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Editorial (ED)

We are pleased to introduce JEMS 7(3) to our valuable followers. There are valuable and endeavored studies in this issue of the journal. We hope that these studies will contribute to the maritime industry. I would like to mention my gratitude to authors who sent their valuable studies for this issue, to our reviewers, to our editorial board, to our section editors, to our foreign language editors who provide quality publications by following our publication policies diligently and also to layout editors who spent great efforts in the preparation of this issue.

Your Sincerely.

Editor
Prof. Dr. Selçuk NAS

Journal of ETA Maritime Science

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Editörden (ED)

JEMS 7(3)'ü siz değerli takipçilerimizin ilgisine sunmaktan mutluluk duyuyoruz. Dergimizin bu sayısında birbirinden değerli çalışmalar yer almaktadır. Dergimizde yer alan bu çalışmaların denizcilik endüstrisine katkı sağlamasını ümit ediyoruz. Bu sayı için değerli çalışmalarını gönderen yazarlarımıza, yayın politikalarımızı titiz bir şekilde takip ederek kaliteli yayınlar çıkmasına katkıda bulunan başta hakemlerimiz olmak üzere, bölüm editörlerimize, yabancı dil editörlerimize ve yayın kurulumuza, sayımızın yayına hazırlanmasında büyük emekleri olan mizanpaj editörlerimize teşekkürlerimi sunuyorum.

Saygılarımla.

Editör
Prof. Dr. Selçuk NAS

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"Better together!"

United Nations Sustainable Development Goals, SDG#5 focuses on "Gender Equality" and 2019 year's World Maritime Day theme has been indicated as "Empowering Women in the Maritime Community" by International Maritime Organization (IMO) which is an agency of the United Nations based in London. The Day of the Seafarer 2019 was celebrated on 25th of June with the hashtag of "#iamonboard with gender equality all around the world as IMO's campaign.

As The Chamber of Marine Engineers, Turkey we are the first organization in Turkey which lead the IMO's #iamonboard with gender equality campaign and it brought a huge impression to the maritime industry worldwide. With the results of our cooperative work with IMO, we are so glad to announce that we have established a new international platform called "SheFarers". SheFarers Platform is non-profit and aims to create awareness on women who work at sea, to promote their careers on board and ashore with specialized educational programs, to protect rights of women on board and to facilitate working standards for all women in the industry whom involve in field work.

SheFarers Platform is established in Turkey however always focuses on brining all female seafarers together internationally and the main project area is to set up a new mentorship program for women at sea and ashore in all maritime fields by starting in Turkey. Thus, SheFarers designated a motto to encourage more women to the maritime industry which is "Better together!".

The first event of SheFarers will be held on 26th of September 2019 which is World Maritime Day and SheFarers invites all to celebrate the theme of "Empowering Women in the Maritime Community" and #iamonboard campaign of IMO.

SheFarers is very active on social media to emphasize women's recognition in every field of the maritime industry and can be followed on the below accounts

Website: www.shefarers.org
Instagram: @she.farers
Facebook: SheFarers
Twitter: @shefarers
LinkedIn: SheFarers
Direct contact: info@shefarers.org

Capt. Ayse Asli Basak
Co-Founder, SheFarers Platform
Board Member, The Chamber of Marine Engineers, Turkey

SheFarers

WOMEN IN MARITIME
IMO's GENDER PROGRAMME

IMO INTERNATIONAL MARITIME ORGANIZATION

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Corresponding Author: Mesut TOKUŞ

Kuru Yük Gemisi Balast Suyu Arıtma Sistemi Entegrasyonu ve Yaşam Döngüsü Maliyet Analizi

Mesut TOKUŞ

Yıldız Teknik Üniversitesi, Gemi İnşaatı ve Denizcilik Fakültesi, Türkiye
mesutokus@gmail.com; ORCID ID: https://orcid.org/0000-0001-8791-3221

Öz

Gemiler yük durumlarına göre stabilitelerini korumak için balast suyu sistemlerini kullanırlar. Gemilerin balast tanklarına alınan balast suları çeşitli organizmalar barındırır ve bu organizmalar gittikleri yeni ekosistemde çoğalma şansı bulduklarında istilacı tür haline gelebilirler. Bu zararlı organizmalar gittikleri bölgelerde ekolojiyi, ekonomiyi ve insan sağlığını etkilemektedir. Bu sebepten dolayı uluslararası kuruluşlar balast suyu yönetimi ile ilgili standartlar ve kriterler oluşturmuştur. IMO (International Maritime Organization)'nun Gemi Balast Suları ve Sediment Kontrolü ve Yönetimi Uluslararası Sözleşmesi'nde almış olduğu balast suyu arıtımı ile ilgili D1 ve D2 standartları bulunmaktadır.

IMO'nun getirmiş olduğu kriterlere göre geliştirilen balast suyu arıtma yöntemleri mekanik, fiziksel ve kimyasal olmak üzere üç ana başlıkta incelenmiş, seçim kriterleri oluşturulmuş ve bu kriterlere göre örnek kuru yük gemisine balast suyu arıtma sistemi seçilmiştir. Seçilmiş olan UV+filtreleme sisteminin, örnek kuru yük gemisine entegrasyon çalışması yapılmıştır. Ürünün yaşam döngüsü maliyetleriyle ilgili risk ve belirsizlikler tanımlanmış, yaşam döngüsü maliyet unsurları belirlenmiş ve maliyet analizi yapılmıştır. Sistemin yaklaşık maliyeti 400.000 € olarak bulunmuş olup, maliyet kırılımı incelendiğinde en büyük maliyetin yatırım maliyeti olduğu bulunmuştur.

Anahtar Kelimeler: *Balast Suyu, Balast Suyu Arıtımı, UV+filtreleme, Yaşam Döngüsü Maliyet Analizi.*

Ballast Water Treatment System Integration and Life Cycle Cost Analysis for Dry Bulk Carrier

Abstract

The ships use ballast water system in order to maintain their stability according to load conditions. Ballast water that is taken to ships' ballast tank contains various organism. These organisms may become invasive species when they have the chance to reproduce in the new ecosystem they are going to. These harmful organisms affect the ecology, economy and human health in regions where they go. For this reason, international organizations have been set standards and criteria related to ballast water management. IMO (International Maritime Organization) has D1 and D2 standarts related to ballas water trematment received in the International Convention for the Control and Management of Ship' Ballast Water and Sediments.

According to the criteria taken by IMO, ballast water treatment systems have been examined under three main topics; mechanical, physical and chemical. Selection criteria have been established in agreement with the methods examined and ballast water treatment system has been selected for a sample dry cargo vessel

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with respect to these criteria. The integration of the selected UV + filtering system to the sample dry bulk carrier has been carried out. Besides, life cycle cost elements have been determined for the UV + filtering ballast water treatment system, cost structure has been formed and cost analysis has been carried out. The risks and uncertainties related with the life cycle costs of the product have been defined. The approximate cost of the system was found as €400.000 and when cost breakdown was analyzed the biggest cost was found as the investment cost.

Keywords: *Balast Water, Balast Water Treatment, UV + filtration, Life Cycle Cost Analysis.*

1. Giriş

Gemiler ticaret ve ulaşım alanında her zaman ilgi gören ve tercih edilen araçlar olmuşlardır. Günümüzde de dünya ticaretinde taşınan malların yaklaşık %90'ı deniz ticareti ile taşınmaktadır [1]. Deniz yolu ile yapılan ticaret son 65 yılda 18 kat büyümüştür. Bu kadar büyük ticaret hacmine sahip olan gemi taşımacılığının emniyetini sağlamak ve ondan yüksek verim almak büyük önem taşımaktadır [2].

Gemiler denizde emniyetli seyahat edebilmeleri için stabilitelerini sağlamaya yönelik balast almaktadırlar. [3]. Yapılan çalışmalar ışığında bu operasyonun bazı olumsuz sonuçlar doğurduğu görülmüştür. Balast boşaltımı sırasında bir ekosistemden alınan deniz suyunun başka bir ekosisteme bir işleme sokulmadan boşaltılması, orada doğal olarak var olmaması gereken organizmaların da sisteme katılması anlamına gelmektedir. Balast suyu ile taşınan organizmalar, boşaltıldıkları ekosistemlerde uygun üreme ortamları bulurlar ise dengesiz çoğalıp istilacı tür olabilmektedirler [4].

Dünya deniz ticareti filoları ile yılda yaklaşık 10 milyar ton balast suyunun transfer edildiği ve balast sularıyla günde ortalama 10000 civarında canlı türünün farklı limanlara taşındığı tahmin edilmektedir. Bu türler biyolojik istilaya sebep olurken aynı zamanda ülke ekonomileri, insan sağlığı ve çevre üzerinde ciddi boyutlarda zararların oluşmasına sebep olmaktadır [5].

Coğrafi bölgeler arasında istenmeyen türlerin balast suyu ile taşınmasını önlemek amacıyla bölgesel ve ulusal önlemler alınmıştır. Bununla birlikte devletlerin ve çevreci örgütlerin aldıkları önlemleri ve iş birliklerini kapsayacak şekilde uluslararası bir kuruluş olan IMO tarafından 2004 yılında Gemi Balast Suları ve Sediment Kontrolü ve Yönetimi Uluslararası Sözleşmesi üye ülkelerin imzasına sunulmuştur [6]. IMO Balast Suyu Yönetimi Sözleşmesi, 5 bölümden oluşmaktadır. Bunlar, genel hükümler, gemiler için yönetim ve kontrol gereksinimleri, belirli alanlarda özel gereklilikler, balast suyu yönetimi için standartlar ve balast suyu yönetimi için ölçümleme ve sertifika gereklilikleridir [7]. Balast suyu yönetimi için standartlar bölümü başlığı altında balast suyu arıtımını doğrudan ilgilendiren D1 ve D2 standartları bulunmaktadır. D1 balast suyu değişim standardı ve D2 balast suyu performansı standardıdır. IMO standartlarını sağlamak için balast suyu arıtma sistemlerine geçiş planı gemilerin balast kapasitesi ve inşa yıllarına göre belirlenmiştir [8].

IMO standartlarına uygun balast suyu arıtma işlemi yapabilmek için çok sayıda balast suyu arıtma yöntemi geliştirilmiştir. Bu yöntemler üç ana başlık altında incelenmiştir. Bunlar; mekanik, fiziksel ve kimyasal yöntemlerdir. Bununla birlikte bu yöntemler tek başlarına balast suyu arıtımı için yeterli değildir. Bu nedenle fiziksel yöntemler birinci, kimyasal yöntemler ise ikinci aşama arıtma yöntemi olacak şekilde birlikte kullanıldığı karma yöntemler geliştirilmiştir [9].

Gemiye uygun balast suyu arıtma sistemi seçimi sistemden alınacak verim ve maliyet açısından oldukça önemlidir. Bir gemiye uygun balast suyu arıtım sistemi seçiminde;

balast suyu kapasitesi, gemi tipi, sistemin tip onayı almış olması, geminin operasyon alanı, alınacak balast suyunun karakteristik özelliği, sistem boyutları, sistemin alınacağı firmanın bilinirliği ve güvenirliliği, yatırım ve işletim maliyeti ve arıtma yönteminin balast tanklarına etkisi gibi birbirinden farklı birçok faktör bulunmaktadır [10].

Bu çalışmada balast suyu arıtımı için uluslararası kuruluşlarca oluşturulmuş standartlar ve onayladıkları balast suyu arıtma yöntemlerinin incelenmesi, örnek kuru yük gemisi için balast suyu arıtma sisteminin seçilmesi, seçilmiş olan balast suyu arıtma sisteminin kuru yük gemisine entegrasyonunun yapılması ve incelenmesi ve balast suyu arıtma sisteminin yaşam döngüsü maliyet analizinin yapılması amaçlanmıştır.

2. IMO Standartları

Zararlı organizmaların coğrafi bölgeler arasında balast suyu ile taşınmasını önlemek amacıyla uluslararası kuruluşlarca alınmış kararlar ve standartlar bulunmaktadır. Uluslararası bir kuruluş olan IMO tarafından yayınlanıp üye olan ülkelerce imzalanan Gemi Balast Suları ve Sediment Kontrolü ve Yönetimi Uluslararası Sözleşmesi gereğince gemiler balast suyu kapasitesine ve inşa yılına göre D1 veya D2 standardına uymak zorundadır. Tablo 1'de gemilerin International Oil Pollution Preventing (IOPP) sertifikasına bağlı D2 standardına güncel geçiş planı gösterilmiştir.

2.1. IMO D1 Standardı

IMO tarafından oluşturulan balast suyu değişim standardıdır. Bu standart gereği gemilerin balast tanklarındaki suyun hacimsel olarak %95'ini değiştirmesi gerekmektedir. Bu değişim 3 farklı yöntem ile yapabilir. Seyreltme en çok tercih edilen yöntemdir ve balast pompaları yardımı ile tanka deniz suyu basıp balast tankında taşırma meydana getirerek değişim yapılmasına dayanır. Ardışık yöntem, balast tanklarını tamamen boşaltıp, yeniden doldurma yoluyla değişim yapılan yöntemdir. Devirdaim yöntemi ise balast tankına üst kısımdan su pompalanırken alt kısımdan su boşaltılması işlemi ile değişim yapılan yöntemdir. Bu yöntemler karadan 200 deniz mili uzaklıkta ve 200 m derinliğe sahip olan bölgede planlanmalıdır [12].

2.2. IMO D2 Standardı

IMO tarafından oluşturulan balast suyu performans standardıdır. Balast suyu arıtma işlemi sonrasında sudaki zararlı organizmaların sayısına getirilen sınırlama ile ilgili bir standarttır. Organizma boyuna ve türüne göre birim hacimdeki izin verilen yaşayabilir organizma miktarı

Tablo 1. *IMO D2 Standardına Geçiş Planı [11]*

	08.09 2017	08.09 2018	08.09 2019	08.09 2020	08.09 2021	08.09 2022	08.09 2023	08.09 2024
08.09.2017 ve sonrasında inşa edilen yeni gemiler	Yeni gemiler teslimde D2'yi sağlamalı							
08.09.2017 öncesinde inşa edilen ve IOPP yenileme sörveyi 08.09.2017 ve 08.09.2019 arasında olan mevcut gemiler						D2'yi sağlamalı		
08.09.2017 öncesinde inşa edilen ve IOPP yenileme sörveyi 08.09.2019 ve 08.09.2022 arasında olan mevcut gemiler			D2'yi sağlamalı					
IOPP Sertifikasına tabi olmayan gemiler	D2'yi sağlamalı							

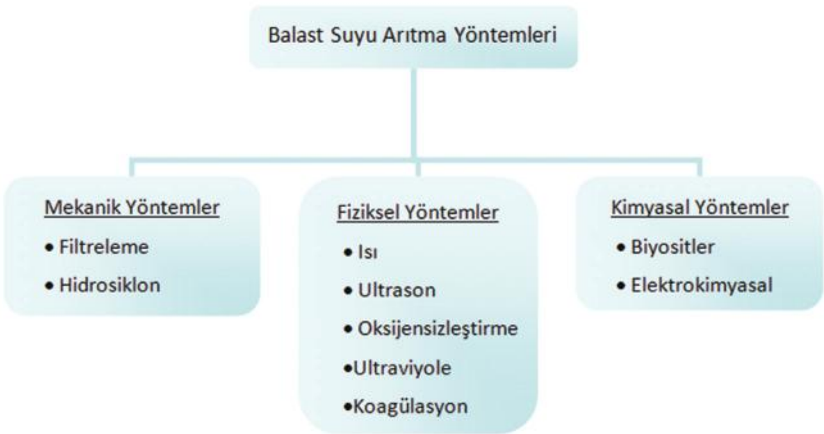
değişmektedir. Tablo 2'de IMO D2 standardı kriterleri gösterilmiştir.

Tablo 2. *IMO D2 Standardı Kriterleri [13]*

Organizma		Birim Hacimdeki İzin Verilen Yaşayabilir Organizma Miktarı
Organizma Boyu ≥ 50 µm		<10 adet / m^3
50 µm > Organizma Boyu ≥ 10 µm		<10 adet / ml
İnsan Sağlığı ile İlgili Standartlar	Toxigenic Vibrio Cholerae	<1 cfu(colony forming unit)/100ml
	Escherichia coli	<250 cfu(colony forming unit)/100 ml
	Intestinal Enterococci	<100 cfu(colony forming unit)/100 ml

3. Balast Suyu Arıtma Yöntemleri

IMO'nun D2 standardına uygun balast suyu arıtımı yapmak için birçok balast suyu arıtma yöntemi geliştirilmiştir. Bu yöntemler üç ana başlık altında incelenmektedir. Bunlar; mekanik yöntemler, fiziksel yöntemler ve kimyasal yöntemlerdir [9]. Şekil 1'de balast suyu arıtma yöntemleri alt başlıklarıyla gösterilmiştir.



Şekil 1. *Balast Suyu Arıtma Yöntemleri*

3.1. Mekanik Yöntemler

Mekanik yöntemler filtreleme ve hidrosiklon yöntemlerinden oluşmaktadır. Temel olarak su balast tankına girmeden önce 40-50 mikrondan büyük organizmalar sudan ayrılıp yeniden kendi ekolojik ortamlarına gönderilmektedir. Mekanik yöntemler tek başlarına kullanıldığında IMO D2 standardını karşılayamadıklarından dolayı yalnızca birinci aşama arıtma yöntemi olarak kullanılmaktadırlar. Hidrosiklon, santrifüj kuvvetler ile katı parçacıkları sudan ayırma yöntemidir [14].

3.2. Fiziksel Yöntemler

Fiziksel yöntemler; ısı, ultrason, oksijensizleştirme, ultraviyole (UV) ve koagülasyon yöntemlerinden oluşmaktadır [9]. Isı ile arıtma yöntemi, balast suyu arıtımı sırasında suyun sıcaklığını arttırıp belirli sıcaklık aralıklarında hedef alınan organizmaları yok etmeye yönelik bir yöntemdir. Gemilerdeki makine sistemi operasyon sırasında sürekli atık ısı üretir. Buradan üretilen atık ısı, yüksek ve düşük sıcaklıktaki soğutma suyundan ve egzoz gazından çıkarılır. Bu enerji ile balast suyunu ısıtarak organizmaların yok edilmesi planlanmıştır [15]. Ultrason yönteminde, sıvı içerisinde oluşturulan yüksek frekanslı titreşimler ile kavitasyon meydana getirilmektedir. Bunun sonucunda yüksek enerjiye sahip hava kabarcıkları oluşumu ve patlaması gerçekleşmektedir [4]. Oksijensizleştirme yönteminde, balast suyuna glikoz, amonyum, nitrat, sakkaroz gibi besin maddeleri eklenmektedir. Böylelikle suda bulunan zararlı organizmalar hızla büyür ve çoğalırlar. Artan ve büyüyen canlı sayısı daha fazla oksijen tüketir ve böylece suda bulunan oksijen hızlıca tüketilir [16]. Ultraviyole yönteminde, UV ışıması ile organizmaların DNA ve RNA moleküllerinde bulunan protein yapısının bozulması sağlanarak etkisizleştirmektedir. Bu yöntemin birinci aşama arıtma yöntemleriyle kullanılması önerilmektedir [17]. Koagülasyon yönteminde ise gemiye alınan balast suyu, karıştırma tankında manyetik toz ve koagülant (pıhtılaştırıcı veya topaklayıcı madde) ile karıştırılmaktadır. Tanktan çıkan su manyetik separatörlere girer ve topak haline gelmiş ve aynı zamanda manyetize olmuş olan zararlı organizmalar ve partiküller separatörler tarafından ayrıştırılmaktadır [12].

