more efficient technologies, or fostering new and clean fuel options, as the International Maritime Organization (IMO) commences to present and penetrate efficient technology and fuel standards in the maritime sector in the last decades.

In order to perform energy system analysis properly; a Reference Energy System (RES) should be developed. The first step of creating the RES is to define the energy sources and respective demands in the analyzed energy system. Then, these sources are classified according to their interaction within the system (i.e. whether they are entering or exiting the system), while demand technologies are grouped with respect to their utilization areas. Consequently, as the final step of RES creation, source and demand items are matched with the help of energy carriers, as well as conversion and process technologies.

Since they operate far from the mainland, ships are required to meet their own energy demands. Furthermore; ships have various systems, requiring a vast amount of energy. Therefore ships may have highly complex energy systems. The naval vessels have been ranked in the second place in terms of energy consumption within all ship classifications (surpassed only by the cruise ships), and managing these complex systems efficiently gets harder day by day.

The major energy demand items of a naval vessel are main propulsion, navigation, operation, lighting, communication, air conditioning, security, services, combat, environmental protection, health and maintenance systems.

In order to protect national benefits and interests over the world seas, states hold and develop navy fleets. In this manner, the existence of navies is also a contributor to global greenhouse gas emissions. IMO regulates greenhouse emissions by setting standards that should be met by maritime vessels. Although these limitations are not for military vessels today, this situation may not be permanent.

Naval ships are classified into many different categories according to their objective functions and operational characteristics. In this paper, the RES model is created for a generic frigate. Frigates are the high-speed military vessels with lengths from 80 to 150 meters and within all types of warships; they have the widest mission range varying from anti-air missile to submarine defense. Since frigates perform a wide range of tasks, they have many different systems with high energy demand. Furthermore, high-speed requirements necessitate the use of high energy consuming propulsion systems. Moreover, large crew size is another contributor to the required amount of energy.

1.1. Related Literature

Baldi had performed energy analysis for two commercial vessels. He reported that the maritime industry activities have increased, fuel prices have soared, and more stringent environmental regulations have been developed. Moreover; he discussed that although its contribution to global warming is relatively low today, maritime transport should be examined in order to decrease related greenhouse gas emissions, and highlighted that there is room for improving the energy efficiency of vessels and that maritime industry can be a part of a sustainable economy [1].

In another related analysis; Sarı *et al*. claimed that the ever-increasing population and rapid technological developments led to an increase in energy consumption and a corresponding increase in demand while decreasing the availability of global resources. They affirmed that energy system analysis has been a hot topic and evaluated the energy consumption and respective demand by developing a reference energy system (RES) model of a generic ship [2].

With IMO's current regulation, on-force by January 1st of 2020, the amount of sulfur in marine fuels will be limited to 0.5% of total fuel mass. Moreover, IMO's limit for the share of sulfur in fuel has already been 0.1% for Emission Control Areas (ECAs) since 2015 [3].

Figure 1. Current and future Emission Control Areas [4].

Trivyza *et al.* set up a simulation model to predict the energy systems' performance during the ship lifetime. This study introduces an innovative method that integrates the economic and environmental aspects of sustainability [5].

In this perspective, Evrin *et al.* have developed an integrated energy system based on hydrogen fuel. In order to supply the ship's electric and fresh water needs, where liquefied hydrogen fuel is used in the steam production cycle. Moreover the hydrogen fueled engine's effectiveness at decreasing greenhouse gas emissions is assessed in this study [6].

Yuan *et al.* assert that shipping contributes heavily to global CO_2 emissions and improving the ship's energy efficiency is an important area of interest. Authors denote that, ship's fuel consumption should be decreased to decrease the ship emissions. However, evaluating ship's fuel consumption with the physical system and simulation models is hard due to factors; such as complexity of the ship energy system, complexity of real-life operational conditions, and variations in real-life weather conditions. In this study, a Gauss process metamodel was developed to estimate ship fuel consumption for different scenarios. This model takes into account the effects of not only operational conditions such as speed and trim, but also weather conditions such as wind and wave [7].

In their study, Baldi *et al.* assert that better utilization of the ship's energy improves a ship's energy efficiency significantly. In order to demonstrate this method's benefits, the authors highlight the importance of applying ship energy system analysis. Data collected from the case study ship's operations are used in conjunction with ship systems' mechanic information to evaluate different energy flows [8].

Gutiérrezet *et al.* declare that several different methods were suggested to measure the ship's fuel consumption and emissions more reliably and that whichever of these methods is the best is still undecided. In this study, four common methods for calculating energy consumption and emissions are compared via a case study. The goals of this comparison are to obtain data needed for better energy management and to determine the best method for applying to any ship [9].

Grados *et al.* discuss the energy and emission calculations problems of ships; however they conclude that energy consumption and emissions should be taken as the key factors when calculating the real power generated by the ship's main machines. In order to evaluate the propulsion system's effect on calculated energy consumption and emissions, data gathered from eight ferries operating at the strait of Gibraltar. For this calculation, after comparing four methods, the authors suggest a different method for these eight cases [10].

1.2. The Significance of Ship Energy System Analysis

Relevant researches show that shipping-related greenhouse gas emissions will increase by 150% to 250% by 2050 when compared to 2008 levels [11]. As a result, maritime transport caused CO2 emissions will constitute 17% of the global total by 2050 [12]. Energy system analysis, by increasing the energy efficiency of a vessel, allows lower fuel consumption and emissions. The vitality of such an analysis becomes more evident when factors such as IMO's more aggressive greenhouse gas emission targets and rapid depletion of fossil fuel sources are considered. Furthermore, for naval vessels, efficient energy management contributes to survivability, thus making this paper even more significant.

2. METHODOLOGY

2.1. Energy Activity Calculation

A number of variables, which affects the result, are used for energy systems calculations. These variables are final energy demand and useful energy demand.

2.1.1. Final Energy Demand

Activity levels are multiplied by both energy demands and energy densities to determine the average energy consumption of each device or system and the energy consumption is calculated annually.

$$D_{b,s,t} = TA_{b,s,t} \times EI_{b,s,t} \quad (1)$$

In Equation (1), *D* refers to the energy demand, *TA* is the total activity. *EI* is energy intensity. *b* is the energy demand system or devices, *s* is the scenario and *t* is the time and is taken as a year. Activity level is defined as the amount of time that and the amount of load at which the device is used, in a period of time.

2.1.2. Useful Energy Demand Analysis

In useful energy analysis, total energy consumption is affected by the fuel type, energy efficiency and available energy density.

For each technology branch:

$$UE_{b,0} = EI_{AG,0} \times FS_{b,0} \times EFF_{b,0} \quad (2)$$

b index stands for the user-defined demand technology; while *UE*, *EI*, *FS*, and *EFF* refer to useful energy, energy intensity, fuel share, and the efficiency of technology, respectively.

The following example illustrates the final and useful energy demand calculation. Consider an aggregate energy branch with a final intensity of 100 GJ per activity, the electricity technology has 20% and diesel technology has % 80 fuel shares. Electricity technology has an efficiency of 100% and diesel engine technology has an efficiency of 45%. Therefore, the useful energy intensities of the relevant technologies are 100×20%×100% = 20 GJ/activity and 100×80%×45% = 36 GJ/activity respectively, and the activity shares are 20/56×100% = 35.7% and 36/56 = 64.3%, respectively.

Table1. Example of useful energy and activity share calculation

	Final Intensity		Useful Intensity	
Heat	100		56 GJ	
	Fuel Share	Efficiency	Useful Energy	Activity Share
Electricity	20	100%	20 GJ	35,7%
F-76 (Diesel)	80	45%	36 GJ	64,3%

2.2. Transport Analysis Calculation

$$Stock_{t,\,y,\,v} = Sales_{t,\,v} \times Survival_{t,\,y-v} \tag{3}$$

$$Stock_{t,\,y} = \sum_{0}^{v} Stock_{y,v,z} \tag{4}$$

Where *t* is technology branch, *v* is the model year, *y* is the calendar year, *t* is the number of types of vehicles. Sales are the number of vehicles added in a particular year: entered as an expression. The *stock* is the number of vehicles existing in a particular year, and *v* is the maximum number of vintage years.

$$FuelEconomy_{t,\,y,\,v} = FuelEconomy_{t,y} \times FeDegradation_{t,\,y-x} \tag{5}$$

FuelEconomy is fuel use per unit of vehicle distance traveled. FeDegradation is a factor that equals 1 when y=v and representing the decrease in fuel economy depending on vehicle age.

$$Mileage_{t,\,y,\,v} = Mileage_{t,\,y} \times MlDegradation_{t,\,y-x} \tag{6}$$

Mileage is the annual distance traveled per vehicle and entered as an expression, defining the historical values and how that variable changes over time from the first scenario year to the end year of the study period. *MlDegradation* is a factor representing the change in mileage as a vehicle gets obsolete; it equals 1 when y=v [13].

$$EnergyConsumption_{t,y,v}=Stock_{t,y,v}\times Mileage_{t\,y,v}\times FuelEconomy_{t\,y\,v} \tag{7}$$

2.2. The Reference Energy System Concept

A simple definition of RES is the flow of energy from primary sources through conversion and process technologies to demand items, as illustrated in Figure 2 [14].

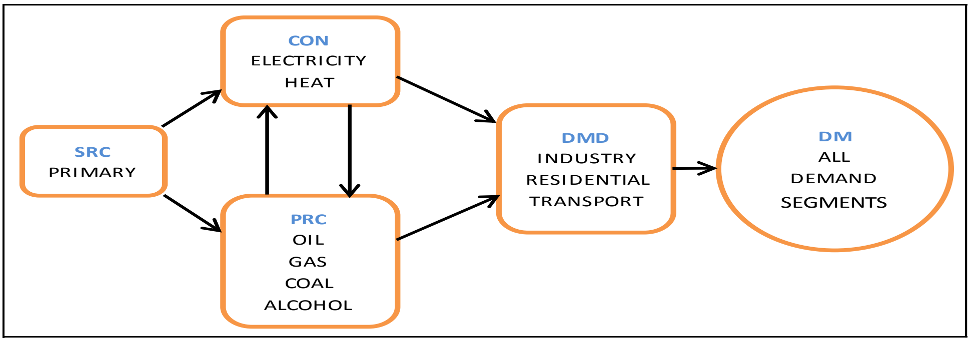

Figure 2. A generalized RES

As a generic frigate has been the subject to this paper's analysis, the RES scheme has been created based on specified demands of a frigate and the energy sources needed to meet these demands. Then, the demand technologies of the frigate have been determined.

2.2.1. Demand Technologies

There are various demand items in a frigate and each demand item exists in the vessel for a specific purpose. For instance, different types of energy technologies are getting used for lighting e.g. lamps, luminaires and projectors. Subsequently, the specific operation voltage and frequency values for each demand item were determined accordingly.

2.2.2. Demands

After determining the demand items, these items were grouped into categories according to their functions. Diesel generators and bow thruster are both responsible for the propulsion of the vessel; therefore they are listed under the "Main Propulsion System" group. Similarly; GPS and gyro compass are the parts of the "Navigation" group. This kind of classification allows a better overall understanding of the energy requirements and flow of energy in a frigate. Moreover, calculating these demands in each category and respective energy requirements will provide a base and guidance for further studies and ship design activities. The frigate's demand technologies and their corresponding groups are listed in Table 2, 3 and 4.

Table 2. Demand technologies and respective demands (1)

MAIN PROPULSION SYSTEM	NAVIGATION
BOW THRUSTER	GYRO COMPASS
LUBRICATION OIL AND TRANSFER PUMP	WINDLASS MANEUVER
FUEL FILLING AND TRANSFER PUMP	ANCHOR WINDLASS
MONITORING AND CONTROL	NAVIGATION RADAR (LPI)
PROPULSION SHAFT AND COUPLINGS	WECDIS
REDUCTION GEAR LUB.OIL.PUMP	FIN STABILIZER SYSTEM
REDUCTION GEAR STAND BY PUMP	SHIP WHISTLE
FUEL SEPARATOR	DYNAMIC AUTOPILOT SYSTEM
OIL SEPERATOR	NAVTEX
MAIN ENGINE AIR VACUUM SYSTEM	GPS
MAIN ENGINE WASHING SYSTEM	DGPS
MAIN ENGINE STARTING SYSTEM	NAVIGATION AND SIGNALLING LIGHT
MAIN PROPULSION SYSTEM CONTROL BOARD	ECHO SOUNDER
STERN TUP SYSTEM	ANEMOMETER
COOLING WATER SYSTEM	DATA DISTRIBUTION UNIT
RUDDER ENGINE	DOPPLER LOG
GOVERNORS	WINDOW WIPER
DIESEL GENERATOR SET	METROLOGICAL MEASUREMENT SYSTEM
MAIN PROPULSION ENGINE	SIGNAL REPEATER
OPERATION	**COMMUNICATION**
SONAR	CRYPTO DEVICE
DEGAUSSING SYSTEM	WARNING SPEAKER
BOAT LAUNCHING ARRANGEMENT	ANNOUNCEMENT SYSTEM-1
VEHICLE CRANE	ANNOUNCEMENT SYSTEM-2
SEVICE CRANE	SATELLITE COMMUNICATIONS SYSTEM
TRANSFER SYSTEM	UHF RECEIVERS
UAV OPERATOR CONSOLE	MF/HF/LF RECEIVERS
USS OPERATOR CONSOLE	FIRE ALARMS
SUBMARINE DIVE LAUNCHING ARRANGEMENT	ALARM DOOR LOCK
UAV WEAPON SYSTEM	IFF
UAV FUEL TRANSFER SYSTEM	GMDSS
ANTISUBMARINE WEAPON TRANSFER SYSTEM	OTHER ALARM SYSTEM
SUBMARINE CHARGE UNIT	MESSAGE COMMUNICATION SYSTEM
AIR COMPRESSOR	X-BAND ANTENNAS
PRESSURE ROOM COMPRESSOR	HF TRANSCEIVERS
HELICOPTER HANGAR COVER MOTOR	VHF LOW BAND TRANSCEIVERS
HELICOPTER TRANSFER SYSTEM	VHF/UHF TRANSCEIVERS
JP-5 FUEL TRANSFER SYSTEM	UNDERWATER TELEPHONE
DIVE COMPUTER	S/P TELEPHONE
PRESSURE ROOM MONITORING SYSTEM	HAND RADIOS
VIDEO MONITORING UNIT	SHIP INTERCOM SYSTEM

Table 3. Demand technologies and respective demands (2)