3.3. Kimyasal Yöntemler

Kimyasal yöntemler, kimyasal bir maddenin balast suyuna eklenerek ya da balast suyunda oluşturularak istenmeyen mikroorganizmaların etkisiz hale getirildiği yöntemdir. Kimyasal yöntemler, biyositler (oksitleyici ve oksitleyici olmayan biyositler) ve elektrokimyasal yöntemlerden oluşmaktadır [9]. Oksitleyici biyositler arasında klor, klor dioksit, ozon, hidrojen peroksit ve perasetik asitler bulunmaktadır. Oksitleyici olmayan biyositler arasında ise gluteraldehit, SeaKleen® ve akrolein vardır [18].

Elektrokimyasal yöntemlerin balast suyu arıtımında kullanımı iki farklı metotla gerçekleştirilmektedir. Birinci yöntemde balast suyunun belirli bir miktarı elektroliz ünitesinden geçer ve elektroliz işlemi ile yüksek yoğunlukta ortaya çıkan serbest klor, klor dioksit, ozon ve hidrojen peroksit gibi dezenfektanlar arıtım için kullanılır. İkinci yöntemde ise balast suyunun tamamı elektroliz hücrelerinden geçirilmekte ve elektriksel alanın öldürücü etkisinden faydalanılmaktadır [19,20].

4. Balast Suyu Arıtma Sistemi Seçimi ve Kriterleri

4.1. Balast Suyu Arıtma Sistemi Feçim Kriterleri

Bir gemiye uygun balast suyu arıtım sistemi seçilmesi için dikkat edilmesi gereken birçok faktör bulunmaktadır. Yatırımcı için en önemli kriter sistemin yatırım ve işletim maliyeti olsa da bunun dışında geminin operasyon alanı, gemi tipi, balast suyu kapasitesi, kurulacak sistemin tip onayı almış olması, sistemin boyutları, sistem için ayrılan kullanılabilir alan, sistemin satın alınacağı firmanın bilinirliği ve güvenirliliği, enerji tüketimi, sistemin kullanılabilirliği ve teslim süresi, balast tanklarına etkisi ve alınacak balast suyunun karakteristik özellikleri ilgili kriterlerdendir [4,21].

Geminin operasyon alanı; IMO'nun belirlediği standartların dışında kendi standartlarını oluşturan ve farklı istekleri olan ülkeler vardır. Örneğin, ABD karasularında balast suyu boşaltmak için United States Coast Guard (USCG) standartlarına uyma zorunluluğu vardır. USCG standartları IMO standartlarından daha katı kurallara sahip olduğundan rotası ABD karasularında olan bir geminin balast suyu arıtım sistemi USCG standartlarına uygun ve onaylı olmalıdır [4].

Tip onayı; seçimi yapılacak olan

balast suyu arıtım sistemi için en önemli faktörlerden biri, IMO'nun yayınladığı rehberlerden balast suyu yönetimi sistemlerinin kabulü ile ilgili rehberlere (G8) ve balast suyu sistemlerinde aktif maddelerin kullanılmasının onaylanması için prosedürlere (G9) tarafından onaylanmış olması gerekmektedir [22].

Gemi tipi ve balast suyu kapasitesi; Balast suyu arıtma sisteminin arıtma kapasitesini belirlemek için balast pompası debisi ve geminin balast suyu kapasitesi önemli bir kriterdir [21].

Alınacak balast suyunun karakteristik özelliği; balast suyu arıtım sistemi seçimi için çok önemli bir faktördür. Bu faktör ve kısıtlar aşağıdaki gibidir:

- Balast suyunun bulanık olması mikroorganizmaların UV ışımasına maruz kalmasını etkilediği için UV yönteminin verimini düşürmektedir [17].
- Balast suyunun tuzluluk oranının düşük olması daha az klor elde edilmesine sebep olacağından elektroliz yönteminin verimini düşürmektedir [19].
- Balast suyunun sıcaklığının düşük olması suyun ısıtılmasına daha fazla enerji gerektirdiği için ısı ile arıtma yönteminin verimini düşürmektedir [15].

Sistem boyutları; yeni inşa edilecek gemilerde dizayn hesaplamalarına balast suyu arıtma sistemi de katılacak şekilde bütünü düşünerek tasarım yapılmaktadır; fakat mevcut gemiye eklenecek bir arıtma sistemine gemide uygun yer bulmak çoğunlukla problemler yaratmaktadır [4].

Yatırım ve işletim maliyeti; ilk yatırım maliyeti alınan sistemin satın alınması ve nakliyesi gibi maliyetleri içerir. İşletim maliyeti ise bakım, onarım, yedek parça, tüketilen enerji, varsa kullanılan sarf malzemeler gibi giderleri içerir [21].

Servis hizmeti; geminin nerede olduğundan bağımsız yedek parça temini, teknik servis hizmeti alınabiliyor olmasını içerir [21].

Personel emniyeti ve eğitimi; tercih edilen balast suyu arıtım sistemi kimyasal yollar ile arıtım yapıyor ise gemi personeline kendi emniyeti için gerekli eğitim verilmektedir. Kimyasal sistemin dezenfektan maddelerinin depolanması gerekmekteyse uygun bir mahal planlanmalı, klas kuruluşundan gerekli izin ve onaylar alınmış olmalıdır [4].

Sistemin kullanılabilirliği ve teslim süresi; sistemin kullanılabilirliğinin kolay olması gemide çalışan personel için avantajdır. Gemiye entegre edilecek balast suyu arıtma sisteminin teslim süresi ise gemi işletmecisi için önemli bir kriterdir [4].

4.2. Balast Suyu Arıtma Sistemi Seçimi

Bölüm 4.1'de detaylandırılan seçim kriterlerine göre ana boyutları verilmiş olan halihazırda çalışan örnek kuru yük gemisi A'ya balast suyu arıtma sistemi seçilecektir. Balast suyu arıtma yöntemlerinden UV+filtreleme, elektroliz+filtreleme ve kimyasal madde+filtreleme yöntemleri arasında bir seçim yapılacaktır. Seçilecek yönteme aşağıda oluşturulan kriterlere göre Tablo 3'te verilen kriter temelli seçim tablosu ile karar verilmiştir. Kriterler tespit edilmiş olup toplam 15 kriter için uzman görüşüne başvurulmuştur.

Gemi Tipi: Kuru Yük Gemisi
Tam Boy: 170 m
Dikmeler Arası Boy: 160 m
Genişlik: 27 m
Derinlik: 14 m
Draft: 9,6 m
DWT: 28500 MT
Balast Suyu Kapasitesi: 9500 m^3

Oluşturulan kriterler aşağıdaki gibidir;
Kriter 1: 9500 m^3 balast suyunu arıtma kapasitesi
Kriter 2: IMO tarafından alınmış tip onayı

Kriter 3: USCG standartlarına uygunluğu
Kriter 4: Sistem boyutu
Kriter 5: Dünya çapında servis hizmeti
Kriter 6: İlk yatırım maliyeti
Kriter 7: İşletim maliyeti
Kriter 8: Balast tankına korozyon etkisi
Kriter 9: Enerji tüketimi
Kriter 10: Personel emniyeti
Kriter 11: Personel eğitimi gerekliliği
Kriter 12: Sistemin teslim süresinin hızı
Kriter 13: Balast suyunun bulanık olması durumunda verim
Kriter 14: Balast suyunun tuzluluk oranının düşük olması durumunda verim
Kriter 15: Balast suyunun sıcaklığının düşük olması durumunda verim

Bu kriterlere göre balast suyu arıtma sistemleri kıyaslanmıştır ve UV + filtreleme sisteminin kuru yük gemisi A için daha uygun olduğuna karar verilmiştir.

5. UV+filtreleme Sisteminin Kuru Yük Gemisine Entegrasyonu

IMO'nun D2 standardına uyum sağlamak zorunda olan kuru yük gemisi A, kendi bünyesinde bulunan entegre olacak sistem ile çalışacak, debisi 420 m^3/saat olan 1 adet balast pompası bulunmaktadır. Gemiye entegre edilecek balast suyu arıtma sisteminin debisi balast pompasının debisinden düşük olmamalıdır. Bu sebeple geminin mevcut balast sistemine saatte 500 m^3 su arıtabilen sistem entegre edilecektir.

Geminin jeneratörü mevcut sistemlerin enerji ihtiyacı ile beraber balast suyu arıtma sisteminin de enerji ihtiyacını karşılaması gerekmektedir. Kuru yük gemisi A'nın mevcut jeneratörleri ekstradan balast suyu arıtma sistemini de çalıştırmaya yetecek kapasitede olduğuna dikkat edilmiştir.

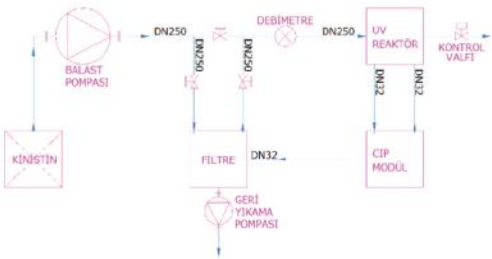
Balast suyu arıtma sistemlerinin mevcut gemiye entegrasyonu, ayrıntılı bir mühendislik çalışması gerektirir. Sistem için gemi üzerinde uygun yerin

Tablo 3. *Balast Suyu Arıtma Sistemi Seçimi için Kriter Temelli Seçim Tablosu*

Kriterler	Balast Suyu Arıtma Sistemi		
	UV + Filtreleme	Elektroliz + Filtreleme	Kimyasal + Filtreleme
Kriter 1	✓	✓	✓
Kriter 2	✓	✓	✓
Kriter 3	✓	✓	×
Kriter 4	✓	○	✓
Kriter 5	✓	○	×
Kriter 6	○	○	✓
Kriter 7	○	✓	×
Kriter 8	✓	×	×
Kriter 9	○	○	✓
Kriter 10	✓	✓	○
Kriter 11	✓	✓	×
Kriter 12	✓	✓	✓
Kriter 13	×	✓	✓
Kriter 14	✓	×	×
Kriter 15	✓	×	×

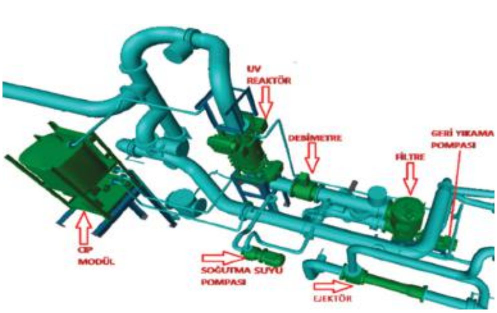
belirlenmesi ekipman yerleşimi, boru devrelerinin dizaynı ve elektrik kablo yollarının çalışılması sistemin seçimi kadar önemlidir. Sistem ekipmanlarının ve balast suyu pompasının birbirine göre lokasyonu, entegrasyon için bir diğer önemli faktördür.

Sistemin entegre edileceği geminin balast sistemi tek hat şematik planıyla uyumlu hale getirilmesi gerekmektedir. Hazırlanan sistem planı için klas onayı alınmalı ve yapılacak yerleşim ve boru dizaynı tek hat şematik planı ile uyumlu olmalıdır. Şekil 2'de balast suyu arıtma sisteminin tek hat şematik planı gösterilmiştir.



Şekil 2. *Balast Suyu Arıtma Sisteminin Tek Hat Şematik Planı*

Balast suyu arıtma sistemini gemiye entegre edebilmek için ilgili boru sistemlerinin ve ekipman döşeklerinin sanal ortamda üç boyutlu dizaynı yapılmıştır. Şekil 3'te balast suyu arıtma sistemi ve elemanları, Şekil 4'de ise nokta bulutu üzerinde model çalışması gösterilmiştir.



Şekil 3. *Balast Suyu Arıtma Sistemi İzometrik Görünüşü*

Şekil 4. *Nokta Bulutu Üzerinde Model Çalışması*

6. Yaşam Döngüsü Maliyet Analizi

ISO standartlarına göre, yaşam döngüsü analizi, bir ürün sisteminin girdi, çıktı ve potansiyel çevresel etkilerinin yaşam döngüsü boyunca derlenmesi ve değerlendirilmesidir [23]. Yaşam döngüsü analizi çevresel performans, maliyet-fayda dengesi ve kullanılabilirlik arasında bir optimizasyon geliştirmeye dayanan bütünsel bir yöntemdir. Şirketlerin daha iyi tasarım ve çevre dostu ürünler yaparak, mevcut kaynakların daha etkin kullanılmasını sağlamayı amaçlamaktadır. Atık yönetim sistemlerini iyileştirerek maliyet tasarrufu sağlama fırsatlarını belirlemelerine ve değerlendirmelerine yardımcı olmak için de kullanılmaktadır [24]. Yaşam döngüsü maliyet analizi ise bir ürünün tüm aşamalarında olası maliyetleri hesaplamak için yapılan analizdir ve yaşam döngüsü analizini destekleyen bir alt bölümdür [25].

Denizcilik alanında yaşam döngüsü analizi ile ilgili yapılan çalışmalar incelendiğinde; ticari ve askeri gemilerde, yeni gemi inşaatı, bakım, onarım ve operasyonu sırasında ortaya çıkan emisyon ve atıklar yaşam döngüsü analizi çerçevesinde yapılan çalışmalara rastlanmaktadır [26-29]. Bunun yanı sıra, gemi emisyonlarının azaltılması senaryoları, Energy Efficiency Operational Index (EEOI) hesaplamaları, IMO kurallarının için yaşam döngüsü analizi yönünden gerçekleştirilebilecek efektif atık yönetim modelinin belirlenmesi gibi çalışmalar da bulunmaktadır [30-32]. Ayrıca Türkiye, balast suyu yönetimi stratejisinin geliştirilmesine yönelik Bilimsel ve Teknolojik Araştırma Kurumu tarafından ortaklaşa yürütülen 1 milyon dolarlık ulusal bir girişim başlatmıştır [33].

Yaşam döngüsü maliyet analizinin temel amacı, sistemi satın alan kişilerin/kurumların ürün maliyetlendirmesine ilişkin risk ve belirsizlikleri en aza indirmektir. Daha önce yapılan çalışmalar, yaşam döngüsü analizi yapılarak endüstriyel ürünlerin üretim ve sonrası maliyetlerinin %80 gibi büyük bir bölümünün üretim öncesi alınacak kararlarla kontrol edilebileceğini belirtmektedir [34]. Yaşam döngüsü maliyet analizinde yapılacak adımlar sırasıyla maliyet unsurlarının belirlenmesi, kullanılacak maliyet yapısının şekillendirilmesi, maliyet tahmin ilişkilerinin kurulması ve formülasyon metodunun oluşturulması ile oluşur [35]. Tanımlanan maliyet yapısının şekli yaşam döngüsü maliyet analizinde kullanılan ürüne, analizin derinliğine ve genişliğine bağlıdır.

Kuru yük gemisi A için ticari ömür yaklaşık 30 yıl olarak kabul edilmiştir. Kuru yük gemisi A'nın yapımı 2009 yılında tamamlanmıştır. Böylelikle yaklaşık 20 senelik bir kullanım ömrünün kaldığı söylenebilir. Geminin öngörülen kullanım ömrüne göre balast suyu arıtma sisteminin yaşam döngüsü maliyet analizi yapılırken 20 senelik verilere göre incelenmiştir.

6.1. Yatırım Maliyeti

Balast suyu arıtma sisteminin yaşam döngüsü maliyetleri arasında en büyük yeri kaplayan maliyettir. Balast suyu arıtma sistemi entegrasyonu için yatırım maliyetlerini (C_Y) 3'e ayırabiliriz. Bunlar; ürün maliyeti ($C_Ü$), entegrasyon maliyeti (C_E), başlangıç lojistik maliyetidir (C_L). Ürün maliyeti, sistemin kendisine harcanan paradır. Entegrasyon maliyeti ise balast suyu arıtma sisteminin entegrasyonu ve entegrasyonu sırasında çıkan revizyonları karşılayacak maliyettir. Başlangıç lojistik maliyeti sistemin kurulumunun yapılacağı konuma sistemin taşınması için gerekli maliyettir. Fakat bu maliyet sistem tedariki yapan firma tarafından karşılanmıştır. Sistemin satın alındığı firma tarafından böyle bir hizmet sağlanmıyorsa lojistik maliyeti de analize dahil edilmelidir. Referans 34'de ve North Atlantic Treaty Organization (NATO) teknik raporunda [36] kullanılan yaşam döngüsü maliyet hesaplama yöntemleri, balast suyu arıtma sistemi için uyarlanmıştır. Modifiye edilmiş yatırım maliyeti hesabı Denklem 1'de gösterilmiştir. Tablo 4'te yatırım maliyeti hesaplanmıştır.

$$C_Y = C_Ü + C_E + C_L \qquad (1)$$

Tablo 4. *Yatırım Maliyeti*

Yatırım Maliyeti [€]	Üretim Maliyeti (€)	Entegrasyon Maliyeti (€)	Başlangıç Lojistik Maliyeti (€)
140000	135000	5000	-

6.2. Sistem Entegrasyonu Araştırma ve Geliştirme Maliyeti

Sistemin entegrasyonun yapılabilmesi için gerekli olup, alınan mühendislik bilgilerini ve dizayn maliyetlerini içerir. Balast suyu arıtma sistemi entegrasyonu için araştırma ve geliştirme maliyeti (C_A) ikiye ayrılır. Bunlar; dizayn maliyeti (C_D) ve 3D tarama maliyetidir (C_T). Dizayn maliyeti, sistemin kurulumu için gerekli mühendislik bilgileri ve sistemi gemiye uygun entegre edebilmek için yapılacak olan dizayn çalışmasında kullanılan maliyettir. Tarama maliyeti ise, sistemin mahale uygun dizaynının yapılabilmesi adına yapılan 3D tarama ile mahalin modelinin oluşturulması için gerekli maliyettir. Denklem 2'de araştırma ve geliştirme maliyeti gösterilmiştir. Tablo 5'te araştırma ve geliştirme maliyeti hesaplanmıştır.

$$C_A = C_D + C_T \quad (2)$$

Tablo 5. *Araştırma ve Geliştirme Maliyeti*

Araştırma ve Geliştirme Maliyeti (€)	Dizayn Maliyeti (€)	Tarama Maliyeti (€)
15500	13500	2000

6.3. Kullanım ve İdame Maliyeti

Sistemin operasyon giderleri, kullanım düzeyine göre değişiklik göstermektedir. Balast suyu arıtma sistemi kullanım ve idame maliyeti ($C_{Kİ}$), UV lambaları enerji maliyeti (C_{LAMP}) ve CIP modülü sıvısı maliyeti (C_{CIP}) olarak ikiye ayrılmaktadır. Avrupa Merkez Bankasının verileri [37] kullanılarak sistem ve gemi bilgilerine göre sistemin 20 yıllık eskalasyona tabi tutulmuş operasyon enerji maliyeti hesaplanmıştır. Tablo 6'da UV lambaları enerji maliyeti hesaplamaları gösterilmiştir.