SERVICE	MILITARY SYSTEM / SECURITY /
COLD ROOMS	TEST PANEL ELECTRONIC WORKSHOP
REVERSE OSMOSIS DEVICE	ANTENNA CONTROL AND COOLING DEVICE
MACHINE WORKSHOP	ED TRANSFORMER
SOLID WASTE DEVICE	GUN POWER AND ESCALATOR CABINET
WASHING MACHINE	GUN LIQUID COOLING CABINET
IRONING MACHINE	MACHINE GUN
CYLINDRICAL IRONING MACHINE	FREQUENCY DISRUPTORS
BOILING POT	TORPEDO BARREL COVER
RANGE	WEAPON CRANE
GRILL	AMMO TRANSFER ELEVATOR
OVEN	BRIDGE DISPLAY AND CONTROL UNIT
WASHING MACHINE	BRIDGE LANCER REMOTE CONTROL UNIT
MIXER MACHINE	CONTROL RADAR
FRYER	LIGHTING RADAR
FRYING PAN SYSTEM	FIBER OPTICAL DIRECTOR
FERMENTATION CABINET	AIR DEFENSE MISSILE IGNITION SYSTEM
GARBAGE GRINDER	VERTICAL LAUNCHER SYSTEM
BOOSTER SYSTEM	3D SEARCH RADAR
MEAT MACHINE	12.7 MM HEAVY MACHINE GUN
LAUNDRY DRYER	CIWS
POTATOES PARING MACHINE	GUN CONTROL SYSTEM
ELECTRIC STOVE	TORPEDO
MICROWAVE OVEN	AIR TARGETS CHEATING SYSTEM
TEA MACHINE	UNDERWATER DECEPTION SYSTEM
HOT SERVICE UNIT	ELECTRONIC WARFARE SYSTEMS
FRIDGE	USER CONTROL INTERFACES
WATER TREATMENT EQUIPMENT	HEADQUARTERS COMPUTER SYSTEM
WATER HEATER	COMMAND CONTROL DEVICES
UV FILTER	BRIDGE CONTROL UNIT
CHLORINE DOSING UNIT	DIVER PUMP
PAPER CROP MACHINE	PORTABLE FIRE HAMPER
CALL DEVICES	MAIN FIRE AND AUXILIARY SEA WATER PUMP
FREEZING	MAIN FIRE PUMP
BREAD CUTTING MACHINE	MAN OVERBOARD ALARM
TOASTER	DAMAGE CONTROL PANEL
BLENDER	NBC SYSTEM
COFFEE MACHINE	CAMERA SYSTEM
TOASTER MACHINE	FIRE ALARM SYSTEM
MEAT GRINDER	FOAM FIRE EXTINGUISHING SYSTEM
PRINTER	FIRE FIGHTING SYSTEM WITH GAS
TELEVISION	GAS DETECTOR
SOUND SYSTEM	CARD READERS
RADIO	FIRE DETECTOR
DVD PLAYER	DENTAL SEAT SYSTEMS
SATELLITE RECEIVER	X-RAY MACHINE
SEWING MACHINE	STERILIZED DEVICE
BARBER EQUIPMENT	SHOCK DEVICE

Table 4. Demand technologies and respective demands (3)

LIGHTING / AIR CONDITIONING	ENVIRONMENTAL PROTECTION / MAINTENANCE
OUTDOOR DECK LIGHTING SYSTEM	DIRTY WATER PUMP
EMERGENCY LIGHTING	BILGE DISCHARGE PUMP
HAND LIGHTING	BILGE SEPARATORS
LUMINAIRES AND PROJECTORS	MUD PUMP
INDOOR LIGHTING	OIL SEPARATOR FILTER
CEREMONY LIGHTS	MUD TANK DISCHARGE PUMP
ENTRANCE LAMPS	WASTEWATER VACUUM PANEL
DOOR LIGHTING	SLUDGE TRANSFER PUMP
CHILLER WATER PUMP	ANTI-FOULING SYSTEM
BOILER SYSTEM	ACTIVE CATHODIC PROTECTION SYSTEM
HEATER	SHARPENING ENGINE
HUMIDITY REGULATOR	DRILLING
AXIAL FAN	WELDING EQUIPMENT
RADIAL FAN	RIVET GUN
HOT WATER CYCLE PUMP	AIR HAMMER
COOLING WATER CYCLE PUMP	PAINT SPRAYING MACHINE
	PORTABLE AIR DRYING DEVICE

2.2.3. Resource Technologies

Resource technologies are the energy sources that are used in the system. Following the determination of the demand technologies, resource technologies are specified depending on the energy carrier types and associated fuels. These sources can be classified into two groups: primary and secondary energy sources.

Primary energy sources; such as crude oil, wood, coal, and geothermal energy, are available in nature. On the other hand, secondary energy sources, such as gasoline, diesel, and electricity-are not available in nature. However, they can be derived from primary energy sources.

In the RES scheme for the frigate, used energy sources are F-76 diesel fuel, lubrication oil, sea water, electricity, and gasoline. F-76 is the common NATO standard fuel used by naval ships. Lubricating oil is required for the friction reduction, wear protection, and cooling of the moving parts of the main engines. In addition, some of the lubricating oil is consumed due to thermal evaporation during the operation in the diesel engines. Seawater is an unlimited source, which is used for cooling purposes. Electricity is required for the operation of various systems in the vessel. Gasoline is used to power rescue boats and rigid inflatable boats.

Although all of the energy sources mentioned above enter the system (input sources), a certain amount of them leaves the system. For instance, the excess amount of F-76 fuel can be transferred to another vessel, lubricating oil can be consumed during the diesel engines operation, and after being used for cooling purposes, heated sea water can be discharged.

2.2.4. Conversion and Process Technologies

The conversion and process technologies that can be found in a frigate are the main propulsion engine, diesel generator set, auxiliary propulsion engines, fuel separators, oil separators, main switchboards, transformers, converters, inverters, and batteries. These systems form a bridge between source and demand technologies. For instance; F-76, as an energy carrier, enters the diesel generator set, where it is converted to heat mechanical and electrical energy, respectively. Then the electrical energy produced by the generator is transmitted to the main switchboard, which distributes the energy to the various demand technologies.

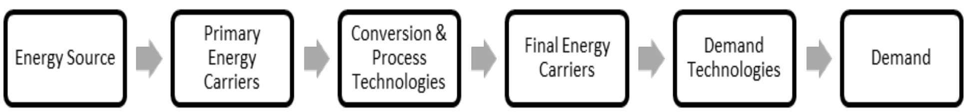

Figure 3. The simplified representation of energy flow.

2.2.5. Primary and Final Energy Carriers

Primary energy carriers, such as pumps and compressors, transport the source energy to conversion and process technologies. Each system in the vessel has a different energy demand. Some of them need electrical energy, while others require heat energy. Furthermore, voltage and frequency requirements can vary among the demand technologies in need of electrical energy. Final energy carriers are these different forms of electrical energy, as well as heat energy, directly consumed in the end-use technologies.

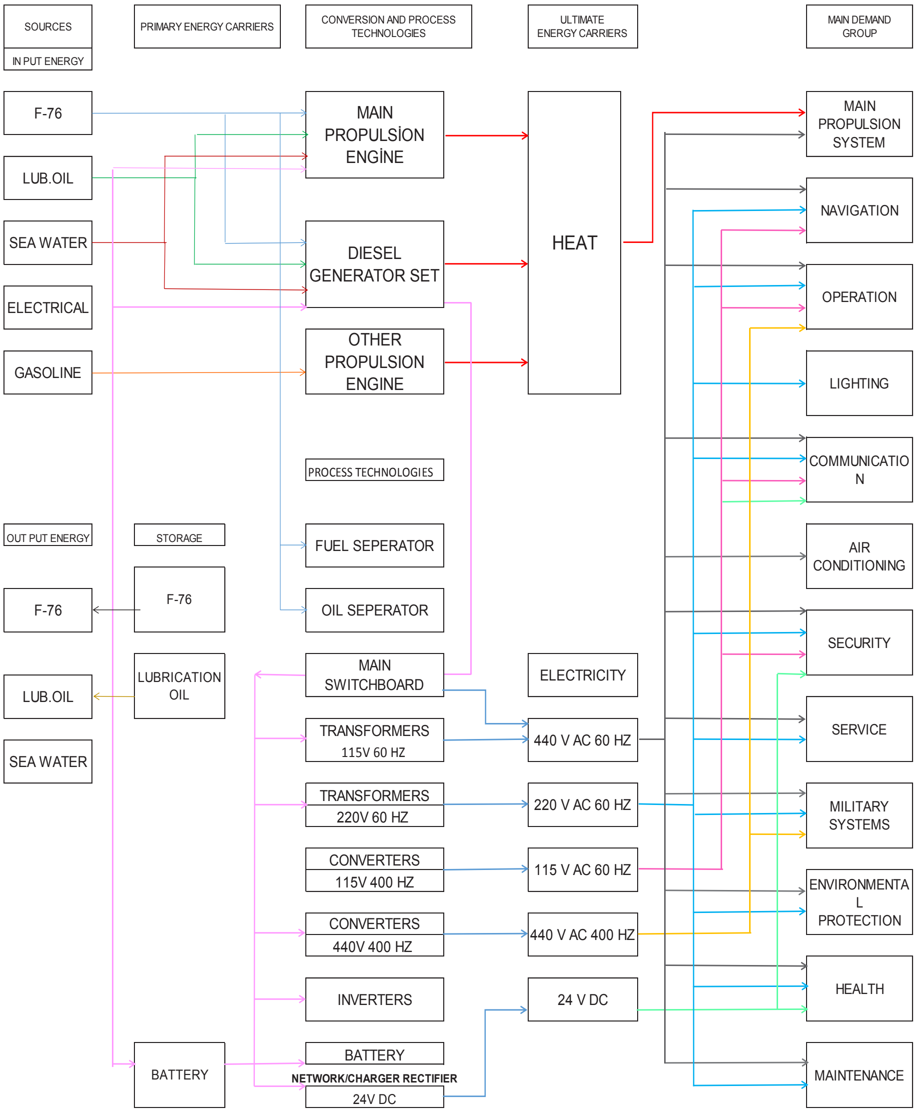

Figure 4. Reference energy system for a generic frigate

5. RESULTS AND CONCLUSION

Energy technologies utilized onboard in a frigate support the main objective function of the ship. The number of energy demands are determined in the contract design phase, then verified during the final sea trials. However, the decision makers may need a detailed energy profile of the ship to address decent arrangements for the possible modifications on the ship configuration, both for the technical and environmental perspectives. With this motivation, a detailed scheme named RES is developed for a generic frigate in this study. The technical parameters for a generic frigate are shown in Table 5, corresponding to each title in the main demand group as illustrated in Figure 4. The calculations are shown only for navigation and lighting demands in Table 5 for “gyro-compass” and “emergency light” under navigation and lighting groups are explained to give a better insight.

In the analyzed energy system of a frigate, two gyro-compasses are on board. Both have an operating voltage of 220V, use alternative current (AC), and have an operating frequency of 60 Hz. Two gyro-compasses use a total of 15 kW energy per hour. Gyro-compasses are used during the navigation, therefore usage percentage of gyro-compasses (%25) is taken from the ship’s annual navigation duration. From the usage percentage, the time interval of gyro-compasses usage is calculated as %25×365×24. Then, utilization factor (1 for gyro-compass) is multiplied with this annual usage duration (2190 hours) and load per hour (15 kWh), in order to find the total annual load (32850 kWh), and also shown in Gigajoule in a different column. Similarly, there are 400 emergency lights on board. However, emergency lights operate at 220V AC under normal conditions, and could be switched to 24V DC in an emergency, as they can operate both alternative (AC) and direct (DC) current.

Table 5. Technical parameters and information for energy system modelling of a generic frigate

SYSTEM	AMOUNT	VOLTAGE (V)	CURRENT TYPE	FREQUENCY (Hz)	ELECTRICITY USAGE PER HOUR (kWh)	ELECTRICITY USAGE PER YEAR (kWh)	USAGE HOUR PER YEAR	TOTAL USED QUANTITY GIGA JOULE (GJ)	UTILIZATION FACTOR	USAGE FACTOR
NAVIGATION										
GYRO COMPASS	2	220	AC	60	15	32850	2190	118,2272	1	0,25
DYNAMIC AUTOPILOT SYSTEM	1	115	AC	60	28	61320	2190	220,6907	1	0,25
ANEMOMETER	1	115	AC	60	0,7	1533	2190	5,517267	1	0,25
DGPS	1	220	AC	60	1,2	2628	2190	9,458172	1	0,25
GPS	1	220	AC	60	1,2	2628	2190	9,458172	1	0,25
NAVTEX	1	220	AC	60	2	4380	2190	15,76362	1	0,25
DATA DISTRIBUTION UNIT	4	220	AC	400	7	15330	2190	55,17267	1	0,25
DOPPLER LOG	1	115	AC	60	1	2190	2190	7,88181	1	0,25
WINDOW WIPER	12	115	AC	60	6	13140	2190	47,29086	1	0,25
ANCHOR WINDLASS	2	440	AC	60	86	6780,2 4	78,8	24,40208	0,9	0,009
WINDLASS MANEUVER	4	440	AC	60	85	6701,4	78,8	24,11834	0,8	0,009
WECDIS	1	220	AC	60	4	315,36	78,8	1,134981	1	0,009
NAVIGATION RADAR (LPI)	3	440	AC	60	22	48180	2190	173,3998	1	0,25
ECHO SOUNDER	2	115	AC	60	1,3	2847	2190	10,24635	1	0,25
NAVIGATION AND SIGNALLING LIGHT	84	220	AC	60	17,5	38325	2190	137,9317	1	0,25
SHIP WHISTLE	1	440	AC	60	16	35040	2190	126,109	1	0,25
FIN STABILIZER SYSTEM	2	440	AC	60	135	295650	2190	1064,044	0,8	0,25
METROLOGICAL MEASUREMENT SYSTEM	1	115	AC	60	1,4	3066	2190	11,03453	1	0,25
SIGNAL REPEATER	15	115	AC	60	4	8760	2190	31,52724	1	0,25

LIGHTING										
OUTDOOR DECK LIGHTING SYSTEM	12	220	AC	60	4	17520	4380	63,05448	1	0,5
EMERGENCY LIGHTING	400	220/ 24	AC/ DC	60/~	90,2	3950,76	43,8	14,21879	1	0,005
HAND LIGHTING	60	220	AC	60	0,6	26,28	43,8	0,094582	1	0,005
LUMINAIRES AND PROJECTORS	4	220	AC	60	6	262,8	43,8	0,945817	1	0,005
INDOOR LIGHTING	540	220	AC	60	19,44	136235,52	7008	490,3116	1	0,8
CEREMONY LIGHTS	300	220	AC	60	3	394,2	131	1,418726	1	0,015
ENTERENCE LAMPS	32	220	AC	60	0,3	1051,2	3504	3,783269	1	0,4
DOOR LIGHTING	60	220	AC	60	1	8760	8760	31,52724	1	1

In conclusion, a ship consists of a highly complex energy network with subsystems and a great number of energy devices. Therefore, estimating the energy demand of a ship may be a challenge. In order to evaluate the ship's energy system correctly; first, the amount and the type of energy required by each system should be determined. Energy is transmitted first from sources to conversion and process technologies, and then from them to demand technologies. In naval vessels, energy should be used correctly due to high demand and long-lasting operations. Hence, energy analysis is important for improving the ship's survivability. If the energy demand is known exactly, the sources can be adjusted precisely. Such energy system analyses for different types of naval vessels will support energy-decision processes in the future.

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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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RESEARCH ARTICLE

ON THE SELECTION OF SHIP WASTEWATER TREATMENT PLANT INCORPORATING ANALYTICAL HIERARCHY PROCESS WITH 0-1 GOAL PROGRAMMING

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ABSTRACT

As a result of the continuous pollution of the air, seas and soil, the deterioration of the natural equilibrium can be felt severely. Therefore, the prevailing vision of sustainable environment is frequently mentioned in the international arena. There are many industrial sources of pollution. Each of them significantly affects the environment. In the seas, the biggest source of pollution is the ships. Pollutants originating from ships are solid pollutants, bilge water, ballast water, anti-fouling system, etc. Another important source of pollution is wastewater. Untreated wastewater discharged to the sea will cause the natural balance to deteriorate. Therefore, wastewater treatment equipment is needed. The integration of equipment in ship design is a challenging process and many criteria must be considered together. In this study, it is stated that the criteria of the ship wastewater system will be evaluated and a set of alternatives is determined by Analytical Hierarchy Process (AHP). In addition, in accordance with a scenario created by considering the integration constraints of these systems into the ship, a hybrid model in which the 0-1 Goal Programming and AHP weights are applied, and the optimum solution (equipment) is selected which satisfies the determined constraints.

Keywords: *Ship Wastewater Treatment Plant, Multi-Criteria Decision Making (MCDM), Analytical Hierarchy Process (AHP), 0-1 Goal Programming.*

ANALİTİK HİYERARŞİ SÜRECİ VE 0-1 HEDEF PROGRAMLAMA YÖNTEMİ İLE GEMİ PİS SU ARITMA ÜNİTESİ SEÇİMİ

ÖZ

Havanın, denizlerin ve toprağın sürekli kirletilmesi neticesinde doğal dengenin bozulması şiddetli bir şekilde hissedilir duruma gelmektedir. Bu nedenle, günümüzde sürdürülebilir çevre anlayışının hakim kılınması, ulusal ve uluslararası arenada sıkça belirtilmektedir. Endüstriyel kaynaklı birçok kirlilik kaynağı mevcuttur. Her biri çevreyi önemli ölçüde etkilemektedir. Denizlerde ise bu kirliliğinin en büyük kaynağı gemilerdir. Gemilerden kaynaklı katı kirleticiler, sintine suları, ballast suları, yosuntutmaz sistemlerden kaynaklı kirleticiler buna örnek gösterilebilir. Bir diğer önemli kirlilik kaynağı ise gemilerde üretilen atık sulardır. İşlem görmeden denizlere salınması halinde doğal dengenin bozulmasına sebebiyet verecektir. Bu nedenle atık suyu işlemden geçirecek ekipmanlara ihtiyaç duyulmaktadır. Gemi dizaynında bir ekipmanın entegre edilmesi oldukça zorlu bir süreçtir ve bir çok kriterin birlikte değerlendirilmesi gerekmektedir. Bu çalışmada bir atık su sisteminin hangi kriterler çerçevesinde değerlendirileceği ortaya konmakta ve belirlenen alternatiflerden hangisinin seçileceği Analitik Hiyerarşi Süreci (AHS) ile belirlenmektedir. Ayrıca, bu sistemlerin gemiye entegrasyonunda yaşanan kısıtlar göz önüne alınarak yaratılan bir senaryoya uygun olarak 0-1 Hedef Programlama ve AHS ağırlıklarının uygulandığı hibrit bir model ortaya konulmakta, ve belirlenen kısıtları sağlayan optimum çözüm (ekipman) seçilmektedir.

Anahtar Kelime: *Gemi Atık Su Arıtma Ünitesi, Çok Kriterli Karar Verme (ÇKKV), Analitik Hiyerarşi Süreci(AHS), 0-1 Hedef Programlama*

1. INTRODUCTION

Leaving all kinds of waste to nature and the effects of these waste on the nature are defined as pollution [1]. Even though the rapid development of science and technology in the world has a very positive contribution to human life, the pollution caused by people against nature is constantly increasing. A continuous production, and consequently a continuous consumption, as well as the fact that a sustainable environmental consciousness cannot be taken socially, causes nature to be adversely affected. As the environmental pollution started to affect the life, the importance of pollution has prevented the convenience of technology. However, individuals, societies, governments, and even global organizations are taking very important steps in order to prevent the adverse effects of environmental pollution. Even small steps are taken seriously for environmental sustainability such as going paperless in formal corresponding [2]. Pollution occurs on land, sea and air. The space debris formed by satellite and space shuttles can be added to this definition. As part of the scope of this study, marine pollution will be discussed later.

71% of the earth's surface is covered with water and 96.5% of this water is in the oceans [3]. Other water sources include groundwater, lakes, rivers, etc. The journey of all wastes on the earth ends in seas and oceans and this pollution is caused by 4 main elements [1]:

- **Land Based (44%):** Pollutants from land to oceans or seas are mostly caused by rivers. The biggest threat from the land is plastic and sewage systems.
- **Air Based (33%):** Dust from the desert is one of the major pollutants in the sea. In addition, acid rain from air pollution significantly affects the pollution of the seas.
- **Maritime Activities and Accidents (12 % + 10%):** Especially, pollution caused by tanker accidents has a negative impact on the seas for decades. Apart from this, sewage waste, solid waste, bilge waste, gas waste from exhaust emission, ballast-borne waste affecting biological equilibrium are considered as maritime activity pollution.
- **Offshore Mining and Drilling (1%):** Pollution due to the drilling of the seabed.

1.1. Ship borne Pollution

The pollution caused by Maritime activity is ranked 3rd according to the total pollution in nature and the main reason for this pollution is the ships. According to United Nations Convention on the Law of the Sea, pollution of the marine environment means "the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities" [4].

World trade, with the increasing world population, is constantly increasing in both volume and value. According to World Trade Organization, in 2017, there is a growth of 11% in value and 4.7% in volume in world trade [5]. In addition, global sea trade realized a growth of 4% in 2017 and it is estimated that this growth will be 3.8% compound annual growth rate (CAGR) between 2018-2023 [6]. In addition, the biggest side effect of the growth of the sea trade volume is the increase in the number of ships and the tonnage. This growth is also 3.3% in 2017 [6]. When the ship numbers are considered, this growth is 14.5% between 2011-2018 [7]. As can be seen from this point, the sea transportation fleet has achieved a lot of growth. Therefore, it is considered that this growth will have adverse effects on marine pollution.

With the growth of world trade and the fact that maritime transport has a significant role in this trade volume, the increase in the number of ships comes into prominence. The negative impacts of each ship on the environment are undeniable. Because, there are many types of pollutants released from the ships. To group these pollutants as in Figure 1 [1, 8, 9]:

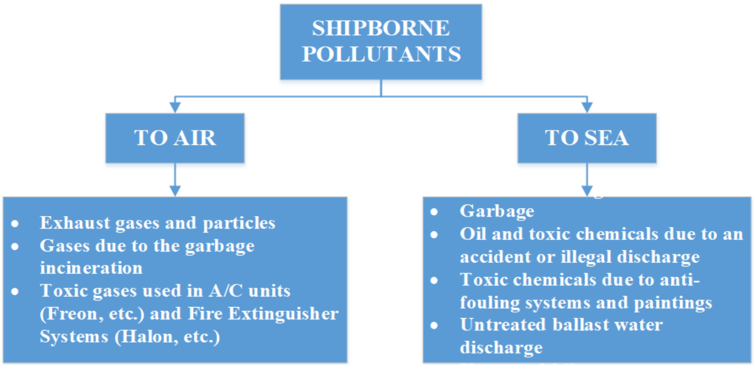

Figure 1. Ship borne Pollutants.

1.2. Wastewater as a Ship borne Pollutant

The diversity of marine pollution is determined to be very high according to Figure 1, however preventive and corrective measures are taken by international organizations and governments for each of these pollutants. In this study, a detailed review of all these pollutants is considered outside the scope, and each topic needs to be evaluated as a separate research area. Therefore, the scope of this study is narrowed as seaborne wastewater.

According to MARPOL 73/78 (Annex IV) [10], sewage refers to:

- Waste from toilets, urinals and WC scupper,
- Drains (wash basin, wash tub, scuppers, etc.) from medical facilities,
- Drains from places in which animal habitat,
- All other drains in a contact with above waste definitions.

In addition, the wastewater is considered in two categories as grey water and black water and their contents are represented by Figure 2. Disposal of the waste mentioned in both section without treatment is prohibited to some extend by national and international regulations.

- **Greywater:** The impact of greywater on pollution of the seas is not as high as other wastes. However, it can be harmful because it contains high bacteria and chemicals, and pollutes the water if it is discharged untreated [11].

- **Black Water:** It is an important source of pollution in the sea. Because it contains high amounts of bacteria and viruses, it can affect both sea creatures and people who consume them. It also causes the spread of diseases in direct contact with people [12].

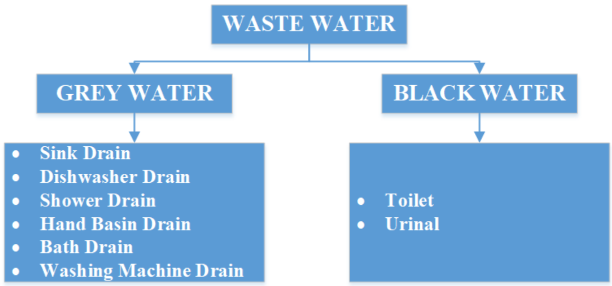

Figure 2. Wastewater Definition.

As a result of international regulations, these wastes can be discharged into the sea by treating them and providing certain conditions, especially as specified in MARPOL. The reference values are provided by IMO Resolution MEPC.159 (55) to ensure that these wastes can be discharged into the sea, and only under these conditions, discharge can take place (IMO MEPC 55/23-ANNEX 26, 2006) [13]. In order to treat these wastes, it is necessary to have a Marine Wastewater Treatment Plant capable of fulfilling the IMO regulations and the ships must receive the International Sewage Pollution Prevention Certificate. Waste treatment is carried out in 3 basic ways: 1) mechanical, 2) chemical, 3) biological. The treatment of waste is provided by hybrid models of these three processes. Therefore, the working principle of wastewater treatment plant can be described as: 1) mechanical-chemical, 2) mechanical-biological, 3) chemical-biological [14].

With the increase in sea trade and the number of ships, it will be inevitable that sea pollution will increase at the same rate. The national and international measures taken in this context with all the details include the issues to be done at the design stage of the ships. In particular, MARPOL 73/78 contains a number of important measures related to ship-borne pollutants. These measures are essential to implement in the ship design from the very beginning, and the selection of suitable equipment and devices for the treatment of pollutants is a prerequisite. The most important challenge faced by the ship design engineers is to make the optimum technical decision while applying the regulations effectively. Therefore, the placement of equipment in ship design is very important. Designers spend a great amount of time and effort to place a lot of equipment in a very limited space and to integrate them in the optimal way. Many criteria need to be considered together, and if there is more than 30 equipment in a machine room, the solution to this situation is almost impossible.

The motivation of this study, as mentioned above, is to look for the answer to the question of how to implement the measures and rules in the protection of the seas and the environment with seriousness and how to ensure the technical requirements of equipment selection in ship design and how to integrate an equipment item. In this context, a literature review is carried out in Section 2 for the purpose of equipment selection. As seen in the literature, the equipment selection study is generally evaluated in terms of land facilities and MCDM methods are used extensively. In Section 3, the research problem is defined and the evaluation criteria of the problem are presented. In Section 4, AHP and 0-1 Goal Programming methods are applied in order to solve the problem. The results of the study are discussed in Section 5.

2. LITERATURE REVIEW

Selection of an equipment is considered as a Multi Criteria/Objective Decision Making (MCDM) problem. A proper selection of an equipment is a crucial issue for any decision maker since it is directly related to both financial and technical aspects. Selection of an improper equipment causes serious problems for a company, factory etc. in terms of efficiency and productivity [15]. In literature, there is numerous studies regarding equipment selection among many alternatives. Dagdeviren [15] proposed AHP-PROMETHEE integrated approach for milling machine selection. The criteria used for selection are price, weight, power, spindle, diameter and stroke. Tuzkaya et.al. [16] utilized F-ANP and F-PROMETHEE for material handling equipment selection and considered criteria such as power and space requirements, reliability, maintainability, adaptability, operational flexibility, power usage, etc. Lashgari et.al. [17] also proposed an integrated MCDM method of F-AHP, F-ANP and F-TOPSIS for loading equipment in mining industry. Some of the technical criteria for selection problem are maintenance, flexibility, availability, production rate, power, etc. Demirel [18] presents ship roll motion stabilizing system selection with hybrid F-AHP and F-TOPSIS methods. Demirel et.al. [19] utilized F-AHP and Electre for selecting ship stabilizing device. When the literature is reviewed there are such studies which discuss equipment selection in various purposes with MCDM techniques as well as roll stabilizer selection for ships are presented in some studies. However, the missing point in which, researchers omit that the integration of equipment on board have certain constraints. All the constraints are required to be evaluated together with a multi-objective optimization perspective. The literature possesses a gap for ship auxiliary system selection under constraints for fulfilling multiple objectives.

3. PROBLEM DEFINITION

In this study, wastewater treatment plants will be evaluated with a purely technical and design perspective and the criteria related to their integration into the ship will be laid down. In the equipment selection literature, maintenance and availability terms are affiliated with technical perspective [16, 17] and we refer them as ease of operation. Adaptability and flexibility terms where we referred to ease of integration, and power, space, weight, capacity terms are also mentioned in the literature [15, 16, 17]. The grounded criteria and the definitions for the evaluation of Wastewater Treatment Plant are shown in the Table 1.

Table 1. Wastewater Treatment Plant Selection Criteria in a Technical and Design Aspect

Number of Criteria	Criteria	Definition of the Criteria
1	Ease of Operation	When it is considered that an equipment item will be used throughout the life-cycle of the ship, it is very important for designers to choose a system that is the easiest to use, with a long maintenance period and a simple working principle.