CIP modülü diğer balast suyu arıtma sistemi ekipmanlarını arıtma sonunda kendi sıvısı ile temizler. CIP modülü sıvısı yıllık gideri 75 €'dur. Denklem 3'te kullanım ve idame maliyeti gösterilmiştir. Tablo 7'de kullanım ve idame maliyeti hesaplanmıştır.

$$C_{Kİ} = C_{LAMP} + C_{CIP} \quad (3)$$

Tablo 6. *UV Lambaları Enerji Maliyeti*

Açıklama	Değer	Yıllık	5 Yıllık	10 yıllık	15 yıllık	20 yıllık
Sistem Kapasitesi	500 m^3/s					
Kullanılan Toplam Balast Suyu Arıtma Sistemi	1					
Gemi Balast Kapasitesi	9.500 m^3					
Sistemin Balast Tanklarını Doldurma Süresi	19 s					
Operasyon İçin Gerekli Güç	70,55 kW					
Yakıt Fiyatı (Şubat 2019)	390 €/t					
Balast Alım Boşaltım Sayısı		23	115	230	345	460
Balast Suyu Alma Süresi (s)		437	2.185	4.370	6.555	8.740
Balast Suyu Boşaltma Süresi (s)		437	2.185	4.370	6.555	8.740
Toplam Balast Suyu Arıtma Operasyon Süresi (s)		874	4.370	8.740	13.110	17.480
Operasyon İçin Gerekli Toplam Enerji (kWs)		61.660	308.300	616.600	924.900	1.233.200
Toplam Balast Suyu Arıtma Operasyon Fiyatı (€)		4.580	24.315	52.504	85.183	123.066

Tablo 7. *Kullanım ve İdame Maliyeti*

Süre	Kullanım ve İdame Maliyeti (€)	UV Lambaları Enerji Maliyeti (€)	CIP Modülü Sıvısı Maliyeti (€)
1. Yıl	4.655	4.580	75
5. Yıl	24.713	24.315	398
10. Yıl	53.363	52.504	859
15. Yıl	86.577	85.183	1.394
20. Yıl	125.081	123.066	2.015

6.4. Tamir ve Yedek Parça Maliyeti

Bakım onarım sırasında ihtiyaç duyulan ya da düzenli olarak değiştirilmesi gereken ekipman parçalarının maliyetidir. Balast suyu arıtma sistemi için tamir ve yedek parça maliyetleri (C_{TY}) UV lambaları değişimi maliyeti (C_{UV}), filtre bakım seti maliyeti (C_{FB}), CIP modülü pompası yedek seti maliyeti (C_{CIPP}), UV sensör maliyeti (C_{UVS}) ve filtre değişimi maliyeti (C_F)'dir. Avrupa Merkez Bankasının verileri kullanılarak sistem ve gemi bilgilerine göre sistemin 20 yıllık eskalasyona tabi tutulmuş tamir ve yedek parça maliyetleri hesaplanmıştır. Tablo 8'de tamir ve yedek parça maliyetleri hesaplanmıştır. Denklem 4'te tamir ve yedek parça maliyetleri gösterilmiştir.

$$C_{TY} = C_{UV} + C_{FB} + C_{CIPP} + C_{UVS} + C_F \quad (4)$$

Yapılan çalışmalar European Maritime Safety Agency (EMSA) balast suyu arıtma çalışmalarına ve standartlarına uygundur [38].

Kuru yük gemisi A'ya UV+filtreleme sisteminin kurulumu sırasında ve yaşam döngüsü boyunca ortaya çıkabilecek maliyetler tanımlanmıştır. Yatırım maliyeti ile araştırma ve geliştirme maliyeti ürünün yaşam döngüsü sırasında tek olmasına rağmen, kullanım ve idame maliyeti ile tamir ve yedek parça maliyetleri ürünün yaşam döngüsü boyunca beklenmedik ya da düzenli olan giderlerden oluşmaktadır. Bununla birlikte 20 yıl içerisinde kullanım

Tablo 8. *Tamir ve Yedek Parça Maliyetleri*

Yıllar	Tamir ve Yedek Parça Maliyeti (€)	UV Lambaları Değişimi Maliyeti (€)	Filtre Bakım Seti Maliyeti (€)	CIP Pompası Yedek Seti Maliyeti (€)	UV Sensör Maliyeti (€)	Filtre Maliyeti (€)
1	-	-	-	-	-	-
2	1.394	-	831	-	563	-
3	2.682	-	856	1.246	580	-
4	1.478	-	881	-	597	-
5	2.845	-	908	1.322	615	-
6	7.455	5.886	935	-	634	-
7	3.019	-	963	1.403	653	-
8	19.959	-	992	-	672	18.295
9	3.202	-	1.022	1.488	692	-
10	1.765	-	1.052	-	713	-
11	10.222	6.824	1.084	1.579	735	-
12	1.874	-	1.117	-	757	-
13	3.604	-	1.150	1.675	779	-
14	1.988	-	1.185	-	803	-
15	26.324	-	1.220	1.777	827	22.500
16	10.020	7.911	1.257	-	852	-
17	4.056	-	1.294	1.885	877	-
18	2.237	-	1.333	-	904	-
19	4.304	-	1.373	2.000	931	-
20	2.374	-	1.415	-	959	-

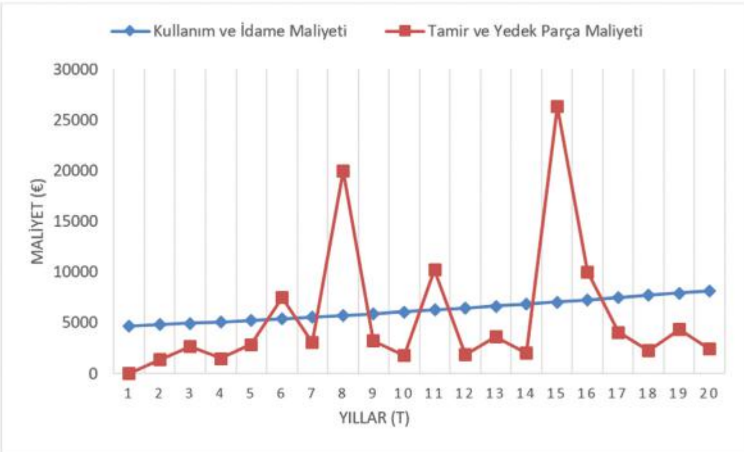
ve idame maliyeti ile tamir ve yedek parça maliyetinin toplamı yatırım maliyetini geçtiği görülmektedir.

Entegrasyonu yapılacak sistemin yaşam döngüsü maliyet analizi ile yaşam döngüsü sırasında ortaya çıkabilecek maliyetlerin zamana göre incelemesi yapılmıştır. Sistemin 20 yıllık yaşam döngüsü maliyetleri Tablo 9'da gösterilmiştir.

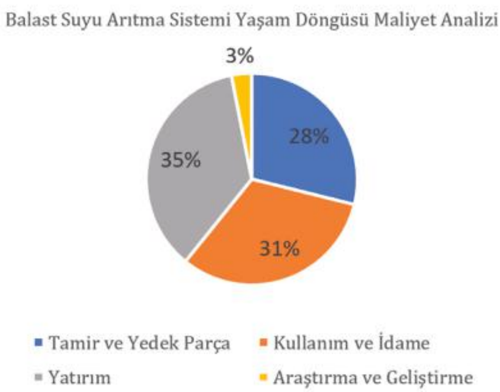
Şekil 5'te balast suyu arıtma sisteminin yaşam döngüsü boyunca kullanım ve idame maliyeti ile tamir ve yedek parça maliyetinin karşılaştırılması, Şekil 6'da ise balast suyu arıtma sistemine yaşam döngüsü boyunca harcanan giderlerin karşılaştırılması verilmektedir.

***Tablo 9.** Yaşam Döngüsü Maliyetleri*

Maliyet tanımı	Yaklaşık Maliyet (€)
Yatırım	140.000
Araştırma ve Geliştirme	15.500
Kullanım ve İdame	123.000
Tamir ve Yedek Parça	110.800
Toplam	389.300



***Şekil 5**. Sistem Maliyetleri Kırılımı*



***Şekil 6.** Yaşam Döngüsü Maliyetlerinin Karşılaştırılması*

7. Sonuç ve Öneriler

Gemiler gemi stabilitesini sağlama, pervanenin suda bulunduğu konumu ayarlayarak sevk sisteminden alınan verimi arttırma ve tekne üzerindeki gerilmeleri azaltma gibi sebeplerden dolayı balast suyu alırlar; fakat gemilerin balast suyunu bir ekosistemden alıp başka bir ekosisteme boşaltması olumsuz sonuçlar doğurmaktadır. Balast suyu ile taşınan organizmalar gittikleri bölgelerde çoğalma şansı bulduklarında istilacı tür olabilmektedir. İstilacı türler taşındıkları ekosistemde ekolojiye, ekonomiye ve insan sağlığına yönelik olumsuz etkilerde bulunmaktadır. Gemi inşa ve denizcilik sektörü incelendiğinde gemi yaşam döngüsü analiziyle ilgili çalışmalara yeni yeni rastlanmaktadır. Bu çalışmada özellikle geminin yaşam döngüsü analizinden çok gemi sistemlerinin yaşam döngüsü analizine rastlanmaktadır. Bir geminin balast suyu sistemi yaşam döngüsü maliyet analiziyle ilgili yapılan bu çalışmanın diğer çalışmalara ışık tutması beklenmektedir.

IMO Gemi Balast Suları ve Sediment Kontrolü ve Yönetimi Uluslararası Sözleşmesi gereğince kuru yük gemisi A için balast suyu arıtım sistemi entegrasyonu kriterleri oluşturulmuş ve sistemin yaşam döngüsü maliyet yönetimi hesaplanmıştır. Ayrıca çalışmada ürünün yaşam döngüsü maliyetleriyle ilgili risk ve belirsizlikler tanımlanmıştır. 20 yıllık yaşam döngüsü maliyet analizinde yatırım maliyetinin % 35, tamir ve yedek parça maliyetinin % 28, kullanım ve idame maliyetinin % 31 ve sistem entegrasyonu araştırma ve geliştirme maliyetinin % 3 olduğu görülmektedir. Bundan sonra yapılacak çalışmalarda balast suyu arıtma sistemlerinin tüm bileşenlerini kapsayacak şekilde, yaşam döngüsü ve maliyetleri analizi yönünden kullanım, geri kazanım ve yeniden üretim seçenekleri değerlendirilmelidir. Bu sayede ömür boyu sistem giderleri minimuma indirilebilir. Yapılacak detaylı çalışmalarla geminin ve bütün alt sistemlerinin yaşam döngüsü maliyet analizlerinin yapılması gelecekte son derece önemli hale gelecektir.

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Corresponding Author: Ali DOĞRUL

Hydrodynamic Investigation of a Submarine Moving Under Free Surface

Ali DOĞRUL

Yıldız Technical University, Naval Architecture and Maritime Faculty, Turkey
adogrul@yildiz.edu.tr; ORCID ID: https://orcid.org/0000-0003-3236-555X

Abstract

Submerged bodies are commonly used in many fields such as scientific researches, military and commercial applications. Especially in military applications, submarines have a significant role as a silent and deterrent vehicle. Contrary to popular belief, submerged bodies also operate in shallow depth that free surface effects come into play. This causes the visual identification of submarines while protecting them from sonar detection. This study focuses on the investigation of free surface effects on submarine hydrodynamics moving forward in different depths. The numerical calculations have been conducted at different Reynolds numbers ranging from 1.5x10^7 to 3.5x10^7 for both bare and appended forms of DARPA Suboff. A commercial CFD solver has been used to solve URANS equations with k-ε turbulence model. The numerical approach has first been verified and validated with the available experimental data. Later, the numerical results have been discussed in terms of total resistance, resistance components and free surface deformations. It has been concluded that the submergence depth has a significant role on resistance components for depth Froude number larger than 0.7 and the appendages have little effect on free surface deformations in all depths.

Keywords: *Appendage, CFD, DARPA, Free Surface, Resistance.*

Serbest Yüzey Altında İlerleyen Bir Denizaltının Hidrodinamik Açıdan İncelenmesi

Öz

Batmış cisimler araştırma, askeri ve ticari uygulamalar gibi pek çok alanda yaygın bir şekilde kullanılmaktadır. Özellikle askeri uygulamalarda denizaltılar sessiz ve caydırıcı bir araç olarak önemli bir role sahiptir. Sanılanın aksine, batmış cisimler serbest yüzey etkilerinin devreye girdiği sığ derinlikte de çalışmaktadır. Bu durum denizaltıları sonar tespitinden korurken görsel olarak tespit edilmelerine sebep olmaktadır. Bu çalışma farklı derinliklerde ilerleyen denizaltının hidrodinamiğine serbest yüzey etkilerinin incelenmesine odaklanmaktadır. Sayısal hesaplamalar 1.5x10^7 ile 3.5x10^7 arasındaki Reynolds sayılarında takıntısız ve takıntılı DARPA denizaltısı için yapılmıştır. Ticari bir yazılım yardımıyla URANS denklemleri k-ε türbülans modeli kullanılarak çözülmüştür. Sayısal yöntem ilk önce eldeki deneysel veri ile doğrulanıp onaylanmıştır. Daha sonra sayısal sonuçlar, toplam direnç, direnç bileşenleri ve serbest yüzey deformasyonları açısından değerlendirilmiştir. Sonuç olarak derinlik Froude sayısının 0.7'den büyük olduğu durumlarda derinliğin dirence önemli bir etkisinin olduğu ve tüm derinliklerde takıntının serbest yüzey deformasyonuna etkisinin çok az olduğu görülmüştür.

Anahtar Kelimeler: *Takıntı, HAD, DARPA, Serbest Yüzey, Direnç.*

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1. Introduction

Nowadays submerged bodies are widely used in various fields. Autonomous underwater vehicles (AUV) are preferred for scientific research in deep seas while swimmer delivery vehicles (SDV) are operated by navy seals for sneak operations. Modern navies contain submarines for several military operations. Another submerged body is the torpedo which is the lethal weapon of the naval battles. This is why researchers study submerged bodies in many aspects.

The prediction of the hydrodynamic performance of submerged bodies is crucial by means of total resistance and effective power. While doing this, it has to be considered that submerged bodies operate not only as totally submerged but also near free surface. Especially the naval submarines can operate near free surface because sonar detection becomes difficult near free surface. In addition, torpedoes operate near free surface because the draft of the target vessel is relatively small. Therefore, special attention has to be given to the submarine hydrodynamics when it is moving close to the free surface. Because the resistance components of a submerged body are similar to a surface ship when operating in shallow depths. The contribution of the resistance components on the total resistance depends on the hull geometry, velocity and proximity to the free surface [1].

In recent years, several studies have been made by researchers about submarine hydrodynamics. Some of them are based on resistance estimation while the rest are focused on self-propulsion characteristics of submerged bodies. A few studies have been made about submerged body hydrodynamics operating near free surface.

Fundamental studies for designing a benchmark submerged body have been made by Groves et al. [2]. They have described a mathematical formulation for DARPA Suboff form both for bare and appended cases. Huang et al. [3] and Liu et al. [4] have conducted several experiments in order to estimate the total resistance of DARPA Suboff model. Well-known DARPA Suboff bare hull (AFF-1) and appended hull (AFF-8) have been investigated by Chase in terms of total resistance and propeller performance both numerically and experimentally [5]. Chase and Carrica [6] have investigated DARPA Suboff AFF-8 model in order to observe the self-propulsion characteristics using INSEAN E1619 model propeller with a RANS solver. Posa et al. [7] have also investigated resistance and propulsion performance of DARPA Suboff model using different turbulence models. There are other studies on submerged body-propeller interaction by means of resistance components and propulsion characteristics [8–11].

The studies mentioned above are made for the condition that the submarine is totally submerged which means that the free surface effects are neglected. Few studies have been made for DARPA Suboff model operating in the depths which free surface effects are significant. Wilson-Haffenden et al. [12] have studied wavemaking resistance of a submarine travelling below the free surface. They have conducted towing experiments for bare form of DARPA Suboff (AFF-1) and calculated total resistance and resistance components such as frictional and residual resistance for different depths in shallow water condition. After that, they have compared the experimental results with CFD simulation results.

Dawson [13] have studied experimental and numerical investigation of submarine hydrodynamics for different velocities and depths. He has focused on the total resistance of Joubert conventional submarine and DARPA Suboff model. He has especially conducted experiments in near free surface depths and compared the results with numerical results based on potential flow theory.

Nematollahi et al. [14] have made a numerical investigation of an underwater vehicle (UWV) and searched the relation between submergence depth and total resistance for different velocities. They have also observed the wake structure behind the submerged body for different depths.

Vali et al. [15] have conducted resistance experiments for a model scale attack submarine in submergence and surface conditions. They have compared the experimental results with the numerical ones based on a RANS solver. They have also estimated the required power for all conditions.

Amiri et al. [16] have focused on the effect of shallow depth on submarine hydrodynamics using CFD method. They have conducted numerical analyses for DARPA Suboff AFF-1 bare form and compared the numerical results with the experimental data in terms of total resistance. They have calculated lift and moment coefficients of the submerged body for different depths.

A recent study has been made by Shariati et al. [17]. The authors have mentioned the significance of the detection of submerged bodies moving near free surface. They have proposed a procedure for the identification of underwater vehicles by observing the free surface deformations along the submerged body. They have estimated the vehicle's velocity and depth with the help of wavelength and wave amplitude.

In this paper, it is aimed to investigate the effect of submergence depth on total resistance, resistance components and free surface deformation of DARPA Suboff submarine model. Both AFF-1 and AFF-8 models have been analyzed in order to show the effect of appendage on submarine hydrodynamics. The numerical analyses have been carried out for different depth Froude numbers that covers a depth range between sub-critical and super-critical conditions in terms of wave making resistance. RANS equations have been discretized using a commercial CFD solver with k-ε turbulence model. The numerical method has been verified for submerged condition with also modelling free surface. After that, the method has been validated with the available experimental data. It has been concluded that the submergence depth has a significant role on resistance components for depth Froude number larger than 0.7 and the appendages have little effect on free surface deformations in all depths.