2	Ease of Integration	An important factor in choosing a system in ship design is easy integration. The need for complex integration with other systems, quite a lot of piping, the need for extra tank and equipment, etc. create quite a problem in terms of integration and, adaptability and flexibility are sought for integration.
3	Volume Requirement	The volume occupied by an equipment item is a critical requirement for a ship. The smaller the volume used, the higher the volume that can be allocated for cargo needs, and this will result in a huge gain considering the impact of the ship on a projection through the life cycle.
4	Weight	Weight is a very important criterion when it is evaluated that hundreds of equipment are used on a ship. Each added extra weight is a resistance gain and has a significant impact on fuel consumption.
5	Capacity	It is an important criterion to choose an equipment item which provides a capacity requirement according to the amount of daily wastewater produced by an individual specified by international regulations. Otherwise, it is quite costly to bear the wastewater transfer fee to be used at the ports due to equipment that does not have sufficient treatment capacity.
6	Power Requirement	As a result of the electrical load required by each equipment item, the total load is determined and the corresponding diesel-generator set is determined. In this context, it is targeted to have a minimum level of power requirement for each equipment item.

These criteria are determined through literature review and Delphi Method together with a group of experts whose profiles are given with Table 2. DM group consists of highly knowledgeable and experienced engineers in ship design. Two meetings were held with DM group to determine related criteria for evaluation of wastewater treatment plant selection.

Table 2. Profiles of Decision Makers

# of Participant	Position	Experience (years)	Graduate Degree
1	Design Engineer (Mechanical Eng.)	18	Ph.D.
2	Design Engineer (Mechanical Eng.)	4	M.S.
3	Design Engineer (Mechanical Eng.)	5	M.S.
4	Design Engineer (Mechanical Eng.)	2	B.S.

4. SOLUTION APPROACH

The weights of the determined criteria and the importance weights of the candidate equipment to be selected is determined by the Analytic Hierarchy Process (AHP). A case scenario equipment integration problem is created and constraints are elaborated. Together with AHP results and constraints, 0-1 Goal Programming approach is implemented to select the optimum equipment.

4.1. Analytic Hierarchy Process (AHP)

Analytic Hierarchy Process (AHP) is a MCDM method developed by Thomas L. Saaty, which takes a practical and easy approach for solving many problems [20]. It identifies a problem in a hierarchical way, separates it into criteria and sub-criteria, and then synthesizes these criteria, thus weights the criteria or alternatives. AHP method is widely used in literature for weighting criteria and selection among alternatives [21, 22, 23]. AHP method has the following steps.

- **Problem Definition and Goal Statement:** Wastewater Treatment Plant selection is shown in Figure 3 in a hierarchical way. Main objective is shown on the top side of the AHP presentation and evaluation criteria are given that all the criteria are in an interaction with alternatives where the bottom of the hierarchy.

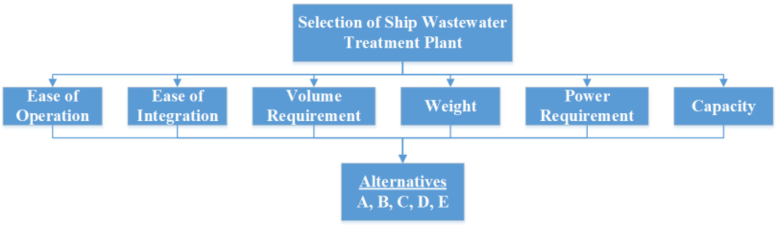

Figure 3. AHP Problem Definition.

- **Listing Decision Criteria and Alternatives:** Decision criteria are given in Table 1 and Alternatives are given in Table 3. Make and model of the equipment are not disclosed because of the confidentiality and will be represented as “A,B,C,D and E”.

Table 3. Ship Wastewater Treatment Plant Alternatives

	Treatment Process Type	**Capacity (m3/day)**	**Length (mm)**	**Width (mm)**	**Height (mm)**	**Full Weight (kg)**	**Energy Consumption (kW)**
A	Biological	7.4	2970	1870	2295	7700	12.75
B	Biological	7.4	3510	1650	1570	7300	7.4
C	Biological	7.0	3000	1500	2000	7800	5.7
D	Biological	8.7	4701	2200	2096	14130	4.2
E	Biological	9.36	3072	2280	1971	7367	6.4

- **Creation of Pairwise Comparison Matrix for criteria and alternatives and obtaining priority vector:** Pair-wise comparisons of the alternatives are done with the same expert group whose profiles are given in Table 2. AHP questionnaire containing the evaluation of both criteria and alternatives were handed out to each decision maker. Thus, comparison matrices are given in Appendix.

Results of the criteria comparison by using AHP method are shown with Table 4.

Table 4. Priority Weight of the Criteria.

Criteria	Priority Weight
Ease of Operation	0.072
Ease of Integration	0.043
Volume Requirement	0.209
Weight	0.075
Capacity	0.526
Power Requirement	0.075
Consistency Ratio	0.097

Results of the alternative comparison by using AHP method are shown with Table 5.

Table 5. Priority Weight of the Alternatives.

ALT.	Ease of Operation	Ease of Integration	Vol. Req.	Weight	Cap.	Power Req.	Alternative Priority Weight
A	0.15	0.181	0.141	0.18	0.14	0.033	0.138—5
B	0.355	0.295	0.363	0.308	0.137	0.073	0.215—2
C	0.136	0.139	0.402	0.177	0.098	0.235	0.182—4
D	0.141	0.157	0.032	0.024	0.24	0.542	0.192—3
E	0.218	0.228	0.062	0.311	0.385	0.117	0.273—1
CR	0.0945	0.0259	0.080	0.012	0.016	0.088	

As seen from Table 4. and 5, the most important criteria is Capacity, and Volume Requirement, Power Requirement, Weight, Ease of Operation, Ease of Integration from highest to the lowest important. Besides, last column of Table 5 shows that alternatives from most appropriate to the least are E,B,D,C,A. In addition, AHP results are consistent since CR is less than 0.1. As seen from the analysis, capacity is the most important criterion with a great impact in decision making. Performance is the top priority in an equipment selection problem. As for a wastewater treatment plant, the lower capacity yields to a design problem.

4.2. Goal Programming

Multi criteria decision making methods are widely in use in selection or ranking problems with less information, however MCDM does not produce solutions when resources are of vital importance. In today's complex decision making environment, managers have to deal with many conflicts of interest with uncertainty. Therefore, goal programming (GP) is proposed to take into account multiple criteria (conflict of interest) for decision making problems [24]. Goal programming is a linear programming approach created to solve multiple objectives. In GP, beyond the purpose of minimization or maximization of one goal, it is attempted to obtain a minimum deviation from which each of the goals can be compromised. Each variable constituting the objective function must have the same unit in linear programming, while we attempt to obtain the sum of deviations in goal programming and calculate the minimum deviation to provide multiple targets with different units. Objective function reflects the minimization of deviations from the desired objectives and constraints represents the resource availability. Thus, the selection problem formulated as Goal Programming since it is attributed to be more powerful than linear programing [24].

4.3. Incorporating AHP into 0-1 Goal Programming

0-1 Goal Programming and AHP methods are commonly used to solve selection problems such as; supplier selection problem is addressed by Dagdeviren and Eren [25], selection of an advertisement strategy is addressed by Alagas et.al. [26], software selection problem is addressed by Girginer and Kaygisiz [27], and maintenance selection problem is addressed by Bertolini and Bevilacqua [28]. Although it is quite simple and straightforward to use, AHP has a certain limitation since it only depends on the intuition of decision maker. However, combination of AHP and Goal Programming improves the solution since it takes into account the constraints.

The general description of hybrid AHP and 0-1 Goal programming objective function can be interpreted as shown in Equation 1 [29, 30].

$$\text{Min Z} = \sum_{k=1}^{K} (w_k d_k^-, w_k d_k^+)$$

is subject to,

$$\left[\sum_{i=1}^{m} (a_{ki} x_k)\right] + d_k^- - d_k^+ = b_k$$

with i=1,2,…m (number of constraints), (1)

$d_k^- . d_k^+ = 0$,

$x_k = \begin{cases} 1 \\ 0 \end{cases},$

$x_k, d_k^-, d_k^+ \geq 0,$

where,

w_k	Priority weight of the k[th] goal
d_k^-, d_k^+	Negative and positive deviation from the k[th] goal
a_{ki}	Coefficients of i[th] constraint in k[th] goal
x_k	Decision variables:
	$x_k = \begin{cases} 1, & k^{th} equipment\ selected \\ 0, & otherwise \end{cases}$
b_k	Goal level (resources)

Decision constraints for selection problem are considered to be length (C1), width (C2), height (C3), weight (C4), power requirement (C5), capacity of the equipment (C6) and AHP weights (C7). The design engineer identifies the design constraints in order to select the most suitable Wastewater Treatment Plant for use on a ship with 50 personnel by minimizing the total deviation as:

- C(1): Length of the equipment is to be less than 3000 mm,
- C(2): Width of the equipment is to be less than 1900 mm,
- C(3): Height of the equipment is to be less than 2000 mm,

- C(4): Weight of the equipment is to be less than 8000 kg,
- C(5): Power requirement of the equipment is to be less than 6 kW,
- C(6): Capacity of the equipment is to be more than 6.75 m^3/day,
- C(7): AHP Constraint.

Thus, 0-1 goal programming problem with AHP can be defined as in Girginer and Kaygısız [27] and shown with Equation 2:

Obj Func. Min $Z=d_1^+ + d_2^+ + d_3^+ + d_4^+ + d_5^+ + d_6^- + d_7^+ + d_7^-$
Subject to

C(1) $$2970 * x_1 + 3510 * x_2 + 3000 * x_3 + 4701 * x_4 + 3072 * x_5 + d_1^- - d_1^+ = 3000$$

C(2) $$1870 * x_1 + 1650 * x_2 + 1500 * x_3 + 2200 * x_4 + 2280 * x_5 + d_2^- - d_2^+ = 1900$$

C(3) $$2295 * x_1 + 1570 * x_2 + 2000 * x_3 + 2096 * x_4 + 1971 * x_5 + d_3^- - d_3^+ = 2000$$

C(4) $$7700 * x_1 + 7300 * x_2 + 7800 * x_3 + 14130 * x_4 + 7367 * x_5 + d_4^- - d_4^+ = 8000 \quad (2)$$

C(5) $$12.75 * x_1 + 7.4 * x_2 + 5.7 * x_3 + 4.2 * x_4 + 6.2 * x_5 + d_5^- - d_5^+ = 6$$

C(6) $$7.4 * x_1 + 7.4 * x_2 + 7 * x_3 + 8.7 * x_4 + 9.36 * x_5 + d_6^- - d_6^+ = 6.75$$

C(7) $$0.138 * x_1 + 0.215 * x_2 + 0.182 * x_3 + 0.192 * x_4 + 0.273 * x_5 + d_7^- - d_7^+ = 1$$

C(8) $$x_i = 0 \text{ or } 1; \; i = 1,2,3,4,5$$
$$x_i = \begin{cases} 1, & i^{th} \text{ equipment selected} \\ 0, & \text{otherwise} \end{cases}$$

C(9) $$d_j^-, d_j^+ \geq 0; \; j = 1,2,3,4,5,6,7$$

When the coefficients of Goal-2 are carefully evaluated, it will be seen that there are very large differences (for example, 7700 in C (4) and 7.4 in C (6)). This constitutes a bias in favor of large coefficients, and the goals with large coefficients become more important. In order to overcome this deficiency, the normalization process specified by Romero [31] is applied. In this context, deviational variables of Objective Function in Equation 2 are required to be revisited as shown in Equation 3:

$$(d_j^-)' = \frac{d_j^-}{\left(\sum_{j=1}^{7}(a_{ji})^2\right)^{1/2}}$$
$$(d_j^+)' = \frac{d_j^+}{\left(\sum_{j=1}^{7}(a_{ji})^2\right)^{1/2}} \qquad (3)$$

Therefore, weighted objective function is given as in Equation 4:

$$Min\ z = \left(\frac{d_1^+}{(2970^2 + 3510^2 + 3000^2 + 4701^2 + 3072^2)^{1/2}}\right) + (d_2^+)' + (d_3^+)' + (d_4^+)' + (d_5^+)' + (d_6^-)' + (d_7^+)' + (d_7^-)' \qquad (4)$$

The solution of the Equation 4 yields to Table 6 which gives decision variables (x_1, x_2, x_3, x_4, x_5) and deviation variables (d_1,…,d_7).

Table 6. Results of 0-1 Goal Programming

Decision Variable	x_1	x_2	x_3	x_4	x_5	$(d_1^+)'$	$(d_2^+)'$	$(d_3^+)'$	$(d_4^-)'$	$(d_5^+)'$	$(d_6^+)'$	$(d_7^-)'$	$(d_7^+)'$
WGP Solution	0	0	0	0	1	72	380	29	633	0.2	2.61	0.727	0

Alternative "E" reflects the minimum total deviation with 0.17. Deviation variables, $d_1^+, d_2^+, d_5^+, d_6^+$, represent that the criterion for the selected equipment is more than the desired goal. This is not the targeted result since constraint 1 to 5 force to select an alternative to have characteristics to be less desired. However, design engineer who is the decision maker is the one who finalize the selection process. Decision variables d_3^-, d_4^-, d_7^- represent that the criterion for the selected equipment is less than the desired goal with a minimum deviation which is the expected.

4. CONCLUSION

In the first stage of this study, the criteria for selecting the ship wastewater treatment system with the design perspective are determined, the criteria are prioritized by AHP method and the optimum solution among the alternatives is chosen by AHP method. In the second stage, technical constraints are determined within the scope of equipment integration and 0-1 Goal Programming method is used in a hybrid manner with AHP in order to find the optimum solution for these constraints. The AHP weights of the alternatives are plugged in as a constraint to the model.

Among the criteria according to AHP method's solution, Capacity has the largest share and dominates other criteria. The capacity of the wastewater treatment system is the most important input for the design. The selection of equipment below the minimum capacity to be produced by the personnel, inevitably issues problems in the long term. The second most important criterion is the volume requirement. It is very critical that the equipment to be selected can be located in the designated location in the ship. The weights of other criteria are shown in Table 4. With the use of criteria weights as model inputs, a selection is made between 5 alternative equipment item by using AHP method and the results of the selection are shown in Table 5. Accordingly, equipment “E” is chosen as the optimal solution.

0-1 Goal Programming method is applied by using technical constraints as model input. Accordingly, equipment “E” is also determined as the optimum solution. Table 7 shows the deviations from the model constraints of selected alternative according to AHP and 0-1 Goal Programming solutions.

The equipment “E” is selected by 0-1 Goal Programming and AHP with minimum deviation of “1.7”. The height value with a negative deviation of 29 mm and weight value with a negative deviation of 633 kg is lower than the specified limit. Length, Width and Power Requirement characteristics of equipment “E” is more than the desired value. Besides, Capacity value of the equipment “E” is the highest among others. From a combined AHP and GP point of view, once AHP is considered as a constraint and forced to satisfy both negative and positive deviations, AHP weights of alternatives dominate other criteria. As mentioned above in this problem, equipment "E" is selected since it has the highest priority level according to AHP. The decision maker, namely the design engineer has to consider that such deviations are to be within tolerable limits where a tolerable limit can be defined as the deviation that does not yield to an over-design.

Table 7. Comparison of AHP and 0-1 Goal Programming Results

Resources	Targeted Goals	AHP and 0-1 Goal Programming Deviation (Equipment E
Length	3000 mm	72
Width	1900 mm	380
Height	2000 mm	29 (slack)
Weight	8000 kg	633
Power Req.	6 kW	0.2
Capacity	6.75 m^3/day	2.61

5. FUTURE STUDY

In this study, combined AHP and 0-1 Goal Programming methods are used to select Marine Wastewater Treatment Plant. It is observed that AHP weights of alternatives dominate other goals in Goal Programming. To elaborate the effect of such hybrid methods, it is highly recommended that researchers carry out GP analysis without AHP goal. Another study can be carried out that AHP weights of selection criteria can be plugged into objective function so that each criteria is evaluated with respect to its priority.

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APPENDIX

Table 8. Pair-wise Comparison Matrix of Criteria (Geometric Mean)

	Ease of Operation	Ease of Integration	Volume Req.	Weight	Capacity	Power Req.
Ease of Operation	1.00	3.64	0.33	0.41	0.14	0.58
Ease of Integration	0.27	1.00	0.22	0.41	0.12	0.94
Volume	3.06	4.58	1.00	6.85	0.24	2.59
Weight	2.43	2.43	0.15	1.00	0.11	0.61
Capacity	7.30	8.45	4.21	9.00	1.00	7.94
Power Req.	1.73	1.06	0.39	1.63	0.13	1.00

Table 9. Pair-wise Comparison Matrix of Alternatives in terms of "Ease of Operation" (Geometric Mean)

	A	B	C	D	E
A	1.00	0.33	0.61	2.28	0.58
B	3.00	1.00	3.48	1.32	2.24
C	1.63	0.29	1.00	1.32	0.35
D	0.44	0.76	0.76	1.00	0.76
E	1.73	0.45	2.82	1.32	1.00

Table 10. Pair-wise Comparison Matrix of Alternatives in terms of "Ease of Integration" (Geometric Mean)

	A	B	C	D	E
A	1.00	0.58	0.92	1.73	0.76
B	1.73	1.00	2.59	1.32	1.50
C	1.09	0.39	1.00	1.00	0.47
D	0.58	0.76	1.00	1.00	0.76
E	1.32	0.67	2.14	1.32	1.00

Table 11. Pair-wise Comparison Matrix of Alternatives in terms of "Volume Requirement" (Geometric Mean)

	A	B	C	D	E
A	1.00	0.18	0.19	7.94	3.41
B	5.54	1.00	0.76	9.00	5.92
C	5.21	1.32	1.00	9.00	5.92
D	0.13	0.11	0.11	1.00	0.38
E	0.29	0.17	0.17	2.65	1.00

Table 12. Pair-wise Comparison Matrix of Alternatives in terms of "Weight" (Geometric Mean)

	A	B	C	D	E
A	1.00	0.58	1.00	8.45	0.44
B	1.73	1.00	2.28	8.45	1.00
C	1.00	0.44	1.00	7.94	0.58
D	0.12	0.12	0.13	0.25	0.11
E	2.28	1.00	1.73	9.00	1.00

Table 13. Pair-wise Comparison Matrix of Alternatives in terms of "Capacity" (Geometric Mean)

	A	B	C	D	E
A	1.00	1.00	1.73	0.49	0.38
B	1.00	1.00	1.73	0.45	0.35
C	0.58	0.58	1.00	0.45	0.33
D	2.06	2.24	2.24	1.00	0.45
E	2.65	2.82	3.00	2.24	1.00

Table 14. Pair-wise Comparison Matrix of Alternatives in terms of "Power Requirement" (Geometric Mean)

	A	B	C	D	E
A	1.00	0.29	0.16	0.11	0.18
B	3.41	1.00	0.23	0.13	0.51
C	6.44	4.40	1.00	0.20	3.87
D	9.00	7.45	4.88	1.00	5.54
E	5.44	1.97	0.26	0.18	1.00

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REVIEW ARTICLE

ON THE ASSESSMENT OF SURVIVABILITY OF SURFACE COMBATANTS

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ABSTRACT

Survivability of a naval surface ship is defined as the durability of the ship to a defined weapon threat, and, the degree of its ability to maintain at least the basic safety and operability of the ship, and is composed of a combination of the ship's susceptibility, vulnerability and recoverability. The empirical stability criteria laid down by Sarchin and Goldberg in 1962 are used to assess the survivability of warships. In recent years, along with deterministic rules, the probabilistic approach that has been made mandatory for the passenger / Ro-Ro ships by the International Convention on the Safety of Life at Sea (SOLAS) have been used for warships. In this study, the fundamentals of using the concepts of the deterministic and stochastic approaches and the concept of probability used in assessing the survivability of warships are emphasized.

Keywords: *Warship, Survivability, Susceptibility, Vulnerability, Recoverability*

SUÜSTÜ SAVAŞ GEMİLERİNİN BEKA KABİLİYETİNİN DEĞERLENDİRİLMESİ

ÖZ

Bir suüstü savaş gemisinin beka kabiliyeti, tanımlanmış bir silah tehdidine karşı dayanımı ve asgari olarak geminin temel emniyetini ve işlerliğini sürdürme yeteneğinin derecesi olarak tanımlanmakta olup geminin vurulabilirlik, yaralanabilirlik ve geri kazanabilirlik özelliklerinin bileşiminden oluşmaktadır. Savaş gemilerinin beka kabiliyetinin değerlendirilmesinde temeli 1962 yılında Sarchin ve Goldberg tarafından atılmış olan ampirik stabilite kriterleri kullanılmaktadır. Son yıllarda ise deterministik kuralların yanında Denizde Can Güvenliği Uluslararası Sözleşmesi (SOLAS) ile yolcu/Ro-Ro gemileri için zorunlu hale getirilen olasılık yaklaşımı, savaş gemileri için de kullanılmaya başlanmıştır. Bu incelemede deterministik ve stokastik yaklaşım ile olasılık kavramının, suüstü savaş gemilerinin beka kabiliyetinin değerlendirilmesinde kullanılma temelleri üzerinde durulmuştur.

Anahtar Kelimeler: *Savaş gemisi, Beka kabiliyeti, Vurulabilirlik, Yaralanabilirlik, Geri kazanabilirlik*

1. INTRODUCTION

The similarity inherent in the design of a warship and a passenger / Ro-Ro ship is the need to survive for both in the event of any damage; of course, by the nature of warships, they are more threatened in the human-made war environment. Besides, while for the survivability of a passenger / Ro-Ro ship to remain in an upright position in any case of damage is sufficient; the ability to remain in an upright position for a warship is a prerequisite and it is of great importance that it fulfills its designated task.

The majority of the stability criteria currently applied to warships are based on the empirical stability criteria produced by Sarchin and Goldberg in 1962. These criteria, which carry out their duties for many years, although they have been renewed over the years by navies such as US Navy (USN) and Royal Navy (RN), have not undergone major changes. However, in recent years - due to the fact that the survivability of the modern warships against the damages caused by the current threats is not known, the modern hull forms and the technique of the structural elements are very different from the ships when the criteria are determined, and the wind and the sea state at the time of the damage must be taken into account - there have been great dissidences about the applicability of these criteria to modern warships [1].

In the late 1950s probabilistic damage stability approach was introduced by K. Wendel. The International Maritime Organization (IMO) adopted the concept of probability for assessing the survivability of passenger ships with SOLAS 1974. Although IMO Resolution A.265 (VIII) was firstly introduced as an alternative to the deterministic stability criteria by SOLAS 1974, with the MSC.19 (58) resolution in SOLAS 1990, the probability concept has been made mandatory for the assessment of the survivability of Ro-Ro ships and dry cargo vessels longer than 100 meters in length. With the MSC.216 (82) (SOLAS 2006) the existing deterministic rules were blended with stochastic process and it became obligatory to be applied for cargo and passenger ships longer than 80 meters in length. The concept of probability was finally finalized by the inclusion of some special vessels such as ocean and fishing boats smaller than 500 tons by the code MSC.281 (85) (SOLAS 2008). At present, studies on probability are underway in the

IMO Working Group on Subdivision and Damage Stability (SDS). For example, as it is mentioned at the report of SDS on 31 October 2018, at the 6th session of the Sub-Committee of Ship Design and Construction new regulations will be discussed to assess the survivability in terms of watertight integrity [2].

In this study, the differences between the methods of assessing the survivability of warships and passenger ships, the methods used to apply the concept of probability of passenger ships to the warships to assess the survivability, and the countermeasures to be taken to increase the survivability of the warship were discussed.

2. WARSHIP SURVIVABILITY

In January 2014, NATO assessed the survivability of warships in terms of susceptibility (how easily the ship can be detected), vulnerability (the ability of the ship and its systems to resist damage.), and recoverability (the ability of the ship personnel to repair and operate the vessel); also pointed out that nuclear, chemical and biological defense should be addressed, as well as the damage caused by collision, grounding or enemy action [3]. These three functions of the survivability is shown in the time-dependent operational capacity diagram in Figure 1.

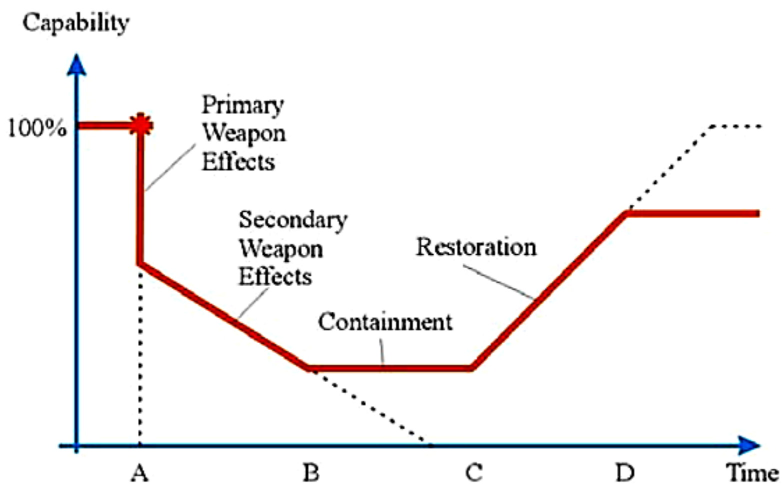

Figure 1. Time-dependent Operational Capacity (Source: [4])

The part up to point A in Figure 1 is a measure of the susceptibility of the ship and up to this point all the functions of the ship are at full capacity. Susceptibility depends on the radar cross section (RCS) of the ship, the threat warning and suppression systems of the ship and the behavior of the attack.

At point A, the ship is hit successfully by the enemy weapon, resulting in a sudden drop in the capacity of the ship's functions after the primary weapon effects such as blast and fragmentation. Secondary weapon effects such as flooding and fire can cause an additional reduction in the capacity of ship functions (from A to B). This will fall to zero in case of ship sinking. The part from point A to point B, represents the ship's ability to resist to the enemy weapons and gives the characteristic of vulnerability.

The part from the point B to the point D, which consists of the prevention and renewal stages, shows the ability of the ship to recover from the damage. In fact, the recoverability process usually starts at the point between point A and point B where the ship personnel would begin their first damage control activities. The capacity of ship functions after recoverability is the indicator of ship design and this capacity is required to be above the operational limit.

In ship design, it is desirable that a warship not to be hit. But this is impossible. No matter how better you design the features that affect the susceptibility of the ship, not being detected by the today's sophisticated radar and weapon systems is out of the question. Therefore, the aim is to reduce the susceptibility as much as possible.

The reverse of survivability is killability. Naturally, in ship design it is desirable to have the killability close to zero. However, it should be taken into consideration that the killability expressed in this article is not expressed only by the total loss of the whole ship. There is a functional hierarchy regarding the initial situation and the whole loss of the ship. Some kill definitions are given below in ascending order [5]:

- **System Kill:** Loss of a system due to damage to one or more components (loss of cooling water system, loss of an auxiliary machine, loss of CIWS, etc.).

- **Operational Kill:** Loss of one or more of the main mission functions of the ship. (Surface warfare, air warfare, submarine warfare and information warfare).
- **Mobility Kill**: Loss of movement or maneuverability of the ship. (Main machine damage, rudder damage, etc.)
- **Total Kill:** Loss of the ship as a result of ship sinking or fire or other phenomenon.

As can be seen, there is a hierarchical structure among these losses. The loss of a system may cause loss of one of the operation functions over time, but a flooding which could lead to the whole loss of a ship may be limited by mobility kill if it can be controlled by ship personnel. Here, the importance of vulnerability and recoverability appears. Because the less is the damage after the ship's being hit, the less will be the losses. Similarly, the greater is the recoverability, the better can the losses be restored and repaired.

3. DETERMINISTIC APPROACH

Until the 1990s, the trend in the design of naval surface ships was about assessing and minimizing susceptibility with detailed platform signature management. Therefore, the probability of the ship's detectability could be generally predictable and accepted as a variable in scenario simulations. Besides, the likelihood of standing vertical has been considered not enough. Most of the simulations have assumed that the probability of being killed by a single hit for small warships was equal to 1.0, while 2 were sufficient for the larger warships to sink. Therefore, survivability analysis was never considered the possibilities of vulnerability and recoverability [6]. For the naval architectures, it was often sufficient to assess the inadequacy of the vulnerability of the design in terms of damaged stability by using deterministic methods imposed by different navies like U.S. Navy (USN) and Royal Navy (RN). Table 1 shows the semi-empirical damaged stability criteria currently used by USN and RN for naval surface ships.