2. Mathematical Background

2.1. Governing Equations

For incompressible and turbulent flows, the continuity equation and momentum equations are given in Cartesian coordinates as below:

$$\frac{\partial U_i}{\partial x_i} = 0 \tag{1}$$

$$\frac{\partial U_i}{\partial t} + \frac{\partial (U_i U_j)}{\partial x_j} = -\frac{1}{\rho}\frac{\partial P}{\partial x_i} + \frac{\partial}{\partial x_j}\left[\nu\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right)\right] - \frac{\partial \overline{u_i' u_j'}}{\partial x_j} \tag{2}$$

Here, P is the mean pressure, *p* the density and *v* the kinematic viscosity of the fluid. U_i velocity can be divided into two components; mean velocity and fluctuating, respectively.

$$U_i = \overline{U_i} + u_i' \tag{3}$$

Turbulent flow around the submarine is simulated using k-ε turbulence model that is widely used in ship hydrodynamics field. The last term of the momentum equation is the Reynolds stress tensor, which is given below:

$$\overline{u_i' u_j'} = -\nu_t\left(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{\partial x_i}\right) + \frac{2}{3}\delta_{ij} k \tag{4}$$

Detailed information about the turbulence model can be found in Wilcox [18].

2.2. Uncertainty Assessment

Estimation of numerical uncertainty was first introduced by Richardson [19] for a dam stress problem. In recent years, several methods have been proposed by many researchers. Besides, Grid Convergence Index method has been recommended by ITTC [20] in ship hydrodynamics problems as a verification procedure. The GCI method was first proposed by Roache [21], later further developed by Celik et al. [22]. Numerical uncertainty is mainly caused by grid spacing, time step size and iteration [23].

In this study, the GCI method was employed to calculate the uncertainty for grid spacing. Background of the procedure is briefly explained below:

$$r_{21} = \frac{h_2}{h_1} \qquad r_{32} = \frac{h_3}{h_2} \tag{5}$$

Refinement factor represents the ratio of two grid sets, which should be greater than 1.3 according to the method of Celik et al. [22]. The refinement factor has been chosen as √2 which is also used in recent studies [11, 24]. Three different cases having different grid numbers are created. In this case, refinement factors are calculated by proportioning the total grid numbers.

$$r_{21} = \left(\frac{N_1}{N_2}\right)^{1/3} \qquad r_{32} = \left(\frac{N_2}{N_3}\right)^{1/3} \tag{6}$$

After checking the refinement factor, the difference between the numerical results is used for calculating the grid convergence condition (R).

$$\varepsilon_{21} = X_2 - X_1 \qquad \varepsilon_{32} = X_3 - X_2 \tag{7}$$

$$R = \frac{\varepsilon_{21}}{\varepsilon_{32}} \tag{8}$$

The value of R determines whether the solution is monotonically convergent (0<R<1) or it has an oscillating convergence (-1<R<0) [25].

3. Numerical Method

3.1. Main Particulars

DARPA Suboff model submarine has been used as a benchmark case. The geometrical properties and the experimental resistance data can be found in the literature [2]–[4]. Figure 1 shows 3-D view of the submarine models AFF-1 and AFF-8. The geometrical properties of DARPA Suboff models can be seen in Table 1.

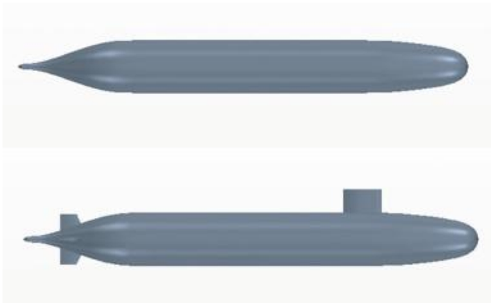


Figure 1. *3-D view of AFF-1 and AFF-8 submarine models*

Table 1. *Geometrical properties of DARPA Suboff [2]*

	AFF-1	AFF-8
λ	24	24
L_{OA} (m)	4.356	4.356
L_{PP} (m)	4.261	4.261
D_{max} (m)	0.508	0.508
S (m^2)	5.989	6.348
∇ (m^3)	0.699	0.706

3.2. Mesh Generation

According to the numerical method, the governing equations are discretized and solved via finite volume method. For this reason, a three dimensional computational domain has been created consisting of finite volume elements. Commercial CFD software STAR-CCM+ has been used for mesh generation and flow simulations. This software offers a trimmer mesh algorithm that provides fully hexahedral meshing in the computational domain.

Prism layers have been created near submarine hull in order to model the flow inside the boundary layer. Some mesh refinements in bow and stern regions have been created to represent the submarine hull surface precisely. In addition, denser mesh has been used in the wake zone for modeling the wake field in the downstream. Special care has been given to the mesh structure near and on the free surface. Mesh refinements have been made to well capture the free surface deformations. Local mesh refinements around the submarine hull can be seen in Figure 2.

Figure 3 shows the wall y+ distribution on the surface of AFF-1 and AFF-8 geometries for V=3.0452 m/s and 3.051 m/s at depth Froude number of 0.7. The wall y+ values are kept between 30-300.

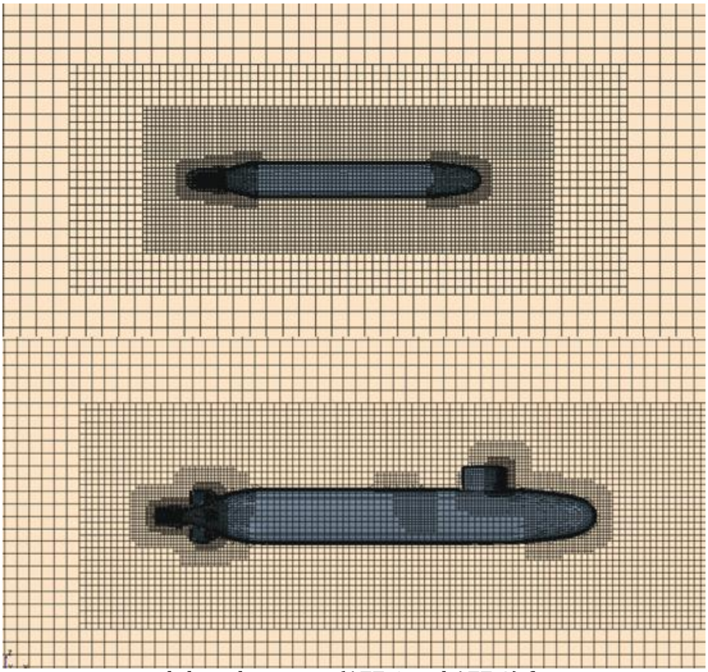


Figure 2. *Mesh structure around the submarines (AFF-1 and AFF-8) from a cross-sectional view*

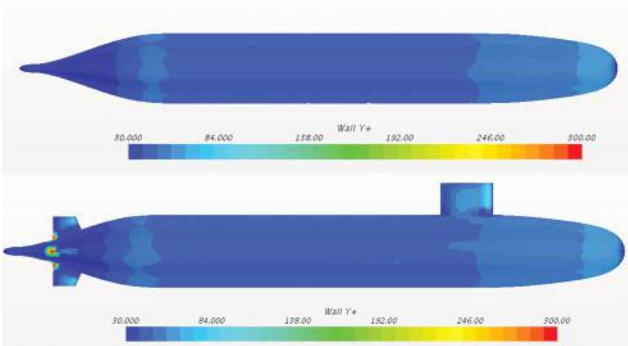


Figure 3. *Wall y+ distribution on the surface of AFF-1 and AFF-8 geometries*

3.3. Physics Modelling

The dimensions of the computational domain and the boundary conditions applied on the surfaces are of great importance. The size of the domain has been determined in accordance with the recommended guideline of ITTC [26]. The distance in the upstream is $1.5L_{pp}$ while in downstream it is $5L_{pp}$. The distance in up and bottom directions are to be $2L_{pp}$ and the transverse distance is chosen as $2L_{pp}$.

Correctness of boundary conditions defines the accuracy of the numerical method and computational time needed for solution. Proper boundary conditions have been applied on the submarine and domain surfaces in order to eliminate the effect of the domain boundaries [27]. The surface in the positive x direction is defined as velocity inlet and the surface in the opposite direction is defined as pressure outlet. The surrounding surfaces are chosen as symmetry plane that dictates the normal component of the velocity is zero, so the wall effects from these surfaces can be eliminated. The submarine surface is defined as no-slip wall which means that all velocity components (so the total velocity) are to be zero. Figure 4 shows the computational domain and the boundary conditions applied on the surfaces. Detailed information about the boundary conditions can be found in the user guide of the CFD software [28].

In this study, turbulent flow around DARPA Suboff model has been solved using standard k-ε turbulence model, which has been widely used for ship hydrodynamics. Querard et al. [29] have stated that standard k-ε turbulence model is useful by means of computational time when compared with similar models. Standard k-ε turbulence model has been used in many recent studies such as Liu et al. [30], Nematollahi et al. [14], Shariati et al. [31], Shariati et al. [17] and Sezen et al. [11].

To simulate the free surface flow of DARPA Suboff model, Volume of Fluid (VOF) method has been employed and a flat wave has been modeled at a desired depth. VOF method solves the position of the free surface instantly and calculates the volume fraction of each cell whether it is filled with water and/or air. In this study, the submarine model has been considered as submerged in all cases, however free surface effects are taken into account by using VOF method.

Since the simulations have been conducted in an unsteady manner, choice of time step is crucial for a time-effective analysis. For implicit unsteady simulations, ITTC [26] recommends the time step as $\Delta t=0.005 \sim 0.01$ L/U for calm water resistance estimation, where L is the ship length and U is the ship speed. In this paper, time step size has been chosen as $\Delta t=0.015$ seconds that satisfies this recommendation.

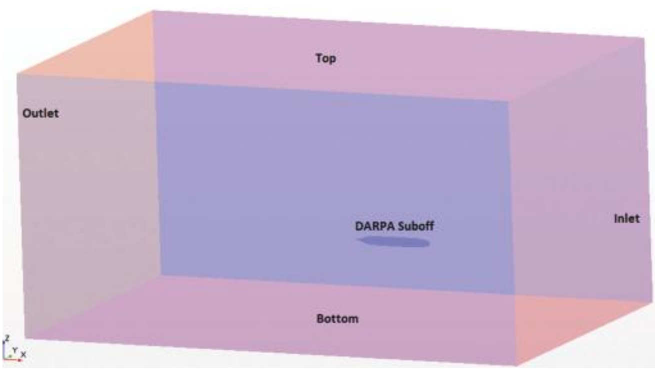


Figure 4. *Computational domain and the boundary conditions*

Convergence of the analysis has been checked in terms of both numerical residual-time history and total resistance. The methodology followed is shown in Figure 5.

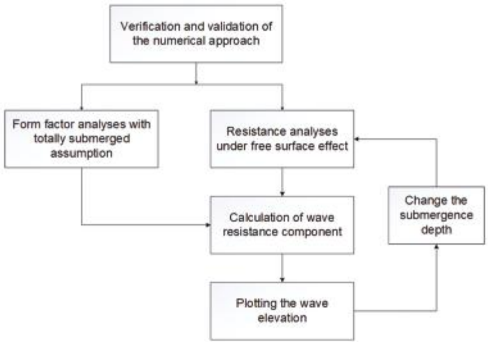


Figure 5. *The methodology followed in this study*

4. Results and Discussions

DARPA Suboff AFF-1 and AFF-8 models have been analyzed in totally submerged condition using different grid numbers. Verification study has been conducted to determine the optimum grid number for both geometries. Later, the numerical method has been validated with the available experimental data using the optimum grid number. Following these steps, the flow around submarine has been simulated at various depths and velocities to observe the effect of depth on resistance components and free surface deformations. In addition, appendage effect has been investigated.

4.1. Verification and Validation

An uncertainty study has been conducted for the verification of the numerical method used in this paper. Numerical uncertainty of grid number has been calculated by generating three different grid numbers by changing grid spacing with a proper refinement factor. Uncertainty for time step size has done for three different time step size using fine grid number. Uncertainty value has been calculated with Grid Convergence Index (GCI) method [22] for both bare (AFF-1) and appended (AFF-8) submarine models. Table 2 shows the generated grid numbers and time step sizes for the CFD method to be verified.

Table 2. *Grid numbers and time step sizes used in uncertainty assessment*

Grid type	AFF-1	AFF-8	Time step (s)
Fine	383965	509267	0.015
Medium	257379	335065	0.03
Coarse	188460	256319	0.06

The uncertainty study has been made for AFF-1 and AFF-8 forms for V=3.0452 m/s and V=3.051 m/s at a depth Froude number of 0.7 (Fn_h=0.7). Spatial (grid number) and temporal (time step) uncertainty analyses have been done using GCI method. According to the uncertainty analyses, fine mesh was chosen for both submarine models to be analyzed at various depths and velocities. Time step size was chosen as the fine one. The spatial uncertainty and convergence condition numbers are presented in Table 3. As can be seen from the table, grid structure for AFF-1 has an oscillating convergence while AFF-8 grid is monotonically convergent. Table 4 shows the temporal uncertainty and convergence condition numbers for AFF-1 and AFF-8 geometries. For both geometries, temporal uncertainty values are too low and the results show that both geometries have a monotonic convergence.

Table 3. *Spatial uncertainty analyses for AFF-1 and AFF-8*

	AFF-1	AFF-8
% GCI_{FINE}	0.21	0.58
R (Convergence condition)	-0.415	0.342

Table 4. *Temporal uncertainty analyses for AFF-1 and AFF-8*

	AFF-1	AFF-8
% GCI_{FINE}	0.002	0.008
R (Convergence condition)	0.056	0.124

The uncertainty study is made at Fn_h=0.7 because it is considered that there will be free surface effects at that depth. In addition to the uncertainty study under free surface effect, similar grid structure was used to simulate the flow around the submarine geometries at totally submerged. So the total resistance has been validated with available experimental data that was gained in totally submerged condition. With the help of the verification and validation study, the grid structure including free surface refinements has been verified and validated. Validation of CFD method with experimental data and the numerical results of the totally submerged condition in terms of total resistance can be seen in Table 5.

Table 5. *Validation of CFD method for AFF-1 and AFF-8*

	AFF-1	AFF-8
Experiment (Totally submerged) [N]	87.40	102.30
CFD (Totally submerged) [N]	86.47	104.70

4.2. Resistance Analyses

In order to calculate the total resistance and resistance components, the validation study is expanded for more ship velocities of which experimental results exist. For the calculation of wave resistance component, several analyses are conducted in totally submerged condition to calculate the form factor of the hull in each velocity. With the help of the form factor, wave resistance could be estimated for each ship. Figures 6 and 7 show the comparison of the numerical results of DARPA Suboff AFF-1 and AFF-8 with the available experimental results [4] and another numerical study [11].

Here, the total resistance consists of frictional resistance and viscous pressure resistance because the submarine is considered as totally submerged. By using the ITTC formula [32] for frictional resistance component, the form factor can

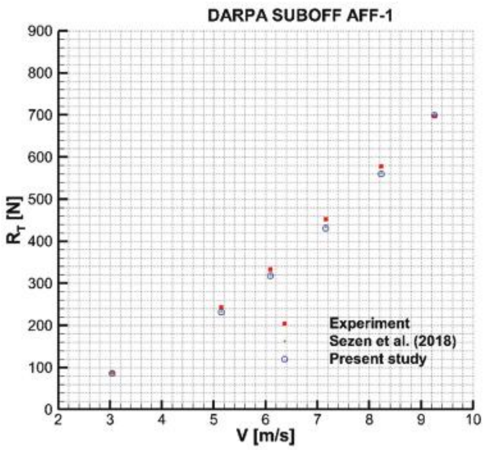


Figure 6. *Comparison of total resistance for DARPA Suboff AFF-1*

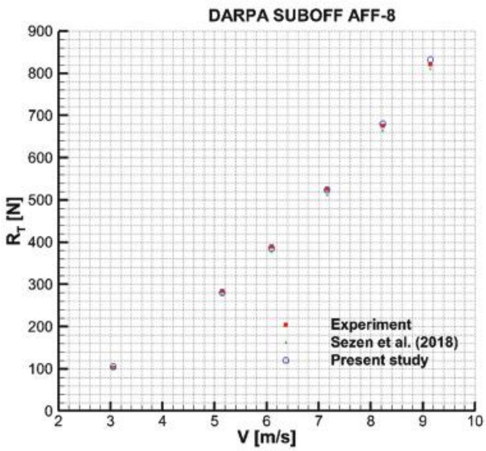


Figure 7. *Comparison of total resistance for DARPA Suboff AFF-8*

be derived at each velocity. The resistance components under free surface can be discretized as below [33]:

$$R_T = R_F + R_{VP} \tag{9}$$

$$C_F = \frac{0.075}{(\log Rn - 2)^2} \tag{10}$$

$$R_F = 0.5 \cdot \rho \cdot S \cdot V^2 \cdot C_F \tag{11}$$

$$k = \frac{R_{VP}}{R_F} \tag{12}$$

Figure 8 presents the calculated form factor for both bare hull (AFF-1) and appended hull (AFF-8). The rudders and the sail in AFF-8 model almost double the form factor, which influences the wave resistance component.

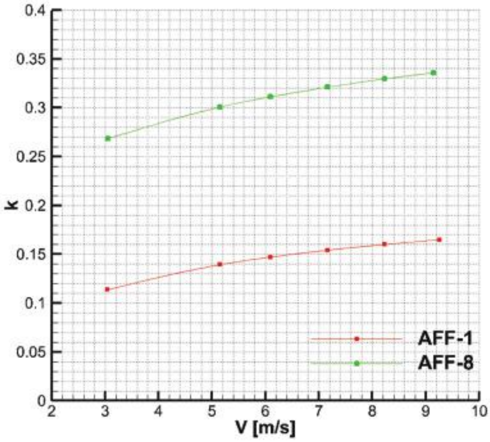


Figure 8. Form factor calculation for AFF-1 and AFF-8

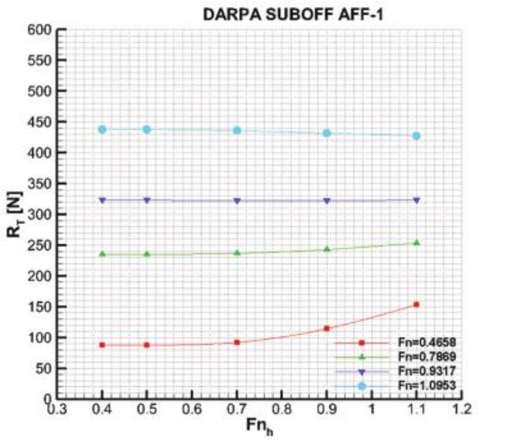
4.3. Free Surface Pattern

Behaviour of the total resistance at different depth Froude numbers are given in Figure 9. Depth Froude number is calculated as follows:

$$Fn_h = \frac{V}{\sqrt{g \cdot h}} \quad (13)$$

Here, V is the submarine velocity, h is the depth between the submarine centerline and the free surface level, and g is the acceleration of gravity which is taken as 9.81 m $/s^2$.

As can be seen from Figure 9, at slow speed, free surface affects the total resistance significantly, especially after a certain depth (Fn_h=0.7). The total resistance stays nearly the same at high speeds while the submergence depth increases. This behaviour is valid also for appended case. Figure 10 shows the wave resistance component for AFF-1 and AFF-8 submarine forms. The wave resistance component was calculated using the form factor at each velocity and submergence depth. As expected, only at slow speed, the wave resistance component rises with the increase in depth, so the total resistance also increases. Figure 11 shows the change on non-dimensional wave resistance coefficient with length Froude number (Fn) at different depths.



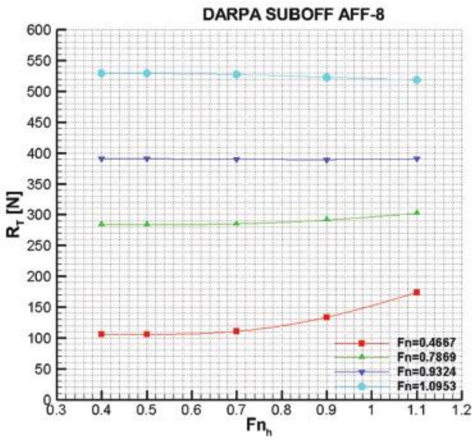


Figure 9. Total resistance of AFF-1 and AFF-8 at different depths

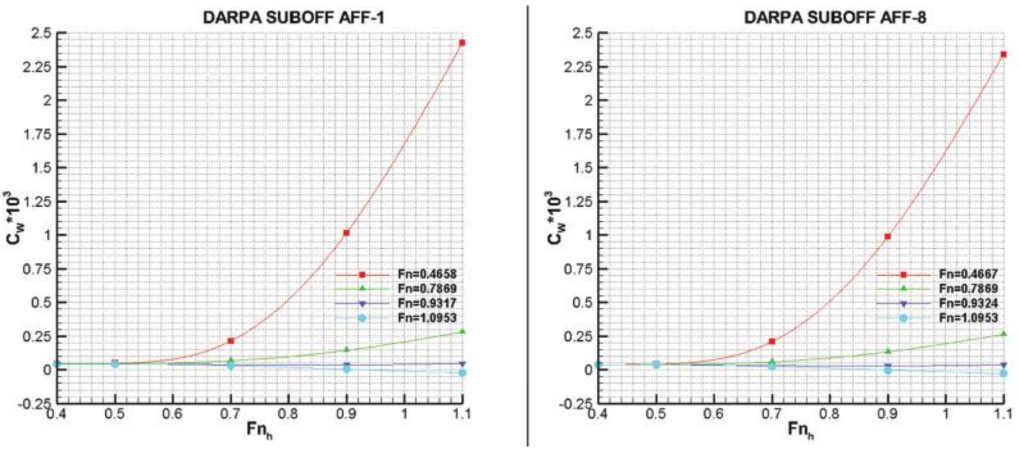


Figure 10. *Wave resistance coefficient of AFF-1 and AFF-8 at different depths*

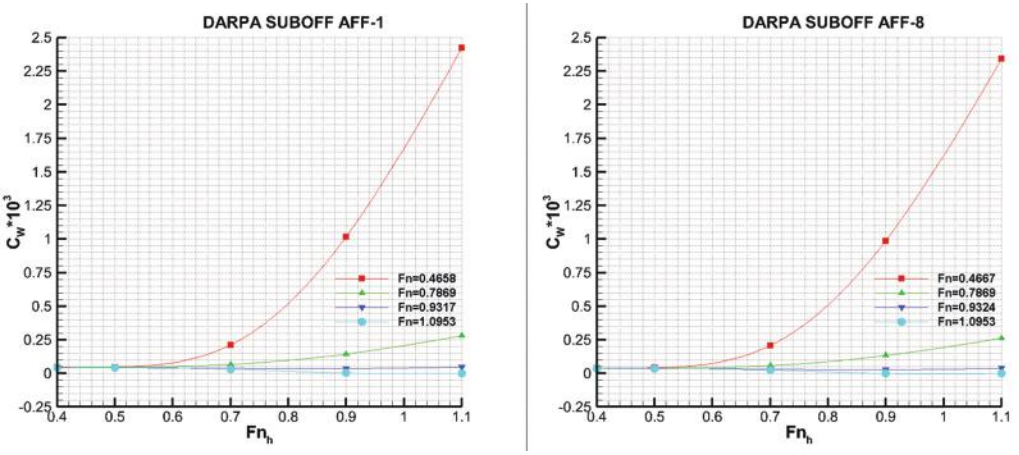


Figure 11. *Wave resistance coefficient of AFF-1 and AFF-8 at various submarine velocities*

Figure 12 shows the wave elevation contours on the free water surface at depth Froude number of 0.7 as sample cases. Detailed wave elevation results for each velocity and depth are given in the figures below.

Figure 13 and 14 show the free surface deformations in the submarine centerline level for low and high velocities, respectively. Figure 9 gives the wave profiles at V=3.0452 m/s for AFF-1 and V=3.051 m/s for AFF-8. It can be seen that the free surface starts to deform after Fnh=0.5 that leads to an increase in total resistance of AFF-1 and AFF-8 models. Figure 14 represents the relation between wave elevation and depth Froude number for AFF-1 and AFF-8 models at V=7.1604 m/s. Figure 14 shows that the free surface deformation slightly changes for high depth Froude numbers which means little increase in wave resistance and total resistance. Both figures also show that the appendages have nearly no effect on wave elevation for all submarine velocities.

One may see the free surface deformations for different velocities along the hull centerline in Figure 15. The free surface starts to deform with the increase in submarine velocity as expected. The wave crest shifts to the submarine stern in

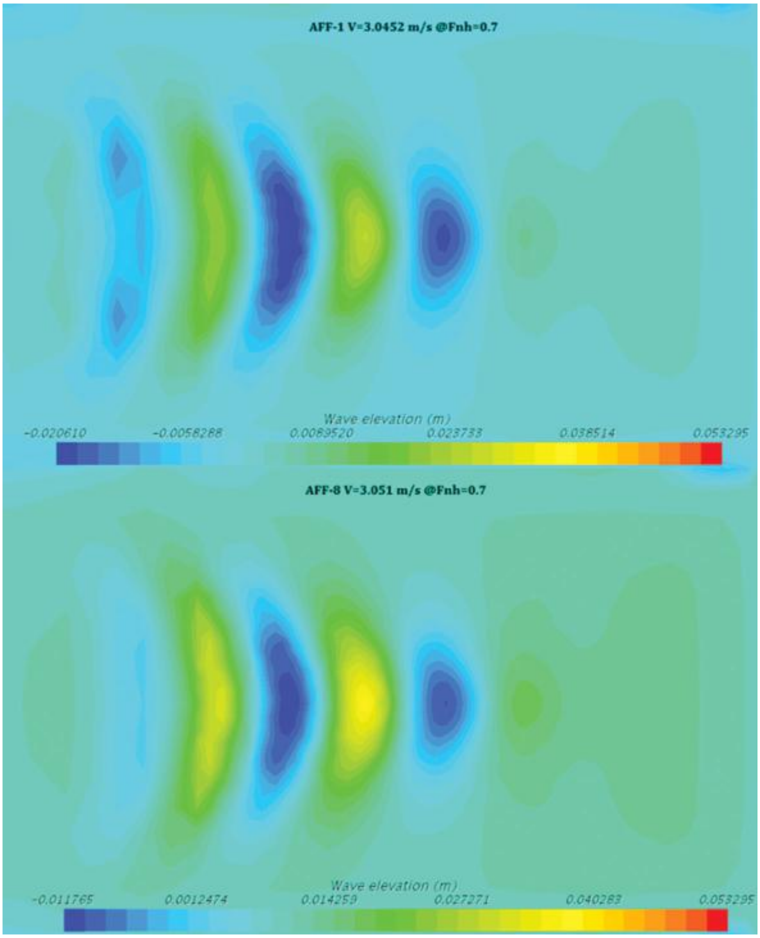


Figure 12. *Wave contours of AFF-1 and AFF-8 for V=3.0452 m/s and 3.051 m/s at Fn_h=0.7*

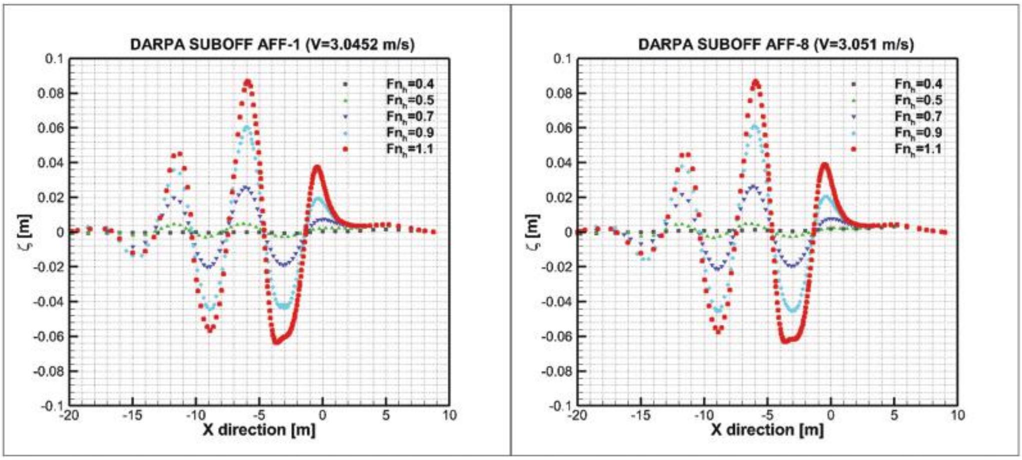


Figure 13. *Wave profile of AFF-1 and AFF-8 at V=3.0452 m/s and 3.051 m/s*

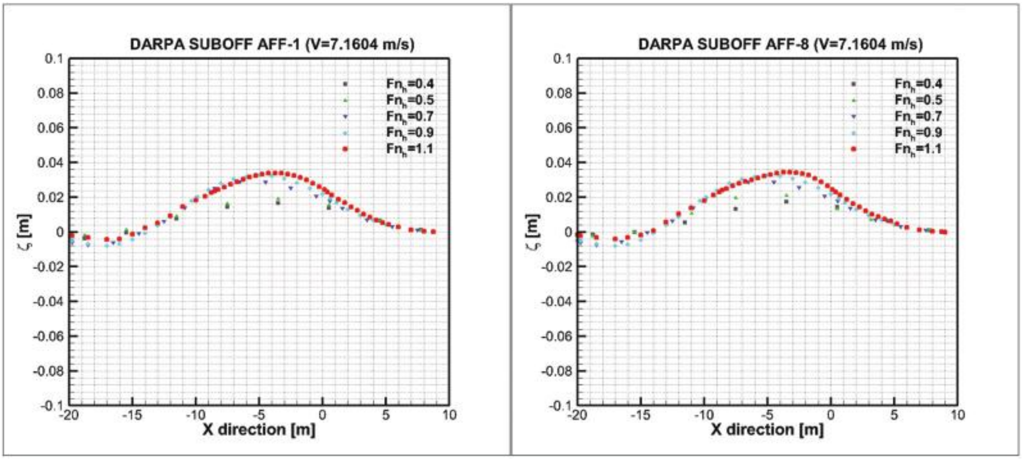


Figure 14. *Wave profile of AFF-1 and AFF-8 at V=7.1604 m/s*

high speeds in both depth Froude numbers (Fnh=0.4 and 1.1). With the increase in depth Froude number, wavelength shows a decrease while the position of the wave crest remains nearly same at slow velocity (V=3.051 m/s) that causes a significant rise in wave resistance and total resistance.

The results show that the contribution of wave resistance on the total resistance is higher at lower velocities when the submarine is very close to the free surface. So, the wave energy is higher which means higher wave heights. Because the energy carried by the waves is directly proportional with the square of the wave height.

5. Conclusion

This study focuses on the numerical prediction of hydrodynamic performance of a benchmark submarine model moving forward under free surface. Different submergence depths and ship velocities were investigated for both bare and appended submarine models. Effect of submergence depth and appendage on resistance components and wave elevation were studied for various ship velocities numerically.

The numerical method discretizing RANS equations were used which were verified and validated with the GCI method.

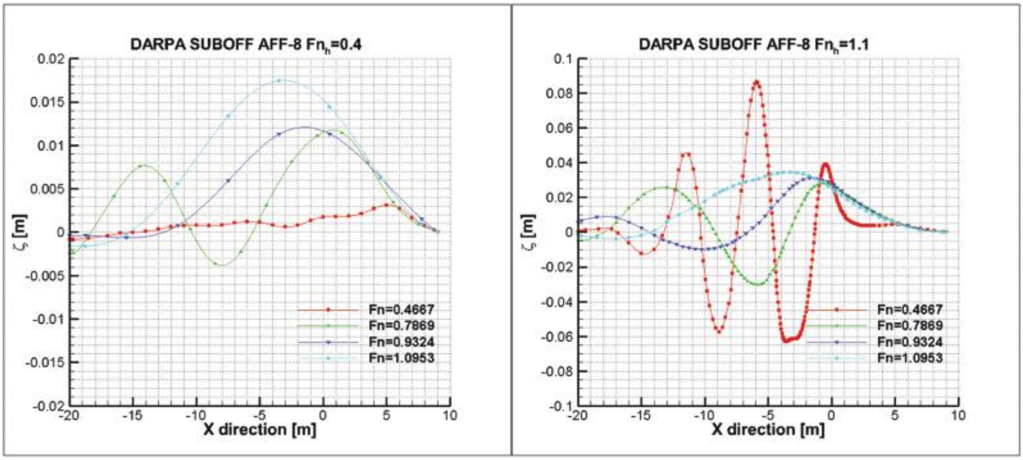


Figure 15. *Wave profile of AFF-8 at Fn_h=0.4 (left) and 1.1 (right) for different velocities*

The numerical results have been in good agreement with the available experimental data. Submergence depth was seen to change in a wide range including shallow depths that causes visual detection of the submarine under free surface.

For the cases in which depth Froude number is lower than 0.7, the submarine behaves like totally submerged that neglects the free surface effects. After Fn_h=0.7, free surface starts to be significant. In this case, free surface deformations can be observed clearly and total resistance shows an increase.

For slow speed (V=3.051 m/s), wave deformations change drastically while the submarine moves near free surface. This leads to a significant increase in total resistance and wave resistance of the submarine for both bare (AFF-1) and appended (AFF-8) geometries.

For high speeds (V>3.051 m/s), submarine total resistance remain nearly constant with the change in submergence depth. This means that the wave resistance remains constant at all depths.

Form factor of the model submarine was calculated with the analyses at totally submerged case. After that, wave resistance of the submarine at various cases were derived using the form factor. It is observed that the submarine appendages (sail and rudder fins) nearly double the form factor. However, the increase in the form factor and the viscous pressure compensates the increase in total resistance. Therefore, the wave resistance remains nearly constant in bare and appended submarine models.

Because of lack of experimental data in submarine hydrodynamics field, CFD can be used widely for parametric prediction of submarine hydrodynamics. Self-propulsion characteristics and motion response under free surface effects can be investigated numerically.

As a future work, self-propulsion characteristics of submerged bodies will be investigated under free surface effects. In addition, different appendage designs and configurations can be studied in terms of resistance and nominal wake field.

Nomenclature

$\overline{U}_i$	mean velocity component
u_i'	fluctuation velocity component
P	mean pressure
ρ	fluid density
k	turbulent kinetic energy
ε	turbulent dissipation rate
R	convergence condition
λ	scale factor
L_{OA}	length overall
L_{PP}	length between perpendiculars
Dmax	submarine maximum diameter
S	submarine wetted surface area
∇	submarine displacement
V	submarine velocity
R_T	total resistance
R_F	friction resistance
R_{VP}	viscous pressure resistance
C_F	non-dimensional friction resistance coefficient
k	form factor
h	submarine depth
Fn_h	depth Froude number
Fn	length Froude number
C_W	non-dimensional wave resistance coefficient
Fn	Froude number
ζ	wave elevation

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Corresponding Author: Ersin Fırat AKGÜL

A Qualitative Research on Ship Investments in Turkey

Ersin Fırat AKGÜL[1], İsmail Bilge ÇETİN[2]

[1]Bandırma Onyedi Eylül University, Maritime Faculty, Turkey
[2]Dokuz Eylül University, Maritime Faculty, Turkey
eakgul@bandirma.edu.tr; ORCID ID: https://orcid.org/0000-0002-2208-0502
ismail.cetin@deu.edu.tr; ORCID ID: https://orcid.org/0000-0002-4951-426X

Abstract
Ship investments including high amount of capital and high risk compared with other investment alternatives are important in the business life of a shipping firm. Therefore, comprehending dynamics on ship investments is essential. The motive of this study rests on this fact and it is aimed to determine the factors affecting ship investments of Turkish ship investors. In this context, a qualitative examination is employed to understand the nature of ship investments from the perspectives of professionals who have close relations with ship investors in Turkey and who are able to evaluate them in an objective manner. Findings reveals that market conditions and timing, payback period of the investment, technical features of the ship and profile, financing capacity and risk perception of investors have been identified as important criteria in ship investments in Turkey.

Keywords: *Ship Investments, Turkey, Ship Investors, Qualitative Research.*

Türkiye'deki Gemi Yatırımları Üzerine Nitel Bir Araştırma

Öz
Yüksek miktarda sermaye gerektiren ve diğer yatırım alternatiflerine kıyasla yüksek risk içeren gemi yatırımları, denizcilik işletmeleri için oldukça önemlidir. Bu nedenle, gemi yatırımlarındaki dinamikleri anlamak önem arz etmektedir. Dolayısıyla bu çalışmada, Türk gemi yatırımcılarının gemi yatırımlarını etkileyen faktörlerin belirlenmesi amaçlanmaktadır. Bu bağlamda, Türkiye'deki gemi yatırımcıları ile yakın ilişkileri olan ve söz konusu yatırımcıları objektif olarak değerlendirebilecek profesyonellerin bakış açılarına yönelik nitel bir araştırma yapılmıştır. Elde edilen bulgular; Türkiye'de yatırım yapılacak gemi yatırımlarının değerlendirilmesinde; piyasa şartları ve zamanlama, yatırımın geri ödeme süresi, geminin teknik özellikleri ile yatırımcı profili, finansman kapasitesi ve risk algısının gemi yatırımlarında öne çıkan faktörler olduğu tespit edilmiştir.

Anahtar Kelimeler: *Gemi Yatırımları, Türkiye, Gemi Yatırımcıları, Nitel Araştırma.*

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1. Introduction

Companies make investments with different characteristics throughout their economic life. In order for the companies to grow and maintain current activities in a competitive environment, they should develop new products and services and fulfill the improvements in the products and services they currently offer in a timely and complete manner. Considering maritime industry, ship investment is vital stage for a shipping company [1]. In addition to the freight earnings obtained from transportation activities, ship investors also rely on the capital gains from the ship investments [2, 3]. Especially between 2003 and 2008, ships were sold from very high levels and profit margin of ship investors were extremely high that was never seen before [4]. However, ship investments require many variables to be taken into account depending on the dynamic nature of the world economy [5]. Apart from other variables, high capital requirements and the changing nature of global markets make ship investors courageous [6]. Wrong investment decisions may not only reveal loss but also diminish the market share of the firm. Accordingly, the competitive power of the firm may be affected in the long-term period [7].