Table 1. US and Royal Navy Damaged Stability Criteria for Warships

Criteria	**RN "DEFSTAN 02-900"**		**USN "DDS-079-1"**	
Damage	LWL<30 m	1 comp	LWL<100 ft	1 comp
Length	30 m< LW <92 m	2 comp of at least 6 m	100 ft <LWL<300 ft.	2 comp
	92 m< LWL	Max {15%LWL/21m}	300 ft <LWL	15%LWL
Angle of list	$< 20^o$		$< 15^o$	
Area "A1"	> 1.4 Area "A2"		> 1.4 Area "A2"	
Area "A1"	$> A_{min}$			
	[$A_{min}=2.74*10^{-2}-1.97*10^{-6}x\Delta$ (m rad) ($\Delta<5000$)]			
	[$A_{min}=0.164*\Delta^{-0.265}$ (m rad) ($\Delta>5000$)]			
"GZ" at "C"	< 60 % "GZmax"		-	
Long. "GM"	> 0		-	
"GZmax"			0.25 ft < "GZmax" – "HA"	
Buoyancy	Longitudinal trim less than that required to cause downflooding		Margin line	

Damaged stability principles of the U.S. Navy are mainly based on the collection of data from experienced events. In 1947, BuShips (The United States Navy's Bureau of Ships) conducted a study of 24 warships that survived from weapon hits during World War II. This data was consisted of a minimum hit length which would result in the maximum survivability of 10 combatants and 14 auxiliaries. This study has offered the basic concept of the damaged length criteria. According to USN and RN damaged stability criteria; for ships less than 30 meters in length, damage of any compartment shall not submerge the ship more than the margin line. Ships greater than 30 meters in length and less than 92 meters must meet the same submergence criteria as those of two compartments. Ships greater than 92 meters in length should meet the submergence criteria in the case of a damage of 0.15 of LWL (at least 21 meters for RN) [7].

Sarchin and Goldberg stated that World War II damage reports recorded cases where a list of 20 deg. or more did not prevent damage control efforts and salvage of ships; therefore, in order to survive, an acceptable upper limit can be considered as 20 deg. list [8]. However, survival is rare in these important angles, and according to World War II damage reports, at the inclination of 15 degrees after damage, personnel begin to abandon ships (with or without order). As a result, for U.S. Navy ships, the criteria for designing equipment and machines to operate in a satisfactory manner up to

15 deg. has been introduced [6] (Figure 2). For Royal Navy ships the list criteria is 20 deg.

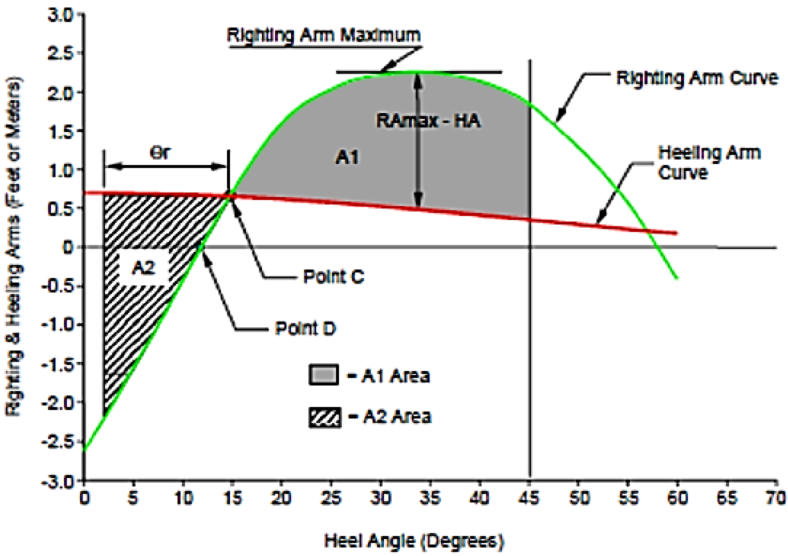

Figure 2. Damaged Ship Righting Arm and Heeling Arm (Source: [9])

4. PROBABILITY APPROACH

According to the basic concept of K.Wendel and the code of IMO A.265 (VIII), there are possibilities for the following events within the scope of damaged stability:

- Probability of flooding of a compartment or group of compartments under consideration, p
- Probability of survival of the vessel as a result of flooding of the relevant compartment or relevant bunch of compartment, s

The whole survival likelihood of the ship, defined as the "Attained Division Index, A", is equal to the total of pi and si values produced for every compartment and bunch of compartment, i, throughout the ship.

$$A = \sum_i (p_i \times s_i) \qquad (1)$$

The code dictates that the gained division ratio must be higher than the "Required Division Index, R" (A > R), composition of the vessel's passenger carrying capacity and a function of the life-saving supplies on board. This is a measure of the acceptable risk of the ship not being able to survive from any damage and increases with the number of passengers on board.

Since the index A is acceptable as a true measure of the safety of ships, it is assumed that this index does not need to be supported by other deterministic conditions. On the basis of the probability approach; if same attained division index is calculated for two different ships with similar size and similar passenger carrying capacities, then these vessels will be equally safe.

5. ASSESSMENT OF THE SURVIVABILITY IN TERMS OF RISK METHODOLOGY

R.E. Ball, in 1994, introduced how to use the stochastic approach of survivability assessment in ship design and general definitions about survivability that were firstly introduced for aircraft combat survivability in 1985. When a warship is in operation, a precise prediction of the ship's survival cannot be made. The warship will probably return from the mission with success, perhaps not. Maybe she will be hit by the enemy, maybe she won't be. Maybe a fire will start when the enemy is hit, maybe it will not. If there is a fire, maybe it will cause the loss of the ship, maybe not.

In any task scenario, there are many random variables similar to those described above that will affect the warship's survivability. As a result of these uncertainties, there is no deterministic conclusion that the ship can survive in war; instead there is a stochastic result: the battleship will perhaps survive, maybe not.

As a result of the random nature of war, the survivability of a warship is likely measured. This probability is indicated as P_S, the survivability of a warship. The probability of survival ranges from 0 to 1; the closer the value is to 1, the more alive a ship is in question.

In this approach, killability, P_K, which is complementary of survivability, is expressed by the multiplication of the probability of occurrence of danger (probability of being hit, P_H) and the impact (probability of damage, $P_{K/H}$) in parallel with the classical risk methodology.

$$P_K = P_H \cdot P_{K/H} \tag{2}$$

A warship entering into the enemy environment will either survive or be killed. Given that there is no other way, survivability is complementary to killability and can be expressed mathematically with the following formula:

$$P_S = 1 - P_K = 1 - P_H \cdot P_{K/H} \tag{3}$$

After the approach which was introduced by Ball in 1994, the function of recoverability by researchers was included in the definition of survivability but not mathematically. The reason for this is the difficulty of developing a model to describe the adequacy of the training of the warship personnel, who are of great importance in the recoverability function. However, it should be kept in mind that there are measures to be taken by the design team regarding the decisions to be taken in the process of assembling damage control systems. If the risk reduction method (the probability of recoverability, P_R) is applied in a holistic manner; it is considered that the mathematical relationship between susceptibility, vulnerability and recoverability within the scope of the possibility of total ship survivability can be expressed as follows:

$$P_K = P_H \cdot P_{K/H} \cdot (1 - P_R) \tag{4}$$

$$P_S = 1 - [P_H \cdot P_{K/H} \cdot (1 - P_R)] \tag{5}$$

6. WARSHIP SURVIVABILITY ASSESSMENT BY STOCHASTIC APPROACH

In this part of the study, methods to assess the functions of survivability by a stochastic approach will be explained.

6.1. Susceptibility

Susceptibility is the inability of the ship to avoid damage in operation and can be expressed as the probability of being hit (P_H) [1]. It is based on the probability of the warship being identified by enemy detection devices (probability of detection, P_{DA}) and the probability of being hit by enemy threat weapons after detection of the warship (P_{HIT}) [10]. In addition to this approach, it is considered that the likelihood of threat suppression should be taken into account in calculating the probability of the susceptibility as a factor of reducing susceptibility. The probability calculation is shown in Figure 3.

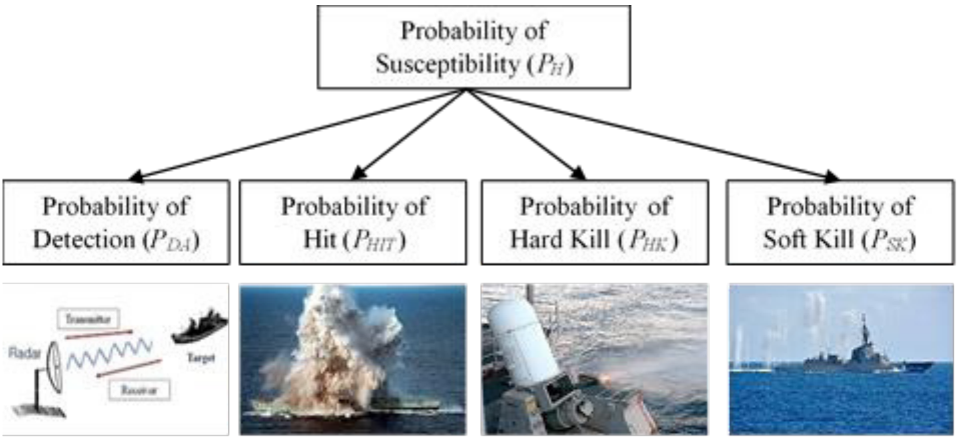

Figure 3. Probability of Susceptibility

The relationship between these probabilities can be expressed mathematically as shown in below:

$$P_H = P_{DA} \times P_{HIT} \times (1 - P_{HK}) \times (1 - P_{SK}) \tag{6}$$

The probability of a warship being detected by an active threat (P_{DA}) is a function of the ship's RCS. The ship's RCS affects how easily the ship can be detected. RCS is defined as the ratio of the power reflected back to the radar to the power density incident on the target and is a function of maximum radar range, R_{max} which is expressed by the following equation [11]:

$$R_{max} = \left[\frac{P_T G^2 \lambda^2 \sigma}{(4\pi)^3 k T_0 B F L \, (SNR)_{min}}\right]^{\frac{1}{4}} \tag{7}$$

According to Equation (7), the maximum detection distance of the radar is proportional to the ¼th force of RCS. For example, if we reduce the ship's RCS by 20%; the detection distance of the ship by the enemy radar will be reduced by approximately 5.5%.

The following formula is obtained when the Equation (7) is rearranged to find the Signal to Noise Ratios (SNR) which is a function of the minimum detectable signal power (S_{min}).

$$(SNR)_{min} = \frac{P_T G^2 \lambda^2 \sigma}{(4\pi)^3 k T_0 B F L R_{max}^4} \tag{8}$$

where,

Symbol	Description	Units
PT	Peak power	Watt
G	Antenna gain	dB
σ	Radar cross section	m2
λ	Wavelength	m
k	Boltzmann constant ($1.38 \times 10^{-23}\, J/K$)	J/K
T_0	Antenna temperature	Kelvin
B	Radar bandwidth	Hz
F	Noise figure	dB
L	Radar losses	dB
R_{max}	Maximum detection range	Km

The probability of a warship being detected by the active threat, P_{DA}, can be defined by the following equation [11]:

$$P_{DA} \approx 0.5 \times erfc(\sqrt{-lnP_{fa}} - \sqrt{SNR + 0.5}) \tag{9}$$

where, Pfa is probability of false alarm.

The probability of hit (P_{HIT}) is the probability of hitting the target area of the enemy threat weapon targeted to the friendly warship and is calculated depending on the characteristics and effectiveness of the threat weapon [12].

For naval surface ships, the hit of a threat weapon anywhere in the ship can be calculated by a probability function. The parameters of this function would be related to the properties of both the threat weapon and the target. This distribution is obviously related to susceptibility. Where there are no actual estimates for hit distribution along the ship, we can assume that the probability of weapon effects along the ship follows a basic mathematical distribution such as piecewise linear or normal distribution [13].

The normal (Gaussian) probability distribution is expressed by the equation given below:

$$p(x) = \frac{1}{\sqrt{2\pi} \times \sigma} \times exp\left[-\frac{(x-\bar{x}^2)}{\sigma^2}\right] \tag{10}$$

This distribution is symmetrical about the mean position and has a general bell curve shape as shown in Figure 4.

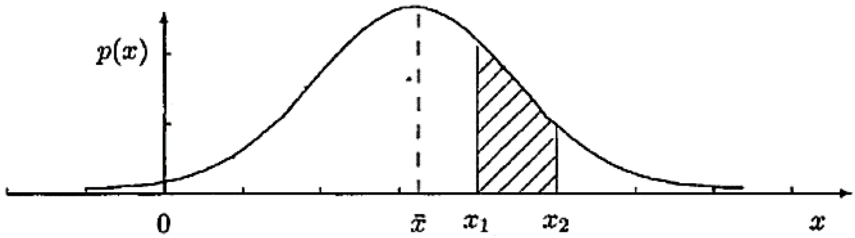

Figure 4. Probability of x Occurring Between x_1 and x_2

The area under the curve between x_1 and x_2 shown in Figure 4 reflects the probability that x occurs between x_1 and x_2, as expressed in Equation (11).

$$p(x_1 < x < x_2) = \int_{x_1}^{x_2} p(x)dx \tag{11}$$

Similarly, as shown in Figure 5, the area under the curve between x_1 and $x=\infty$ indicates the probability of occurrence of x between x_1 and $x=\infty$. This is expressed in Equation (12).

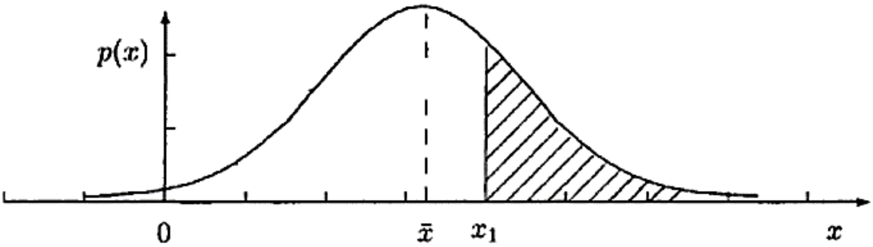

Figure 5. Probability of x Occurring Between x_1 and $x = \infty$

$$p(x_1 < x < \infty) = \int_{x_1}^{\infty} p(x)dx \quad (12)$$

The full area below the curve which is the probability of occurrence of x between $-\infty$ and $+\infty$, of course, represents the certainty of a formation represented by 1 as shown in Equation (13).

$$p(-\infty < x < +\infty) = \int_{-\infty}^{+\infty} p(x)dx = 1 \quad (13)$$

In practical applications, Equation (13) is generally calculated in terms of standard variables (u), from the mean value ($\bar{x}$) as defined by:

$$x = \bar{x} + u \times \sigma \quad (14)$$

or,

$$u = \frac{x - \bar{x}}{\sigma} \quad (15)$$

Substitution of Equation (11) into Equation (12) and changing the variable x into u through Equation (15) with $dx = \sigma\, du$ finally leads to:

$$p(u_1 < u < \infty) = \frac{1}{\sqrt{2\pi}} \int_{u_1}^{\infty} e^{-\frac{1}{2}u^2} du \quad (16)$$

Equation (16) cannot be evaluated by known functions; therefore it is calculated numerically and available as special tables.

In many statistical studies and in the analysis of navigation errors, the convenient measure of error is standard deviation; however, in the weapon effect analysis usually uses the 50% error. This means that the end areas on both sides of the mean value ($\bar{x}$) must be equal to 0.25 as shown in Figure 6.