Decisions in the financial management of the shipping industry consist of three main pillars which are investment on new building or second hand vessels, financing related with debt and equity capital markets and freight market operations [8]. Given the intense trade activities in Europe and enclosed seas, a need has revealed to explore how to develop current trade and investment activities to ensure the fulfilment of the demand in the region. Accordingly, one of the most important factors that determine the profitability and efficiency is the sound investments [1]. Considering the geographical situation of the region, maritime transport is conducted via small size vessels, which is called "coaster", bearing lower operational and financial risks compared with large-tonnage vessels.

With its connection to Europe, Asia, the Caucasus, the Middle East, and Africa; Turkey is a country at the crossroads of trade and steps forward in the region. Especially since the 1980s, the majority of maritime transport in the Mediterranean and Black Sea is carried out by Turkish owned merchant fleet consisting of coasters that vary in the range of 1.000-12.000 dwt. As emphasized by Tamer Kiran, chairman of board of directors of the Turkish chamber of shipping, in the monthly ordinary meeting held in March, 2019 [9]:

"...Turkish owned merchant fleet, which has a 35% market share in the Mediterranean and Black Sea with around 700 ships, stands out as the strongest fleet of our region."

According to the figures extracted from IHS Sea-web database by Istanbul Freight Index (ISTFIX) Research Department, Turkish-controlled coaster merchant fleet between 1,000 - 12,000 dwt consists of 765 ships with around 3,44 million dwt as of the beginning of 2018 that accounts for 35% of total ship supply by total carrying capacity in the region. These numbers support the speech of Mr. Kiran.

To maintain competitive power in the region, ship investments in Turkey that are affected by many volatile parameters, should be carried out thoroughly. In this respect, ship investments in Turkey are regarded as research setting in this study considering current supply power of Turkish-controlled merchant fleet in Mediterranean and Black Sea and it is aimed to determine the determinants affecting ship investments in Turkey by considering qualitative research perspective. It has been observed that there are studies regarding ship investments whether on timing or structural relationship with other parameters. However, as indicated by Celik-Girgin et al. [10], studies on ship investments have substantially been formed by considering market analysis and research models are limited to a certain extent by considering various parameters. In this sense, there is the need for different points of view. To comprehend the dynamics on the issue, a qualitative examination is employed to understand the nature of ship investments from professionals' perspectives in this study. Qualitative research process includes semi-structured interviews applied to the professionals who are able to objectively evaluate the industry mainly because of having close relations with ship investors and experience in the industry. It is expected that comprehending the dynamics of ship investments in Turkey may provide valuable contribution both to the scholars and practitioners.

The remaining part of this paper is structured as follows. Previous studies on ship investments are discussed in section 2. Afterwards, methodology used is explained in section 3. Then, findings of the analysis are provided in section 4 and they are discussed with the current literature in discussion and conclusion.

2. Previous Studies on Ship Investments

Regarding previous studies, it is seen that the majority of the studies on ship investments are related with market analysis to determine the appropriate conditions for ship investments, ship valuation, comparison of the existing valuation models and investment alternatives and the effects of external factors on ship investments. However, the studies are substantially based on secondary data sources and include empirical analysis. Accordingly, there is a gap in the related literature that address the determinants of ship investments from qualitative research perspective. Therefore, the motive of this study rests on the shortcomings in the current literature and therefore it is intended to explore the factors affecting ship investments in Turkey by taking into account primary data sources.

Dikos and Marcus [11] investigated second hand ship valuation by using charter rates and new building ship prices in dry bulk market for 1976-2002 time period. The model they developed is based on real options approach and asset play valuation exists in second hand prices. Alizadeh and Nomikos, [12] developed a model on investment decisions in dry bulk ship sale and purchase market using price-earnings ratio for the period 1976 and 2004. They suggested that comprehending the relationship between second hand ship price and earnings can be regarded as an important signal to estimate the future price of second hand ships and to reach a decision on whether to invest or not. Alizadeh and Nomikos [13] conducted a preliminary study in which the same ratio can be regarded as a guide on whether to enter tanker market. The authors illustrated that ship prices and freight earnings are the key factors in sale and purchase transactions. Yin, et al. [14] assessed dry bulk ship investment decisions in tough and peak times by developing a model based on real option approach. The authors claims that the model developed has advantages over the traditional net present value method in uncertain investment environments in the current dry bulk shipping market. Alizadeh and Nomikos (15) investigated price-volume relationship in sale and purchase market for dry bulk ships. Findings reveal positive relationship between price of second hand dry bulk ships and ship sale and purchase volume. Accordingly, investors tend to invest more, depending on high capital gains from ship investments. Bulut et al. [16] investigated shipping assets and decisions whether to enter dry cargo shipping market considering business cycles. Return on Equity (ROE) performance analysis was applied, and the findings revealed that the investors have a tendency to place ship investment at peak market conditions in which the ship prices are higher and the ROE rates remarkably decline.

Scarsi [1] examined the reasons why ship investors operating in the dry bulk market still make mistakes in ship investments despite their knowledge and experience. It was emphasized that errors in ship investments are usually caused by reading the market inadequately and failure to analyze market cycles.

Tsolakis, et al. [17] analyzed second hand tanker and dry bulk vessel prices over the period of 1960 and 2001. They developed error correction model considering newbuilding price, time charter rates and interest rates to figure out price valuation. They found that second-hand ship prices for the subject vessels are much more affected by new building prices rather than time charter rate on prices of second hand vessels. Merikas, et al. [18] analyzed investment decisions with other parameters namely freight rate, cost of shipbuilding, volatility in freight rates, crude oil price and interest rates. The authors measured investment decision as the ratio of second hand ship price over new building ship price in tanker market. According to the findings, investing in second hand vessels is more logical in rising freight market to meet demand. On the other hand, it is proper to invest in new building vessels in bad market as a result of optimism for the future of market. Fan and Yin [19] examined the relationship between second hand ship prices, new building ship prices, and time charter rates in container market by applying Var Cointegration model and Bai-Perron test and found that the price of new building price is more volatile than time charter rates and second hand prices, when the freight rates are lower. On the other hand, time charter rates are more volatile when freight rates reach high levels. Moreover, second hand prices increase when the freight market is stable. Fan and Luo [7] proposed that container liners are affected by market-driven factors to expand their capacity even if order book is full. More specifically, investments increase when demand for shipping services and charter rates are higher. Besides, the authors indicated that deciding whether to invest new building or second hand ship is initially regarded than deciding ship size. In this sense, new building vessels steps forward compared to the second hand vessels. However, if demand is so intense and there is a queue at shipyard for building new vessels, then second hand ships become more preferable.

In addition to traditional Discounted Cash Flow (DCF) methods, different approaches have been examined in the evaluation of ship investment alternatives. In this respect, Bendall and Stent [6] examined the Real Option Analysis (ROA) in order to make a ship investment decision under uncertain market conditions. According to the results of the analysis, ROA was found to be more robust in real market conditions compared to the traditional DCF approach. In the following years, ROA methodology was also applied by the same authors considering different conditions and markets [5, 20] and similar results were reached.

Greenwood and Hanson [21] investigated investment cyclicality and capital returns in dry bulk industry by proposing a model based on behavioral perspective of cycles. According to the findings, firms overvalue demand for shipping services and invest more during booms and undervalue the actions of their competitors. Kalouptsidi [22] examined fluctuations of demand for shipping services and time-to-build effect on investment by using second hand and new building ship sales, fixtures and scrapping activities for the period 1998 and 2010. Findings suggests that time to build decreases, while investment volatility increases. Marlow [23] analyzed the role of incentives on investment levels in UK shipping industry by applying an empirical model to test various variables to whole markets. Surprisingly, a negative relation was found between incentives and investment levels.

There is a limited number of studies on ship investments carried out on the national scale. Arslan and Gurel [24] aimed to emphasize that firms can reach a solution by using fuzzy logic methodology if they face multi-criteria decision making problems. By doing so, authors exemplified ship investment alternatives in different type and tonnage for an investor having an intention to enter shipping market by using fuzzy logic method. Arslan [25] evaluated the process of strategic investment decision of an institutionalized shipping company in Turkey by using the case study method.

There are also studies on the national scale that can be indirectly related with ship investments. Within the scope of operating costs; Saban and Güğerçin [26] showed the effects of the factors affecting the operating costs on transportation costs in maritime transportation with an example and emphasized the importance of determining the cost structure correctly in decision making processes. Erol et al. [27] found a significant and positive relationship between ship age and daily operating costs. Additionally, it is emphasized that there is a negative relationship between ship size and crew expenses when ship age is considered as constant. Within the scope of the shipping market analysis; Dursun and Erol [28] examined the financial structure of the maritime transport sector in Turkey applying ratio analysis. According to the findings, it is emphasized that the profitability of assets in the sector has decreased to 1% due to the crises experienced, whereas costs have increased to 85% in total net sales. Derindere Köseoğlu and Adıgüzel Mercangöz [29] examined the impact of the 2008 global financial crisis on the Baltic Handysize Index and Istanbul Freight Index empirically and found that all coaster tonnage revenues included in the analysis were structurally changed due to the 2008 crisis. Erol [30] examined the freight revenues of the ships called to Turkish ports considering their flags and ownership. According to the findings of his study, it is determined that the total freight revenues are obtained mostly by ships with foreign flags and foreign owners. Atar et al. [31] found that short-distance maritime transport and combined transport provide great advantages in coastal regions. However, due to the high average age of the existing coaster fleet, possible risks, especially investment requirements, were emphasized.

In the study conducted by Erol and Dursun [32], financial risks in the maritime sector and protection methods from these risks were discussed. In the study, it is emphasized that the most appropriate derivative instruments for tramp shipping firms are forwards and call options in terms of the ability of the parties to meet their special needs.

Korkmaz [33] found positive and significant relationship between industrial production and total trade and the number of ships calling at the ports in Turkey. Tunalı and Akarçay [34] also found a positive and significant relationship between industrial production and maritime transport.

3. Methodology

Qualitative research has become popular among scholars since it provides a new and alternative way of understanding the behaviors, attitudes and perceptions. Qualitative research offers important opportunities in a world where context and processes become more important than results [35]. There are three kinds of data collection techniques in qualitative research which are in-depth open-ended interviews, direct observations and written documents [36]. Since the main purpose of this study is to present a realistic picture to the reader on determinants of ship investments in Turkey from perspectives of professionals, interviewing was employed. Semi-structured interview technique is preferred because it is both standard and flexible to a certain extent; it can remove the limitations of the survey forms and can gather in-depth information on the subject [37]. In this study, there is a cyclical research process consisting of two stages. The aim of the cyclicality of the research process is to provide systematic comparison [38], and it was intended to analyze the current literature by reviewing the studies in ship investments in the first stage.

Field research was conducted by the first author in the second stage of the study. The number of the participants was not predetermined. In order to maximize the variations, participants were recruited by purposive sampling method. To obtain different insights and perspectives on the subject, it was intended to involve participants from various affiliations. Since data quality depends on the participants from whom data is obtained, participants to be included should be experts in the scope of the research [39]. Therefore, professionals who are able to evaluate the industry objectively on the factors affecting ship investments in Turkey would be deemed appropriate. Accordingly, sale and purchase brokers that offer intermediary services for ship investments, senior representatives of non-governmental organizations in Turkish maritime industry, the consultants who offer consultancy services to the parties on various topics, and a ship operator who charters a ship under certain conditions from the ship owners and operates it on his own account are determined as the research group of field research in this study. Details of participants are shown in Table 1. The permissions of all participants were taken whether they were willing to participate in the study. Before starting the interviews, the reasons leading to this study were shared with the participants. A semi-structured interview form was used in each interview and whenever the doubts on how to respond to the questions occurred, the questions were clarified and simplified by giving comprehensible examples. Once the interview was done, the audiotape of each interview was transcribed according to the strategies depicted by Poland [40]. Due to the anonymity reasons, names of the participants and the institutions they work for are kept confidential. Additionally, the responses and examples on other companies that are not allowed to record of the participants were not quoted or transcribed in the study. Data were collected until the saturation was reached. Data collected from each interview were analyzed to reach the themes in ship investments in Turkey by considering induction logic. The data, obtained within the scope of the circular research process shown in Figure 1, are compared with the literature and a framework for determining the themes is formed.

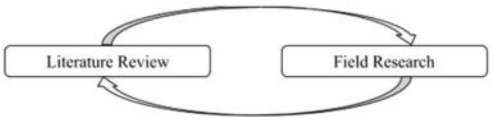

Figure 1. *Research Process*

Responses collected from all participants were analyzed by using Maxqda Qualitative Data Analysis Software, which is one of the leading software package for qualitative research including but not limited to grounded theory, literature reviews, exploratory market research, qualitative text analyses, and mixed methods approaches worldwide. It is an important tool to help the researcher in describing the collected data, identifying themes and correlating them meaningfully.

Table 1. *Details of Participants*

Participant	Code of Participant	Title	Sector Experience (year)	Date	Duration	Place of Interview
S&P Broker 1	SP-1	Owner, Broker	16	23.01.2018	1h 35m	Maltepe, Istanbul
S&P Broker 2	SP-2	Owner, Broker	15	23.01.2018	1h 20m	Kartal, Istanbul
S&P Broker 3	SP-3	Broker	11	23.01.2018	1h 15m	Etiler, Istanbul
Association 1	A-1	Secretary General	15	25.01.2018	1h 10m	Fındıklı, Istanbul
Association 2	A-2a	Director	28	26.07.2018	1h 55m	Ümraniye, Istanbul
Association 2	A-2b	Research Specialist	10	26.07.2018	1h 55m	Ümraniye, Istanbul
Consultant 1	C-1	Head of Research	15	26.01.2018	1h 45m	Ümraniye, Istanbul
Consultant 2	C-2a	Owner, Consultant	31	10.01.2019	1h 05m	Ataşehir, Istanbul
Consultant 2	C-2b	Consultant	55	21.01.2019	53m	Ataşehir, Istanbul
Consultant 3	C-3	Scholar, Consultant	41	22.01.2019	1h 40m	Moda, Istanbul
Ship Operator 1	SOP-1	Owner	39	21.01.2019	38m	Koşuyolu, Istanbul

The program allows code comparisons between interview documents with its four-window interface by organizing and categorizing complex and large data sets, managing the categories, which are called "code", and retrieving the coded segments. Baş and Akturan [39] explained how to use the program in detail.

Data collected from participants were examined to determine the factors affecting ship investments by applying both content analysis and descriptive analysis in this study. While the aim of content analysis is to reach the themes and relationships that can explain the data collected, the aim of descriptive analysis is to summarize and interpret the data obtained according to the themes determined. During the coding process, the concepts and words expressed by the participants were used as codes, and when the concepts and words used by the participants were inadequate at the point of coding, different concepts were identified as codes by the authors. Coding was performed while analyzing the responses of the participants. Similar codes are collected in certain categories. To verify the findings, peer review examination was conducted on January 8, 2019 and April 17, 2019 with a scholar who substantially works in the field.

4. Findings

In line with the purpose of the study, market conditions and timing, payback period of the investment, technical features of the ship and profile, financing capacity and risk perception of investors are found as the criteria that shape ship investments in Turkey.

4.1. Market Conditions and Timing in Ship Investments

Given that the demand for maritime transport services is directly linked to international markets, the parameter of market conditions is the main factor driving ship investments. This is supported by one of the participants' contribution as follows:

A-1: "...The positive impact of global developments on world trade is reflected in maritime trade. Therefore, ship investors invest in such an environment if they have sufficient resources."

Reading the market and taking the right action at the right time is of great importance in ship investments. Due to the capital intensive structure of the industry, it is necessary to plan ship investments thoroughly. It is important to pay attention to markets, especially freight markets, during the planning process of ship investment to comprehend the current situation of the markets and the expectations of the future. In this context, a participant emphasized this situation as follows:

C-1: "...Vessels are assets, even if they are not liquid. Commodity, S&P, new building and demolution markets needs to be followed as if following stock markets. Indices such as BDI, ISTFIX can be analyzed for technical analysis. But the basic analysis is certainly not different from the stock market. It is needed to know the profitability of the firms and the sector and also the commodity markets. For example, a dry cargo ship owner must follow the markets for all cargoes. In addition, macroeconomic information is very important. They have to dominate the economic structure, supply-demand balances of the countries to which they are transporting."

As a matter of fact, market conditions may be worse at the time of ship delivery than when the order was placed since delivery of the ship may take a few months, and this may have unexpected consequences. A participant stated this fact as follows:

C-3: "...There is an average of one year between the time that the order was placed and the time of ship delivery. Ship orders placed by the majority at the same time by taking into account the current market conditions constitute supply surplus at the time the ships are delivered. So, ship owners harm one another with their behaviors and the market is badly affected."

4.2. Evaluation of Ship Investment Alternatives

The evaluation of ship investment alternatives is a very important process. Planning correctly reduces the likelihood of undesirable situations. When the statements of the participants are considered on how investors evaluate investment alternatives, it is seen that the payback period is taken into account. In other words, it is important to know how long the investment pays itself. In this context, participants used the following statements:

SP-3: "...The best time to invest in ships is when the price/earnings (p/e) ratio is at the lowest levels. For instance, assume that a ship purchased from 2 million usd, and expected to generate 200.000 usd freight income per year, will not be a good investment as price/earnings ratio will be 10. In other words, the ship will pay back its price in 10 years, which is considered a long time. However, if the investor estimates p/e ratio as 5-6 years even if the purchasing price is 3 million usd, then the investment becomes attractive."

As indicated by Bendall and Stent [5] there is a high correlation between international trade activities and demand in maritime industry. Therefore, developments in any side of this relationship may generate an unpredictable change in the costs and earnings of ship investors. Accordingly, tendency of ship investments declines when uncertainty exists. This is emphasized by a participant as follows:

SOP-1: "...The new building cost of a ship with a capacity of 5,000 dwt is around 8 million usd and the return of this amount is 15 years under the conditions of today. While it is hard to estimate next 3 years, it is impossible to foresee a long period of 15 years. And at the end of 15 years, you'll have an old ship. Even though the first 5 years will not cost much, the money will need to be spent on the repair and maintenance of the ship after 5 years. Considering the current economic conditions, investment is not attractive, given the high loan rates. That's why many of our friends are not investing today. Even if they have cash, the bank is giving 4-5% interest today. If you foresee that you will get around 7%-8% of ROI per year, it might make sense to invest in a ship. Other than that it is not rational".

4.3. Technical Features of the Ship

The technical features of the ship investment alternatives are emphasized among the factors that the investors should pay attention. It is determined that the type of ship, design, machinery and equipment of which the investors are familiar, are found as important criteria in ship investments. One of the participants has the following view:

C-2b: "…In terms of ship investment, the speed and fuel consumption of the ship in technical terms are very important items. Additionally, country in which the ship was built is an important criterion for some ship investors in Turkey. In this sense, they expect to invest in ships that are built in Germany, Holland, etc. If it was built outside these countries, they look for who carried out the project. In some cases, in order to take advantage of the low cost of production, German, Dutch, and Scandinavian ship owners can build their ships in different countries, particularly in China, by determining the design of the ship and bringing its surveyors and inspectors as the head of the project. Even if the ship is made in China, her machine, auxiliaries, pumps, valves, all filters etc. come from Europe."

It has also been stated that some ship investors have an intention to look for the ships with certain brands of equipment. Familiarization with specific brands facilitates maintenance and minimize uncertainty by providing insights to determine problems that may arise in the future. In this context, a participant shared following statements:

AS-2a: "…The first and most important criterion to invest in a ship is the brand of main engine for many ship owners. Indeed, many of them look for a ship having Japanese or Korean machines, because they proved themselves as being long life machines and do not cause major problems. Any machine with high operating costs may harm not only mentality of investor, but also the financial and operational structure of the firm. The firm may face unexpected costs and the plans for the whole year may fail. The most important criterion in ship management is that the voyage should start and end immediately. The more the voyages, the more profits will be. Because, when calculating the TC equivalent, the daily earnings are calculated. However, the slightest failures in the equipment negatively affect the whole process".

4.4. Profile, Financing Capacity and Risk Perception of Ship Investors

The profile of ship investors is often another important factor in shaping investments. The difference of perspectives between Europe and Turkey is illustrated by a participant as follows:

C-1: "…European ship investors determine the ship they need and try to obtain the required budget afterwards. On the other side, Turkish ship investors are generally in search of ships suitable for the cash in their pocket and sometimes they are in search of assembled ships. In such cases, parameters on technical requirements, which are determined by the ship's structure are ignored."

Perspectives on ship investments vary between investors with high and relatively limited capital power. The statements of a participant supporting this fact are as follows:

SP-2: "…I think there are economic reasons for keeping the work under control and being reluctant to sail in distant places. When switching to large tonnage, many things need to be changed, from equipment to crewing. The higher the costs, the higher the freight income should be. When the markets were good, everyone was somehow risk seekers. Today, things are just the opposite. People have to cut it all away. There are many problem areas. If you want to work in South Asia, you have to pass the Suez Canal. There is always a risk that there will be an extra insurance for the pirates in

Aden region, the cost of protection, and the question of whether there will be a voyage for return. As the main objective of the firms, holding high cash and having high credibility, is to maximize earnings, such companies do not hesitate to invest in large tonnage."

"...Investors who have high capital power and operate mostly in different sectors and then enter into the maritime sector, prefer not to diversify but to be bound by a single tonnage. Instead of generating a portfolio consisting of vessels from different tonnages, they prefer to buy a series of vessels from a certain tonnage. They have an intention not to diversify their fleet and to remain connected to a single tonnage segment. The rationale of this thought is to reduce breakeven cost per ship, and to expand profit margin when a vessel from the fleet is sold."

Speaking of capital power, it will be useful to refer to the evolution of shareholder structure of ship owner companies in Turkey. Due to the high capital requirement of ship investments, Turkish ship investors often miss many investment opportunities due to lack of sufficient capital. However, especially in recent years, Turkey has been one of the attractive destinations for Arab investors who are mainly from Qatar and Syria and who have huge amount of cash ready for investments. In this sense, Arab investors has begun to take place as shareholders in many sectors including Turkish shipping industry. This fact is expressed by one participant as follows:

SP-1: "...It can be said that the profile of Turkish ship investors has changed recently. Due to the low prices, it is observed that Turkish ship investors have turned to bigger tonnages. One of the main reasons for this may be the increase in the number of the Arab shareholders. Due to problems in the Middle East, Turkey has become an attractive place for Arab investors, especially from Syria and Qatar. Despite the fact that the company is registered as a Turkish company, Arab investors are among the shareholders. This was also supported by the government. In order to draw hot money into the country, no tax is applied to the cash coming from abroad. Thus, Turkey has started to become one of the tax havens for foreigners."

Small tonnage ships, which are called coaster ships, are the backbone of ship investments in Turkey since they bear lower risk and cost of capital compared with larger vessels. Given their low draft structure and high maneuver capability, they are the mostly preferred ships in Turkey. Following statements of participants exemplified the issue.

SP-3: "...I believe that there is a problem with access to the markets. We are attracted to with the idea that the risk will increase at the entrance to the larger or distant markets. Therefore, we focus on small-tonnage vessels, partly because the risk is less."

SP-2: "...In the tonnage ranging up to 20,000 dwt, a small number of 20,000 dwt ships were built in the world after 2000. This was mainly because of that when the markets were in an upward trend, no one wanted to deal with small tonnage. With the decline of the markets, investments in this tonnage accelerated with the perception of lack of supply in the small tonnage. One of the main reasons for this is that due to reduced risk appetite since the volatility of earnings is not much. This tonnage is highly predictable compared with higher tonnages. There is a tendency to enter this market even if the ship is run at a loss.

5. Discussion and Conclusion

Previous studies support our findings on the importance of reading the market thoroughly and taking the actions at the right times in ship investments. As asserted by Alizadeh and Nomikos [13] timing in maritime transport industry where competition and cyclicality are intense, is important. Scarsi [1] associates reading the market and timing with business life of a shipping company. More specifically, ship investors operating a ship or a fleet having a lower breakeven points generate higher profits when direction of trend in freight market is upward. Besides, these ship investors are able to survive longer compared with the ones having higher breakeven points in bad market conditions. To sum up, as emphasized in our findings and also current literature, reading the markets and obtaining high level commercial and technical up-to-date information is an important factor in ship management, because it determines the effectiveness of investments.

Discounted cash flow analysis has traditionally been used for evaluating maritime investment alternatives for a long time as demonstrated by Evans [38], Gardner et al. [39]. However, new evaluation tools have been developed to be applied for ship investment alternatives. In this sense, Real Options Analysis (ROA) has drawn considerable attention for the evaluation of ship investment alternatives recently. Bendall and Stent used ROA for ship investment evaluation in their studies [5, 20]. On the other hand, our findings reveal that price/earnings ratio is also used to determine payback period of investment. The fact that ship investors generally consider price/earnings ratio while evaluating ship investment alternatives is also emphasized by Alizadeh and Nomikos [12, 13].

Considering the current literature, profile and risk perception of ship investors have been taken into account from the behavioral perspective, which has been a trend topic among scholars recently. For instance, Duru [40] alleged that the risk attitude of investors is a key enabler for ship investments referring to behavioral economics. However, our findings point out how ship investments are shaped based on the profile, risk perception and financing capability of ship investors. Moreover, one of the important drivers shaping ship investments and that is not sufficiently emphasized in the current literature, is found as technical characteristics of the ship such as fuel consumption, speed, brands of equipment, built country etc., in this study.

Although timing is an important criterion, speculative investments in bad market conditions, where freight and ship prices are at very low levels, also involve risks. Although shipping markets have a cyclical structure, if market recovery is delayed, ship investors will have to bear significant opportunity costs.

Since ship management is an international business, it can be directly affected by global developments as well as country or region-based developments. In such a dynamic environment with many variables, ship investments turn into a strategic process, and this fact puts ship investments into risky investments category. However, it may be possible to minimize the risk if the factors highlighted in this study are taken into consideration during the evaluation of investment projects and subjected to detailed analysis.

For shipowners who are familiar with a particular ship type in technical issues such as carrying capacity, ship type, ship machinery and auxiliaries, maintenance processes will be easier and unexpected events will be less likely to occur, even if they are experienced, it will be easier to intervene with these events. In fact, a ship which is not suitable to sail due to technical errors will cause huge losses. Most of the freight revenues will be lost. Therefore, such technical issues are emphasized as one of the factors to be considered in ship investments.

In order to grow in a capital-intensive sector, investment is required. However, it is very difficult to make investments in today's world where financing sources are not easily accessible compared to previous years. Since maritime industry in Turkey has not involved in capital markets due to its closed structure, and also access to credits has been limited, international partnerships has gained importance recently in Turkey. Investors from Arab countries have recently been shareholders in ship investments in Turkey. This may lead to the influences and revision of traditional assumptions, institutional structure of the companies.

It is always beneficial for investors to act according to their risk perception and financing capacity in ship investments where investors who buy dreams instead of ships are often disappointed. Regardless of the market conditions, it should be remembered that the investors who know their limits could survive.

This study has an exploratory nature and the findings obtained can be tested with various quantitative methods in the future. Besides, the sample can be expanded in the future and the findings can be enriched, although the individuals working in different sectors are selected as participants in order to ensure diversity in this study.

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Corresponding Author: Ferdi ÇAKICI

A Numerical Application of Ship Parametric Roll under Second Generation Stability Criteria

Ferdi ÇAKICI

Yıldız Teknik Üniversitesi, Gemi İnşaatı ve Denizcilik Fakültesi, Türkiye
fcakici@yildiz.edu.tr; ORCID ID: https://orcid.org/0000-0001-9752-1125

Abstract

In this study, the parametric roll motion for the benchmark container ship form C11 is investigated by using the second generation stability criteria, which were intensively studied by IMO (International Maritime Organization). According to the IMO regulations, vulnerability criteria range between 1 and 3. While level 1 is only dependent on ship geometry and speed, level 3 is required to perform direct stability assessment with reliable robust software. The application of level 1 is considerably easy yet it is extremely conservative. Therefore, in the present study, level 2 application is performed that is less conservative than level 1 and easier than level 3. Parametric roll motion is analysed based on GM variation technique. Based on C2 assessment procedure which is calculated as an average of values of different Froude numbers and wave directions, it is found that the benchmark hull C11 was not vulnerable for the parametric roll resonance.

Keywords: *Benchmark Hull C11, Parametric Roll, GM Variation Approach.*

Yeni Nesil Stabilite Kriterleri Çerçevesinde Parametrik Yalpa Hareketi için Sayısal bir Uygulama

Öz

Bu çalışmada, IMO (Uluslararası Denizcilik Organizasyonu) tarafından yoğun bir şekilde çalışılan yeni nesil stabilite kriterlerinin kullanımı ile referans konteyner gemisi formu C11 için parametrik yalpa hareketi araştırılmıştır. IMO kurallarında göre zafiyet kriteri 1 ve 3. seviye arasında değişmektedir. Seviye 1 uygulaması sadece gemi geometrisine ve hızına bağlı iken, seviye 3 uygulaması güvenilir sağlam yazılımlarla doğrudan stabilite değerlendirmesi yapılmasını gerektirir. Seviye 1'in uygulaması oldukça kolaydır fakat bu seviye aşırı derecede tutucudur. Bu sebeple, mevcut çalışmada uygulaması seviye 1'e kıyasla daha az tutucu ve seviye 3'e göre daha kolay olan seviye 2 uygulanmıştır. Parametrik yalpa değerlendirmesi GM varyasyon yaklaşımı ile elde edilmiştir. Değişik gemi hızları ve dalga yönlerine dayalı olan C2 hesabı kullanılarak yapılan değerlendirme ile mevcut gemi formunun parametrik yalpa rezonansı için zayıf olmadığı tespit edilmiştir.

Anahtar Kelimeler: *C11 Konteyner Gemisi, Parametrik Yalpa, GM Varyasyon Yaklaşımı.*

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1. Introduction

Parametric roll is usually known as an amplification of roll motion caused by periodic change in restoring terms in waves, which leads to dynamic instability of motion. Generally, this phenomenon is observed in head and following waves when encounter frequency of the ship is about twice of roll natural frequency in the absence of sufficient damping to dissipate additional accumulated energy as described in the report of Belenky et al., 2011 [1]. Once parametric roll starts, excessive roll angles are achieved and eventually ship could capsize. Even when the parametric roll does not result in capsizing, in some situations, the cargo could be damaged and it might be dangerous for the crew as well.

First researches on the parametric roll of ships were conducted in Germany in the late 1930s. The main objective of this research was to explain the reason for capsizing of some small ships in severe following seas. After this study, researchers continued to investigate parametric roll phenomena for decades [2]. Kerwin (1955), and Paulling &Rosenberg (1959) published milestone studies on parametric roll motion by considering the temporal variation of metacentric height, GM [3, 4]. Using this approach, IMO [5] also considered parametric roll phenomena by publishing informative documents. In this approach, restoring and damping terms are handled nonlinearly.

In the 1990s, there were some incidents where relatively large ships such as container ships and cruise ships experienced severe roll motion in head seas. These incidents started to attract the attention of researchers on the parametric roll in head seas as well (for example, APL CHINA casualty in October 1998) [2]. Apl China case was studied by France et al. (2003) [6] and they established detailed consideration in terms of the practical importance of parametric roll motion [7].

Different solution techniques for direct stability assessment, level 3, were applied by the researchers in terms of computation of parametric roll as well. For instance, Shin et al. (2003) implemented Rankine panel methods for parametric roll analyses and obtained reasonable results. However, this method is computationally expensive [8]. Retardation (impulse response) function approach proposed by Cummins (1962) that has solution of convolution integrals can be another powerful choice in terms of accuracy and efficiency of numerical computation for the solution of the parametric roll [9, 10]. In this approach, time-domain damping forces are calculated in the equation of motion by adopting the frequency-based damping forces in the retardation function. Then the nonlinear restoring force on an instantaneous wetted surface is introduced [10]. By taking advantage of being computationally cheaper, Spanos and Papanikolaou (2007) have used the retardation function approach in the parametric roll analysis of a fishing vessel [11]. Kim and Kim (2011) proposed a multi-level approach for parametric roll analyses to compare three techniques which are GM variation approach, retardation function approach, and Rankine panel method approach [12]. Pesman (2016) investigated the effects of the variable accelerations on parametric roll motion during operation by using a commercial flow solver [13]. Umeda et al. (2016) performed a numerical study of parametric roll in oblique waves using low –speed manoeuvring forces and they supported their numerical predictions with experiments [14]. Lee and Kim (2017) investigated numerically effects of parametric roll motion on added resistance. They noted significant increase in the added resistance induced by parametric roll [15]. Wang et al., studied on parametric roll of ship under the random wave by a numerical simulation. The authors reported that the parametric roll motion of ship remarkably change when the ship undergoes the wave group rather than a single wave [16].

In this study, GM variation approach is used to predict parametric roll motion. Restoring terms in the equation are deduced by fitting a seventh order polynomial for accurate representation of righting arm, GZ curve. Viscous roll damping forces are calculated by adopting the most prominent and commonly used model proposed by Ikeda to have an accurate simulation of the parametric roll [17].

2. GM Variation Approach

In level 2 vulnerability criterion of the parametric roll, two values are calculated: C1 and C2. If one of these criteria is less than 0.06 limit value, ship is considered invulnerable for the parametric roll motion. It is noted that 'C1 assessment procedure' is easier to implement but more conservative compare to 'C2 assessment procedure'. The value of C1 is found more than 0.06 meaning the ship is vulnerable to parametric roll motion. Therefore, in this study, C2 assessment procedure, which is calculated as an average of values of different Froude numbers, is applied step by step for the benchmark hull C11. Main properties of C11 are given in Table 1.

Table 1. *Ship Data of C11*

L_{PP} (m)	262
T (m)	12
B (m)	40
Volume (m^3)	71559.52
KG (m)	17.51
GM_calm water (m)	2.749
Vs (m/s)	10.51
C_B	0.576
C_M	0.957
OG/d	-0.459
T_ω ,wave period (s)	21.78
L_{BK}/L_{pp}	0.277
B_{BK}/B	0.01

In Table 1, while L_{pp} denotes the ship perpendicular length, T denotes the ship draught, B denotes the ship breadth. KG denotes the vertical position of the center of gravity. GM value in calm water denotes the metacenter height. Vs denotes the service speed. C_B denotes the block coefficient. C_M denotes the mid ship coefficient. L_{BK} denotes the bilge keel length, B_{BK} denotes the bilge keel breadth. T_ω denotes the period of the selected wave ($\lambda_\omega = L_{pp}$). Here λ_ω denotes the wavelength of the wave.

If a ship sailing in longitudinal seas is considered (following or head), there is no heeling moment based on waves and the nonlinear equation of parametric roll can be written as follows:

$$(I_{44} + A_{44})\ddot{\phi} + B_{44L}\dot{\phi} + B_{44NL}\dot{\phi}^3 + \Delta GZ(\phi,t) = 0 \quad (1)$$

Where, B_{44L} stands for the linear roll damping coefficient, B_{44NL} stands for the nonlinear (cubic) roll damping coefficient, A_{44} stands for the added mass in roll motion, I_{44} stands for transverse moment of inertia, Δ stands for displacement force of the ship and finally GZ(ϕ,t) denotes for the righting arm with respect to time which is introduced with a seventh order polynomial.

$$GZ(\phi,t) = [GM_m + GM_a\cos(\omega_e t)][a\phi^7 + b\phi^5 + c\phi^3 + d\phi] \quad (2)$$

Since the waves are passing through the ship in time, a periodic cosine function is used to correct the value of GM. Here, GM_m is mean value of GM for ten different wave crest positions, GM_a is the amplitude of GM changes for ten different wave crest positions $GM_a = 0.5(GM_{max} - GM_{min})$In other words, GM_{max} and GM_{min} are maximal and minimal instantaneous values of GM_m's for a number of wave crest and trough positions along the ship. In Equation (1), ω_e is the encounter frequency and *a, b, c, d* are the restoring coefficients calculated using least squared method (see Table 4).

In our case, ten different wave crests positions and ten different effective heights are used. GM_m , GM_a and effective wave height values for the benchmark hull C11 are taken from IMO document (SDC 5/INF.4 Annex 13, page 6) and given as follows [18]:

13, submitted by France). Please note that H_{eff} (the maximum effective wave height) is equal to 11.936 m [18]. This value is used to generate ten effective waves where heights of these waves varied between 1.194 and 11.936 m with a step of 1.194 m. Length of all waves (λ_ω) is equal to the length of the ship.

Table 2. *Effective Wave Heights, GM_m and GM_a Values [18]*

H_{eff} (m)	1.194	2.387	3.581	4.774	5.968	7.162	8.355	9.549	10.742	11.936
GM_m (m)	2.764	2.84	2.909	2.961	3.001	3.044	3.095	3.155	3.224	3.303
GM_a (m)	0.473	0.936	1.315	1.605	1.851	2.087	2.301	2.5	2.697	2.883

Table 3. *Effective Wave Heights, GM_m and GM_a Values (A Stability Software)*

H_{eff} (m)	1.194	2.387	3.581	4.774	5.968	7.162	8.355	9.549	10.742	11.936
GM_m (m)	2.785	2.856	2.908	2.949	2.988	3.035	3.088	3.150	3.218	3.301
GM_a (m)	0.487	0.953	1.305	1.593	1.850	2.091	2.311	2.519	2.741	2.947

Table 4. *GM_m and GM_a Differences Between IMO and Used Stability Software*

H_{eff} (m)	1.194	2.387	3.581	4.774	5.968	7.162	8.355	9.549	10.742	11.936
GM_m (m)	0.76%	0.56%	0.03%	0.41%	0.43%	0.30%	0.23%	0.16%	0.19%	0.06%
GM_a (m)	2.96%	1.82%	0.76%	0.75%	0.05%	0.19%	0.43%	0.76%	1.63%	2.22%

On the other hand, GM_m and GM_a values for the benchmark hull C11 are also calculated with the help of a stability software and results are given in Table 3. Differences between Table 2 and Table 3 are given in Table 4.