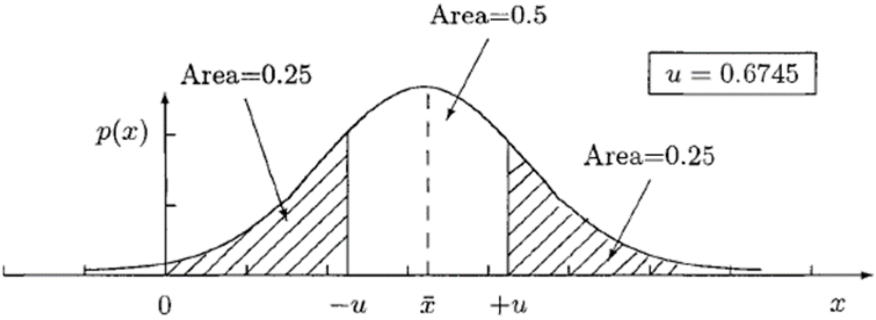

Figure 6. Linear Error Probable (LEP)

From the special tables for standard variables of normal (Gaussian) probabilities for this situation $u = \pm 0.6745$ is calculated, and because the total area below the curve is equal to 1, the center area is therefore equal to 0.50 and defines the possible linear error (LEP). Thus, by using the definition u in Equation (15), LEP as distance is expressed as follows;

$$LEP_{range} = 0.6745 \times \sigma \tag{17}$$

Accordingly, the probability of hitting a 11.8 meters length main engine room from the center point with a Harpoon Block II guided projectile which has a range error probable of 11.5 meters is calculated as follows;

$\bar{x} = 0$ (Hitting from the center point of main engine room)

$\sigma = 11.5/0.6745 = 17.05\ m.$

$x = \pm 6.4\ m.$

$u = 6.4/17.05 = \pm 0.375$

From the special tables for standard variables of normal (Gaussian) probabilities;

$P(u > 0.375) = 0.3538$

As a result, the possibility of the guided projectile hitting the main engine room from the center point;

$$P(-0.375 < u < +0.375) = P_{HIT} = 1 - 2 \times 0.3538 = 0.2924$$

6.2 Vulnerability

Warships must protect themselves against threats and asymmetric threats from enemy elements; but despite all its sophisticated defense systems, it is still vulnerable to attacks. In addition, they may also face dangers such as collision and grounding. In this context, in a most basic sense, the vulnerability ($P_{K/H}$) is the level of damage that occurs on board after being hit by an enemy or a damage.

Traditionally, the vulnerability assessment of a ship is carried out in the later stages of the design process. This is because the design must have reached a certain level of maturity in order to obtain sufficient information to do the needed analysis. In addition, because the design is often subject to change, it is not desirable to spend money and time on detailed damage analysis. However; this delay in the assessment means the placement of the bulkheads and the general arrangement. Because of that; combining the foundations of vulnerability reduction measures to the real sense of design can only be achieved when the vulnerability assessment is done at an early stage (concept design stage). Therefore, it is considered that the key to ensuring the survivability of a ship is the use of vulnerability measures in the early stages of ship design. These measures include;

- Structural strengthening of ship and sensitive spaces,
- Implementing a subdivision policy correctly,
- Providing as many redundancies as possible for critical systems, separation of redundancy systems and extra protection of systems if critical systems cannot be backed up,
- Using of shock absorbers to reduce shock wave effect,
- Providing of passive and active damage suppression.

Nowadays, some companies, which are supported by Defense Ministries, are involved in the design of warships. These companies examine the survivability of warships with the software they developed. These software provide support to some degree of integrated survivability analysis. However, these software are often unwieldy because they require a complete arrangement of the ship, including the superstructure, and do not evaluate trade-offs.

Within this scope, Boulougouris and Papanikolaou, developed a new method parallel to the method used to assess the survivability of passenger / Ro-Ro vessels based on the probability approach. In this method, as in the probabilistic approach, the attained division index, $A,$ is calculated by multiplying the probability of flooding of a compartment or group of compartments under consideration, p, which is calculated by probability density function (piece-wise linear distribution) with the probability of survival of the ship as a result of flooding of the compartment or group of compartment under consideration, s, which is calculated by a semi-empirical deterministic criterion.

Since both the radar profile of the ship and the machinery and exhaust emissions are highest at the amidships, this point is usually the target point of the projectiles (Figure 7) [14]. For this reason, the hit point probability density function is as follows:

$$imp(x)\begin{cases} 4x & x \leq 0.5 \\ -4x+4 & x > 0.5 \end{cases} \tag{18}$$

Regarding the “Damage Function” used in the literature of defense analysis, it is assumed that the missile has an effect within a radius r of the hit point which has the log-normal distribution [15]. This function can be represented in a slightly modified form as in below:

$$d(r) = 1 - \int_0^r \frac{1}{\sqrt{2\pi}\cdot\beta\cdot r}\cdot exp\left[-\frac{\ln^2(r/\alpha)}{2\cdot\beta^2}\right]dr \tag{19}$$

where,

$\alpha = \sqrt{R_{SS}\cdot R_{SK}}$, $\beta = \frac{1}{2\sqrt{2}\cdot z_{SS}}\cdot \ln\left(\frac{R_{SS}}{R_{SK}}\right)$,

R_{SS} , the absolute save radius meaning $d(R_{SS}) = 0.02$

R_{SK}, the absolute kill radius meaning $d(R_{SK}) = 0.98$

Z_{SS}, constant equaling 1.45222

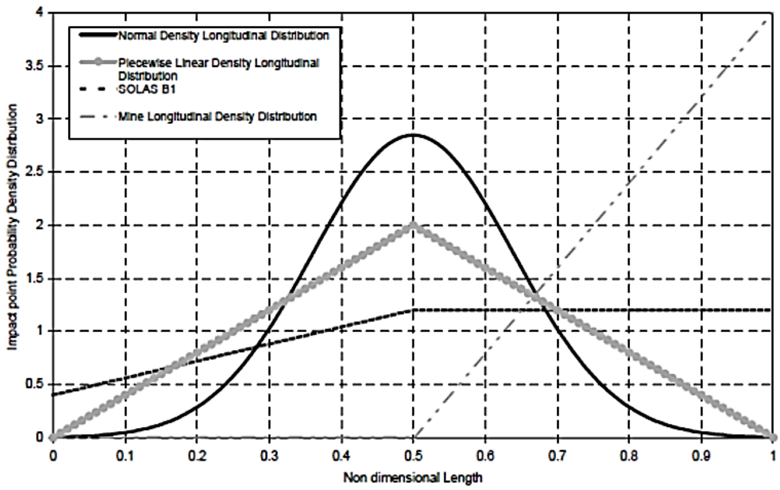

Figure 7. Longitudinal Damage Distributions

Boulougouris and Papanikolaou stated that as a first approach, R_{SS} could be taken as 0.15 LWL according to DDS-079-1 where R_{SK} can be assumed to be equal to 0.02 LWL.

Equation (19) can be simplified to the linear distribution in order to be easily solved by the known functions [16]:

$$Dam\ (y) = \begin{cases} 177.78y, & 0 \leq y \leq 0.075 \\ -177.78y + 26.67, & 0.075 < y \leq 0.15 \end{cases} \tag{20}$$

The hit point and the damage-length density functions can be combined to find the possibility of damage of a compartment or a group of compartment of a warship between x_1 and x_2 boundaries:

$$p_{i_{x_1}}^{x_2} = \int_0^y Dam(y) \cdot \int_{x_1}^{x_2} Imp(x)\, dx\, dy \tag{21}$$

The approach used to assess the probability of survival after damage is a quasi-static probability approach adapted to the currently valid, semi-empirical deterministic criterion used for warships. This approach assesses the probability of post-damaged recovery and is based on a semi- empirical survival criterion as used by USN and RN [1]. The equation of survival criteria to be used in quasi-static probability method to the survivability of warships is following:

Table 2. Survival Criteria (s_i) for Warships (source: [13])

$s_i = 1$	θ_{roll} = 25 deg.	Wind speed according to DDS-079-1
	A1 $\geq$ 1.4A2	Min Freeboard $\geq$ 3 in + $(H_S(0.95))$- 8 ft.
$s_i = P(H_S \leq 8ft)$	Ship meets DDS-079-1 damaged stability criteria	
$s_i = 0$	θ_{roll} = 11 deg.	Wind speed $\leq$ 11 knots
	A1 $\leq$ 1.05A2	Margin line immerses.

By applying this criteria; for naval surface ships operating in East Mediterranean $P(H_S \leq 8ft) = 0.90$ where for naval surface ships operating in North Atlantic $P(H_S \leq 8ft) = 0.56$ [17].

As an example the bulkhead arrangement of a Gabya class frigate is shown in Figure 8. The results of one compartment damage of a Gabya class frigate obtained by the Equations (18) to (21) are given in Table 3.

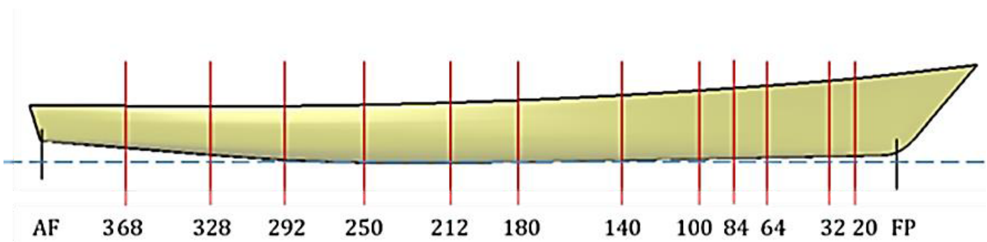

Figure 8. Bulkhead Positions of a Gabya Class Frigate

Table 3. One Compartment Damage Case

x_1	x_2	x_1u	x_2u	y	p_i
0	20	0.000	0.049	0.049	0.001
20	32	0.049	0.078	0.029	0.001
32	64	0.078	0.157	0.078	0.020
64	84	0.157	0.206	0.049	0.008
84	100	0.206	0.245	0.039	0.005
100	140	0.245	0.343	0.098	0.088
140	180	0.343	0.441	0.098	0.117
180	212	0.441	0.520	0.078	0.081
212	250	0.520	0.613	0.093	0.115
250	292	0.613	0.716	0.103	0.111
292	328	0.716	0.804	0.088	0.056
328	368	0.804	0.902	0.098	0.044
368	408	0.902	1.000	0.098	0.015

The calculations show that for the given bulkhead arrangement of Gabya class frigate 1 compartment damage case contributes about 0.37 to the attained division index, while 2 and 3 compartments contribute about 0.54 and 0.06 respectively. In this case, the attained division index for the given bulkhead arrangement of Gabya class frigates for is calculated as A = 0.97.

6.3 Recoverability

Recoverability is related to re-increasing the capacity of the ship's platform against time and is expressed as a partial or complete ability to rebuild ship's capacity and to maintain the recovered capability for a period of time [4].

Recoverability includes eliminating primary damage effects and controlling the secondary effects of damage. Secondary damages are elements that reduce the survivability of the ship starting after being hit over time. If fire / smoke, damage in to the components of the systems and flooding are not controlled over time, more vital systems will be disabled. If fire cannot be controlled, it can damage the power lines and disable the ship's control system, resulting in loss of movement and / or operational capability. In a more dangerous scenario, secondary damage can have fatal consequences if fire reaches the fuel system, tanks or ammunition.

At this stage, the effects of the systems on each other and the responses of the personnel in these systems should be taken into consideration. For example, the cooling system may be disabled due to the damage of the pumps, and combat central control stations can work for a while without cooling system, but before the ambient temperature reaches a level that would prevent the operation of the devices, the personnel must activate the system. As seen from the example, there is a need for a time-based methodology that takes into account both the interaction of the systems and components with each other and the personnel effects.

The most important issue in the calculation of recoverability is the consideration of personnel effects. Simulations, where personnel are classified according to their ability levels, where the starting positions are determined according to the scenarios, in which damage control functions are performed individually according to defined rules, are carried out as better damage control simulations.

7. CONCLUSION

Despite the fact that new methodologies have been used to assess the survivability of civilian ships, the empirical stability criteria adopted by Sarchin & Goldberg in 1962 continue to be used in assessing the survivability of military ships. These criteria, used by major Navies such as USN and RN, have changed little over time. In accordance with the developments in the assessment of the survivability of the passenger / Ro-Ro vessels, the concept of probability was also considered in assessing the survivability of military ships.

Although flag states do not have to obey the regulations of SOLAS; the countries comply with these regulations for warships of their own free will. In this context, it is considered that the importance of the deterministic stability criteria of Navies will be preserved in the design of warships, but the concept of probability will be used more as an alternative assessment.

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LETTER TO THE EDITOR

THIS IS THE LAST CALL FOR PLANET LOVERS, COME AND SAVE YOUR PLANET: PROJECT PROPOSAL

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ABSTRACT

This study aims to provide brief information about the scope, purpose, main targets, main activities, expected outcomes and impact of the Erasmus Plus project entitled "This is the last call for Planet Lovers, Come and Save Your Planet: Project Proposal". It deals with the topics of energy efficiency, carbon footprint, green buildings, green practices, climate change policies in the globe, and global resources. The project has been designed as a training course which will arouse the environmental awareness of youth workers and stimulate them to gain environmental literacy skills. It aims to enable the youth workers and young generation to gain environmentally-friendly behaviors and competencies to find alternative ways how to struggle with climate change which has a huge impact on our globe. Within the project program, the youth workers will take part in international, cross-cultural learning environment where they will get knowledge about the policies and implementations done in Europe. Significance of being an environmentally literate person has been emphasized within the frame of this study and further recommendations have been suggested.

Keywords: *Erasmus Plus, Climate Change, Environmental Sustainability, Environmental Literacy.*

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BU GEZEGENİNİ SEVENLER İÇİN YAPILAN SON ÇAĞRIDIR, GEL VE GEZEGENİNİ KURTAR: PROJE ÖNERİSİ

ÖZ

Bu çalışmada, "Bu Gezegenini Sevenler İçin Yapılan Son Çağrıdır, Gel ve Gezegenini Kurtar: Proje Önerisi" başlıklı Erasmus Plus projesinin kapsamı, amacı, temel faaliyetleri, hedefleri, beklenen sonuçları ve etkisi ele alınacaktır. Proje kapsamında enerji verimliliği, karbon ayak izi, yeşil binalar, yeşil uygulamalar ve iklim değişikliği politikaları ele alınacaktır. Proje gençlik çalışanlarına çevresel farkındalık kazandırmak ve onlara çevre okuryazarlığı becerisi kazandırmak amacıyla eğitim kursu olarak tasarlanmıştır. Proje, gençlerin çevre-dostu davranışlar ve gezegenimizi büyük ölçüde etkileyen iklim değişikliği sorunsalına yönelik alternatif çözümler üretebilme konusunda yetkinlik kazanmasını amaçlamaktadır. Gençlik çalışanları, uluslararası öğrenme ortamına dahil olarak iklim değişikliği konusunda Avrupa Birliği'nde gerçekleştirilen uygulamalar ve politikalar konusunda bilgi sahibi olacaktır. Çalışma kapsamında çevre okuryazarı bir birey olmanın önemi vurgulanmıştır ve bu konuda önerilerde bulunulmuştur.

Anahtar Kelimeler: *Erasmus Plus Projesi, İklim Değişikliği, Çevresel Sürdürülebilirlik, Çevre Okuryazarlığı.*

1. INTRODUCTION

In recent years, environmental threats on our planet have started to increase. The Intergovernmental Panel on Climate Change (IPCC) 2007 climate change report states that continuation of Greenhouse Gas (GHG) emissions at current proportions or above causes further warming and will trigger global climate system changes much larger than observed in the 20th century during the 21st century [1] Scientists have high confidence that global temperatures will continue to rise for decades to come, largely due to greenhouse gases produced by human activities. IPCC, including more than 1,300 scientists from the United States and other countries, forecasts a temperature rise of 2.5 to 10 degrees Fahrenheit over the next century. According to the IPCC, the extent of climate change effects on individual regions will vary over time and with the ability of different societal and environmental systems to mitigate or adapt to change. Global sea level has risen by about 8 inches since reliable record keeping began in 1880. It is projected to rise another 1 to 4 feet by 2100. This is the result of added water from melting land ice and the expansion of seawater as it warms [2]. Greenhouse gas emissions have great impact upon the environment and climate change. Burning of coal, natural gas, and oil for electricity and heat is the largest single source of global greenhouse gas emissions. Greenhouse gas emissions from industry primarily involve fossil fuels burned on site at facilities for energy. Greenhouse gas emissions from buildings arise from onsite energy generation and burning fuels for heat in buildings or cooking in homes. All these factors have play significant role in climate change and give harm to nature and natural balance. Along with changing climatic conditions and increasing environmental threats, developing sensitivity to environmental issues has become a preferred situation. The United Nations (UN), IPCC, and various international bodies have urged governments and world leaders to step up their efforts to develop climate change policies that will lead to GHG emissions.

Climate change is a significant concept the effects of which are threatening our society and our future. Even though its impacts are severe, they can be lessened and green steps can be taken. Within this frame, enabling individuals to gain and improve environmental literacy skills can be a useful initiative in terms of creating awareness In accordance with this, environmental education is the basis for encouraging individuals to develop sensitive and positive feelings and behaviors towards environment [3] and take measures against environmental hazards and minimize environmental damage. As suggested in Belgrad Declaration, environmental education develops a world population with high level of awareness and interest in environment and related problems. Based upon these findings, environmental literacy can be handled as one of the key competencies of the era and a concept encountered frequently in literature. Miller [4] has identified environmental literacy as individual's behavior or choice the consequences of which will affect the environment and competency to find the most sustainable solutions for environmental problems increasing at an alarming rate. Similarly, Disinger and Roth [5] defined environmental literacy as the ability to perceive both harmful and harmless effects of environmental systems and to adopt the environmentally-friendly sides of these systems, and to take appropriate actions to restore and improve problematic situations. Simmons [6] stated that moral and ecologic reasoning, ecology-knowledge, socio-political information (cultural, political, economic and other social factors and the relationship between ecology and environment), strategic environmental thinking, adoption of environmental responsibility behavior are key factors of environmental literacy education, which will be the fundamental aspects of our environmental literacy training, as well.

There are some environmental education programs that aim to bring environmental literacy around the world and their effectiveness in promoting environmental literacy is largely overlapping. The majority of these trainings approach young people and children within the context of their educational environment in school [7]. Since 1994, Foundation for Environmental Education (FEE), a non-profit and non-governmental organization that supports sustainable development through education, enables students to participate in activities focused on entertainment and learning. These educational activities are envisaged to increase the awareness and interest level of individuals. Based upon this core idea, as a significant concept; climate change and environmental literacy are the fundamental topics we want to handle in our project proposal entitled "This is the last call for planet lovers: Come and save your planet". We have designed an Environmental Literacy Training Course aiming to enable the youth to gain ecologic and environmental literacy skills.

As younger generations will be a role model for children and who will generate our future, they have been selected as the main target group for the project. Training course aims to raise the consciousness level of youth workers and provide them with required data, practical implementations about environmental matters. Project has the unique aim of enabling the young people to gain knowledge, insight about the concept of Climate Change, Water Crisis throughout sphere, water and energy sources in the world, extinction of species due to global warming, concept of global warming, greenhouse gas emissions, carbon foot print, green practices and implementations such as green buildings, Leadership in Energy and Environmental Design (LEED) certificate for green buildings, green ICT systems that reduce the carbon foot print, energy sufficiency, UN Framework Convention on Climate Change (UNFCCC), Kyoto Protocol. In order to solve the climate change problem, global solutions are required. With this respect, raising the awareness level of youth is quite significant. Therefore, our training course on climate change desires to touch lives of youth workers and create a change in their knowledge, behaviors, and manners toward environment, environmental matters and concern.

2. SCOPE OF THE PROJECT

It is one of our main objectives to encourage young people to produce solution within the frame of Kyoto Protocol, share their situation in their own country, earn from each other on the basis of non-formal education methods, and to adopt environmentally friendly behaviors in their personal and institutional lives. Within the frame of the project, workshops based on practical, common and round-table methods will be held out. In the energy workshop, we will work on alternative energy sources, energy efficiency, saving measures and systems. In the water workshop, we will discuss the current situation of water resources globally. In order to promote the useful use of technology, we will organize workshops on green cloud computing, green data, green ICT topics, and share the green-life tips that will enable them to make better use of technology. We will make discussion about climate change negotiation process, Cancun Agreement, Global Serigraph Emissions, Green Climate Fund, Bali Action Plan, Low Carbon Technologies, Paris Climate Change Agreement Articles, National Series Gas Inventory Report. Hands-on training will be designed on how organic coffee can enter soil as a fertilizer. Field visits in Fethiye will be performed and green activities of the institutions carrying out environmental activities will be observed. Within the scope of the project, we will perform a Carbon Footprint measurement workshop for our own lives, as well. We will also organize workshops on recycling electronic waste. Our workshops address important environmental issues.

3. EXPECTED IMPACT

Our project will positively influence local associations, institutions and young people and encourage them to develop environmental activities. The results of the project will be shared with local public institutions, Non-governmental Organizations (NGOs), youth groups and youth committees. Recognition and visibility of the project will be increased by carrying out dissemination activities with other associations and institutions. It is thought that it will affect other institutions, organizations, associations and groups locally. Local and national dissemination of our project will encourage other institutions to take action on this issue. It will contribute to the development and awareness of the other young people in the local area, and we believe that it will lead them to think critically and develop their own green solutions for our planet.

Our partners will help to increase the recognition of the project in different countries by expanding them in their own countries. They will also share project outputs in their local and national communities and contribute to the awareness of other young people. In this respect, we think that our project will have cross-cultural and cross-national impact.

4. OUTCOMES OF THE PROJECT

Participants will have experience in Erasmus Plus, and will develop knowledge and qualification about the program. They will establish cultural bridges in a multicultural, multi-national, multi-lingual, multi-lingual learning environment, gain cultural competence at the melting point of cultures, gain the chance to develop their language competences. Our digital workers, who are intertwined with technology and who are digital native speakers of the digital age, will learn how to use technology better in accordance with green standards, and develop competence and capacity for low carbon and environment-friendly green technological applications. They will adopt in eco-conscious behaviors and attitudes about climate change, they will have environmental literacy skills, and be familiar with the concept of Environmental, Economic and Social Sustainability. They will be able to produce solutions for the sustainability of the world and protection of natural resources.

They will gain knowledge about Kyoto Protocol, Carbon Footprint, Greenhouse Gas Emission, Climate Change Negotiations, Global Water, Energy Crises, Global Warming, Alternative Energy Resources, Water and Energy Saving Methods, Recycling, Recycling of Electronic Waste, Green Cloud Informatics, Green ICT, Green Building Standards and Certifications, Climate Change Report under the scope of Smart 2010 EU Policies, articles and results, Ribbon Task Force, Climate Change Negotiation Process, Cancun Agreement, Green Climate Fund, Bali Action Plan, Low Carbon Technologies, Paris Climate will have knowledge, competence and experience about National Greenhouse Inventory Report, will develop capacity on this issue.

5. CONCLUSIONS AND SUGGESTIONS

The training program designed within the frame of the project will raise the awareness of younger generation related to globe-wide environmental problems. As target group is international youth workers coming from different geographical, social and economic backgrounds, it is believed to create a tremendous impact in cross-cultural and international level. It is projected to increase the motivation and interest of them to develop and take part in similar activities, encourage their peers and arouse their interest to develop green-themed projects and adopt environmentally-friendly behaviors and produce green solutions. The training program is supposed to stimulate younger generation to gain environmental literacy skills as well.

Environmental literacy has been handled as a core skill of today’s society in terms of creating well-educated citizens who pay utmost attention to the posing threats. The topic should be integrated to the school, university and college curriculum of youth workers as elective courses. Green seminars and workshops can be carried out in universities and NGOs.

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Figures and Tables: Figures and tables should be numbered consecutively. In the text referring to figures and tables should be made by typing "Figure 1" or "Table 1" etc. A suitable title should be assigned to each of them.

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YAZIM KURALLARI

Genel Bilgiler: Yazılar; Microsoft Word'de tek satır aralığı ve iki yana yaslanarak hazırlanmalıdır. Yazı tipi: Times New Roman, 12 punto. Kenar boşlukları: sol 4,5 cm- sağ 3,5 cm- üst 5 cm- alt 7 cm- üst bilgi 3,25 cm- alt bilgi 6 cm, oluk 0. Kağıt ölçüsü: A4. Sayfa numaraları sayfanın alt ortasında -1-, -2-, -3- şeklinde yer almalıdır. Dipnot kullanılmamalıdır.

Yazı Yapısı: Yazı şu sırada hazırlanmalıdır: Başlık, Yazarlar, Özet, Anahtar Kelimeler, Başlık (Türkçe), Özet (Türkçe), Anahtar Kelimeler (Türkçe), Ana Metin, Ek (varsa), Referanslar.

Başlık: Başlık; açık, net, anlaşılır olmalı ve 15 kelimeyi geçmemelidir.

Öz: Yazı, 100-200 kelimelik, arka plan, amaç, yöntem, bulgular ve sonuçtan oluşan yapılandırılmış bir özeti içermelidir.

Anahtar Kelimeler: Yazıyı sınıflandırmaya yarayacak, anahtar görevi yapan 3-5 kelime yer almalıdır.

Sayfa Sayısı: Dergiye gönderilecek yazıların boyutu, kaynakça dahil asgari 2000 kelime veya 5 sayfa, azami 7000 kelime veya 25 sayfa arasında olmalıdır.

Birimler: Yazının uluslararası alanlarda da kolay izlenebilir ve anlaşılabilir olması için Uluslararası Birim Sistemine (https://www.britannica.com/science/International-System-of-Units) uygun olarak hazırlanması gerekir.

Referans: Referanslar dipnotlar ile değil metin içinde açılacak parantezlerde yer alan referans numarası ile ([2] gibi) yapılmalıdır.

Referans Listesi: Makalenin ana metninden sonra sadece yazıda gönderme yapılan eserler yer almalıdır. Gönderme yapılan eserler, ana metin içerisinde atıf yapıldıkları sıraya göre listelenmelidir, yani ilk atıf yapılan eser [1], ikinci atıf yapılan eser [2] olmalı ve bu şekilde devam etmelidir. Bir referans listesi örneği aşağıdadır.

Örnekler:

[1] Berndt, T. (2002). "Friendship Quality and Social Development", ***Current Directions in Psychological Science***, vol.82, no.3, pp.114-140. **(Tek yazarlı makale)**

[2] Rother, M. and Shook, J. (1999). "Learning to See: Value Stream Mapping to Create Value and Eliminate Muda", ***The Lean Enterprise Institute***, vol.22, no.4, pp.3-4**. (Çok yazarlı makale)**

[3] Okamoto, G. (1999). ***Smart Antenna Systems and Wireless LANs,*** Boston: Kluwer Academic Publishers. **(Tek yazarlı kitap)**

[4] Author, A. (Year). "Title of document", Retrieved from http://wwwwwwwwwwwwwwwww wwwwwwww wwwwwwwwwww. (Access Date: 00.00.0000). **(İnternet kaynakları)**

[5] Lastname, F.N. (Year). Title of dissertation (Doctoral dissertation). University Name, Institute Name, City. (Retrieved from Name of database). **(Yayınlanmış tez)**

[6] Bergmann, P. G. (1993). Relativity, ***In the New Encyclopedia Britannica,*** (Vol. 26, pp. 501-508). Chicago, IL: Encyclopedia Britannica**. (Ansiklopedi)**

[7] Author, A. A. (Year, Month Day). "Title of article", ***Title of Newspaper***. Retrieved from http://www.someaddress.com/full/url/wwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwwww wwwww wwwwwwwwwwwwwwwwwwwwwwwwwwwwwww. **(Gazete makalesi)**

[8] Önaçan, M.B.K., Uluağ, M., Önel, T. and Medeni, T.D. (2018). "Selection of Plagiarism Detection Software and Its Integration into Moodle for Universities: An Example of Open Source Software Use in Developing Countries". Ricardo Queirós (ed.), Emerging Trends, Techniques, and Tools for Massive Open Online Course (MOOC) Management, ***IGI Global***, 250-265, pp. 255. **(Kitap bölümü)**

Notasyon ve Kısaltmalar: İlgili bilim alanının standart notasyon ve kısaltmaları kullanılmalı, yeni notasyonlar ise metin içinde ilk geçtiği yerde tanımlanmalıdır. Gerekli durumlarda, notasyon ve kısaltmalar ek olarak konulabilir.

Denklem ve Formüller: Denklem ve formüller ardışık olarak numaralandırılmalı ve bu numaralar sağa dayalı parantez içinde yazılmalıdır. Metin içinde denklem ve formüllere parantez içinde yazılan numaraları ile atıfta bulunulmalıdır. Metin arasında verilmesi uygun olmayan kapsamlı formüller şekil olarak hazırlanmalıdır.

Şekiller ve Tablolar: Şekiller ve tablolar, ardışık olarak numaralandırılmalıdır. Bunlara metin içinde "Şekil 1" veya "Tablo 1" şeklinde atıfta bulunulmalıdır. Her bir şekil ve tablo için uygun bir başlık kullanılmalıdır.

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