In this study, Table 2 complies with related to document (SDC 5/INF.4 Annex

2.1. Calculation of Restoring Terms

For the restoring terms, seventh order polynomial is applied for more accurate representation. First, Gz-ϕ curve of the C11 is obtained with the help of a stability software, Maxsurf, Stability [19], as seen in Figure 1.

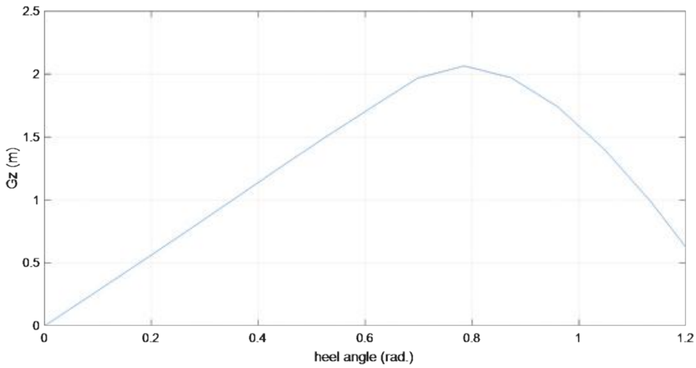

Figure 1. *Gz-ϕ Curve of C11*

Then, seventh order polynomial is fitted by using MATLAB software curve fitting toolbox as seen from Figure 2.

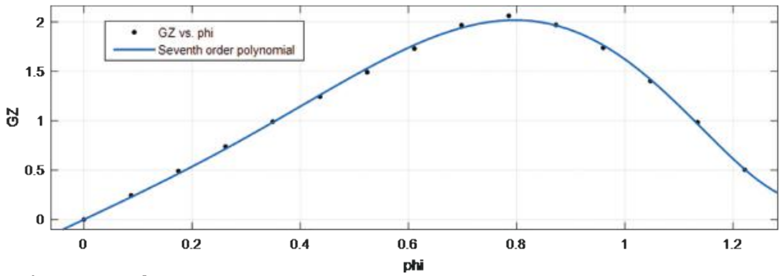

Figure 2. *Gz-ϕ Curve and Curve Fitting*

Related coefficients are calculated as in Table 5:

Table 5. *Coefficients for Restoring Terms*

a	0.6017
b	-1.8610
c	0.9087
d	0.9316

2.2. Calculation of Damping Terms

To evaluate damping terms, simplified prediction method is used. Method for determining linear and cubic roll damping coefficients by using the equivalent linear roll damping coefficients in Ikeda's simplified formula is given in related document (SDC 4/5/1/Add. Page 18) [20]. B1 (B_{44L}) and B3 (B_{44NL}) linear and cubic damping coefficients are found as presented in Table 6. It should be noted that Ikeda's simplified formula divides the equivalent roll damping into the frictional (B_F), the wave (B_W), the eddy (B_E) and the bilge keel (B_{BK}) components. These four components are calculated empirically according to Ikeda's formula at zero speed. On the other hand, the lift component (B_L) is added empirically to the total damping coefficient (the one which is obtained using Ikeda's empirical formula at zero speed) considering forward speed of the ship [17, 20]. It is interesting to note that the linear damping coefficient B1 increases as the forward speed of the ship increases since the lift damping is linear.

Here k denotes the speed factor. k=0 denotes zero forward speed, k=0.5 denotes 5.255 m/s forward speed, k=0.866 denotes 9.102 m/s and finally k=1 denotes service speed 10.51 m/s. Negative speed factor is only related to the heading angle which corresponds to following waves.

3. Simulation Studies

Parametric roll motion equation is solved for each of the ten effective wave heights and seven speeds. (Equation 1 is solved 70 times and time series of solution is obtained). Solution is performed numerically by using MATLAB-Simulink with the Runge Kutta solver at fourth order. Solution time is set to $T_\omega \times 15$ and time step size is set to $T_\omega / 40$. Encounter frequency is

Table 6. *Obtained Damping Coefficients Using Ikeda's Simplified Method*

k (speed factor)	-1	-0.866	-0.5	0	0.5	0.866	1
B1 (kNms)	503495	447860	295902	88308	295902	447860	503495
B3(kNms^3)	76833120	76833120	76833120	76833120	76833120	76833120	76833120

Table 7. *Encounter Frequencies*

k (speed factor)	-1 (following)	-0.866 (following)	-0.5(following)	0	0.5 (head)	0.866 (head)	1 (head)
ω_e (rad/s)	0.233	0.267	0.359	0.485	0.611	0.703	0.737

calculated as $\omega_e = \omega - k_0 V_s \cos(\chi)$ (see Table 7). Here ω is wave frequency and it is found by using dispersion relation in deep water ($\omega=\sqrt{2\pi g/\lambda}$). While λ is wavelength and it is equal to L_{pp} in our case, g denotes the gravity, k_0 denotes wave number ($k_0=2\pi/\lambda$) and χ denotes the heading angle.

Please note that Initial conditions are taken as identical in simulations. (ϕ = 0.0872 rad and $\dot{\phi}$ = 0 rad/s). Table 8 reveals the simulation parameters. For calculation of added mass value in roll motion, Bhattacharyya's method [21] which approximates the value of roll added mass %20 of the roll inertia moment is used.

Table 8. *Simulation Parameters*

I44+A44 (tonm^2)	23761121
B44L (kNms)	Depends on the case, see table 6
B44NL(kNms^3)	76833120
Δ (kN)	719549
GM_m	Depends on the case, see table 2
GM_a	Depends on the case, see table 2
a	0.6017
b	-1.8610
c	0.9087
d	0.9316
ω_e	Depends on the case, see table 7

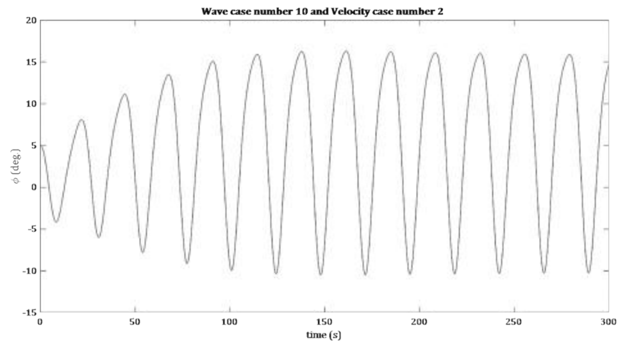

Figure 3. *Time Series of Roll Motion for the Case WS10, k=-0.866*

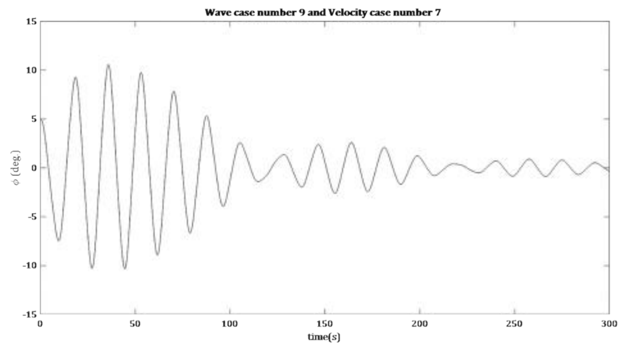

Figure 4. *Time Series of Roll Motion for the Case WS9, k=1*

Table 9. *Obtained Maximum Roll Angles as a Results of Seventy Simulations*

Speed Factor, k	maximum roll angle (deg.)									
	WS1	WS2	WS3	WS4	WS5	WS6	WS7	WS8	WS9	WS10
-1	5.0	5.0	5.0	5.3	5.6	5.9	6.1	6.3	6.4	6.3
-0.866	5.0	5.0	5.0	5.4	6.4	7.9	10.2	13.0	15.3	16.3
-0.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
0	5.6	6.6	7.5	8.5	10.6	12.8	15.6	17.3	18.3	18.0
0.5	5.3	16.5	28.2	32.0	34.7	37.1	39.0	40.7	42.1	43.5
0.866	5.0	5.0	5.7	6.6	7.4	8.6	11.9	28.0	31.1	33.3
1	5.0	5.0	5.0	5.5	6.2	6.9	7.7	8.5	10.5	26.0

Table 9 reveals maximum roll angles as a result of seventy simulations. In Table 9, WS depicts the wave case i.e. WS1 refers to wave case 1 (H_{eff} = 1.194m). Time series of the solution for WS10, k=-0.866 and WS9, k=1 are illustrated in Figure 3 and Figure 4, respectively.

4. Calculation of C2

C2 (Fn) is calculated as a weighted average from the set of waves given in Table 10 for a given Froude number and speed factor:

$$C2 = \left[\sum_{i=1}^{3} C2_h(Fn_i) + C2(0) + \sum_{i=1}^{3} C2_f(Fn_i) \right] / 7 \quad (3)$$

$$V_i = V_s k_i$$

k_i =1, 0.866, 0.5

$$C2_h(Fn) = \sum_{i=1}^{N} W_i C_i \quad (4)$$

$$C2_f(Fn) = \sum_{i=1}^{N} W_i C_i \quad (5)$$

$$C_i = \begin{cases} 0 & \phi_{roll,max} < 25 \deg \\ 1 & otherwise \end{cases} \quad (6)$$

W_i is the weighting factor for the respective wave, divided by the number of occurrence, and N is number of wave cases specified in Table 10. These formulations can also be found in [22].

Table 10. *Wave Case Occurrences [22]*

Hs(m)/ Tz(s)	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	sum
0.5	1.3	133.7	865.6	1186	634.2	186.3	36.9	5.6	0.7	0.1	0	0	0	0	0	0	3050.4
1.5	0	29.3	986	4976	7738	5569.7	2375.7	703.5	160.7	30.5	5.1	0.8	0.1	0	0	0	22575.4
2.5	0	2.2	197.5	2158.8	6230	7449.5	4860.4	2066	644.5	160.2	33.7	6.3	1.1	0.2	0	0	23810.4
3.5	0	0.2	34.9	695.5	3226.5	5675	5099.1	2838	1114.1	337.7	84.3	18.2	3.5	0.6	0.1	0	19127.7
4.5	0	0	6	196.1	1354.3	3288.5	3857.5	2685.5	1275.2	455.1	130.9	31.9	6.9	1.3	0.2	0	13289.4
5.5	0	0	1	51	498.4	1602.9	2372.7	2008.3	1126	463.6	150.9	41	9.7	2.1	0.4	0.1	8328.1
6.5	0	0	0.2	12.6	167	690.3	1257.9	1268.6	825.9	386.8	140.8	42.2	10.9	2.5	0.5	0.1	4806.3
7.5	0	0	0	3	52.1	270.1	594.4	703.2	524.9	276.7	111.7	36.7	10.2	2.5	0.6	0.1	2586.2
8.5	0	0	0	0.7	15.4	97.9	255.9	350.6	296.9	174.6	77.6	27.7	8.4	2.2	0.5	0.1	1308.5
9.5	0	0	0	0.2	4.3	33.2	101.9	159.9	152.2	99.2	48.3	18.7	6.1	1.7	0.4	0.1	626.2
10.5	0	0	0	0	1.2	10.7	37.9	67.5	71.7	51.5	27.3	11.4	4	1.2	0.3	0.1	284.8

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***Table 10.** Wave Case Occurrences [22] (Cont')*

Hs(m)/ Tz(s)	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	sum
11.5	0	0	0	0	0.3	3.3	13.3	26.6	31.4	24.7	14.2	6.4	2.4	0.7	0.2	0.1	123.6
12.5	0	0	0	0	0.1	1	4.4	9.9	12.8	11	6.8	3.3	1.3	0.4	0.1	0	51.1
13.5	0	0	0	0	0	0.3	1.4	3.5	5	4.6	3.1	1.6	0.7	0.2	0.1	0	20.5
14.5	0	0	0	0	0	0.1	0.4	1.2	1.8	1.8	1.3	0.7	0.3	0.1	0	0	7.7
15.5	0	0	0	0	0	0	0.1	0.4	0.6	0.7	0.5	0.3	0.1	0.1	0	0	2.8
16.5	0	0	0	0	0	0	0	0.1	0.2	0.2	0.2	0.1	0.1	0	0	0	0.9
sum	1.3	165.4	2091.2	9279.9	19921.8	24878.8	20869.9	12898.4	6244.6	2479	836.7	247.3	65.8	15.8	3.4	0.7	**100000**

For C2 calculation, maximum roll angles obtained from the simulations are updated by linear interpolation in the pre-computed values in Table 10. If the resulting maximum roll angle is larger than 25 degrees, weighting factor of the wave cases is added to C2. Final value of C2 is calculated as the average value of the seven intermediate coefficients as following:

$$C2 = \frac{0+0+0+0+17524+18.2+0.1}{100000 \times 7} = 0.0251$$

Since the value of C2 is lower than 0.06, the ship is considered to be invulnerable to parametric roll motion.

5. Results and Discussion

In this section, results of IMO and current study are compared to each other and presented in terms of maximum roll angles. Results are shown in Table 11. In Table 11, the coloured highlighted region is extremely important when considering the contribution to the C2 calculation since these values are close to 25 degrees (interpolation region).

***Table 11.** Comparison Study*

Speed Factor	**maximum roll angle (deg.) (Current Study)**									
-1	5.0	5.0	5.0	5.3	5.6	5.9	6.1	6.3	6.4	6.3
-0.866	5.0	5.0	5.0	5.4	6.4	7.9	10.2	13.0	15.3	16.3
-0.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
0	5.6	6.6	7.5	8.5	10.6	12.8	15.6	17.3	18.3	18.0
0.5	5.3	**16.5**	**28.2**	32.0	34.7	37.1	39.0	40.7	42.1	43.5
0.866	5.0	5.0	5.7	6.6	7.4	8.6	**11.9**	**28.0**	31.1	33.3
1	5.0	5.0	5.0	5.5	6.2	6.9	7.7	8.5	**10.5**	**26.0**
Speed Factor	**maximum roll angle (deg.) (IMO)**									
-1	4.59	4.93	5.16	5.31	5.42	5.49	5.54	5.56	5.56	5.55
-0.866	4.73	5.20	5.54	5.79	6.00	6.18	6.32	6.42	6.48	6.48
-0.5	5.03	5.71	6.35	6.88	7.40	7.90	8.40	8.83	9.27	9.64
0	5.63	7.21	8.71	10.09	11.48	12.92	14.19	15.19	16.00	16.40
0.5	4.41	**16.36**	**27.36**	35.38	42.99	48.53	50	50	50	50
0.866	4.00	3.91	3.96	4.02	4.11	5.97	**22.86**	**31.11**	37.52	42.19
1	3.89	3.73	3.73	3.75	3.81	3.90	4.00	4.12	**18.53**	**28.34**

Maximum roll angle differences between IMO and current results might differ by following reasons:

- Different calm water restoring representation.
- Different damping evaluation.
- Different added mass value in roll motion

It should be noted that the value of C2 was found 0.0251 in the related document as well ((SDC 5/INF.4 Annex 13, page 5) [18]. It means that the small variations in the solutions do not significantly affect the value of C2 as this value is obtained from interpolated data.

Remark: It should be noted that the solution of equation of motion is strictly dependent on the coefficients in the equation. For instance, if the experimental data for roll decay motion were available for forward speeds for related ship, it would be possible to obtain damping terms more accurately. Solution of Equation 1 is also related to added mass value in roll motion and the treatment of temporal nature of restoring terms. It should be noted that although Level 2 is less conservative compared to Level 1, it is more conservative compared to Level 3. For the cases that Level 2 is not satisfied, the direct assessment procedure based on numerical time domain solutions (3D panel methods in time domain or the state of art Unsteady Navier-Stokes Equations with suitable turbulence closure equations) should be applied to discover whether the ship is vulnerable to parametric roll motion.

6. Conclusion

In this study, the parametric roll motion for the benchmark container ship form C11 was analysed within the second generation stability criteria proposed by IMO. Damping terms in the motion of equation were calculated by using Ikeda's simplified method. Restoring terms were calculated with a stability software. Added mass in roll motion is approximated as %20 of the total roll inertia moment. Nonlinear one degree of freedom parametric roll motion equation was solved in the time domain with the appropriate initial conditions. Then, 'C2 assessment procedure' proposed by IMO was implemented to the benchmark hull C11 in order to obtain statistically parametric roll in irregular waves. Results showed that the hull is invulnerable for the parametric roll resonance. Since the application of Level 2 'C2 assessment procedure' represents the roll motion dynamics with a reasonable fidelity, this assessment procedure strongly recommended before direct stability assessment.

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Corresponding Author: Levent BİLGİLİ

The Social Cost and Environmental Life Cycle Analysis of Passenger Ships in Istanbul

Levent BİLGİLİ

Bandırma Onyedi Eylül University, Maritime Faculty, Turkey
lbilgili@bandirma.edu.tr; ORCID ID: https://orcid.org/0000-0001-9431-5289

Abstract

Calculating the inventory of shipping emissions is crucial in order to guide the authorities to prepare regulations on emission reduction. On the other hand, the effectiveness of the measurement techniques can only be accurately observed by the calculation of social costs. In this study, firstly, the emission inventory and social cost of passenger ships operating in Bosphorus are calculated. Then, these calculations were repeated in case of declaration of the Marmara Sea as Emission Control Area (ECA). The total amount of emissions in current situation decreases by 7.75 % in case of ECA declaration. The total cost of fuel switching increases approximately 39.52 %; however the total social cost decreases by 50.56 %. The total economic benefit is calculated as $ 117,739,686.97. According to the LCA results, fuel switching increases the deleterious impacts on human health, ecosystem quality and climate change, while the impacts on raw resources decreased.

Keywords: *Ship Emissions, Social Cost, Life Cycle Assessment.*

İstanbul'daki Yolcu Gemilerinin Sosyal Maliyet ve Çevresel Yaşam Döngüsü Analizi

Öz

Gemi emisyon envanterinin hesaplanması, emisyon azaltımı için gerekli düzenlemelerin yapılması için ilgili otoritelere kılavuzluk etmesi açısından çok önemlidir. Öte yandan, emisyonların etkilerinin kesin bir şekilde bilinmesi, bu emisyonların sosyal maliyetlerinin de hesabıyla mümkündür. Bu çalışmada ilk olarak İstanbul Boğazı'nda faaliyet gösteren yolcu gemilerinin emisyon envanteri ve bu emisyonların sosyal maliyetleri hesaplanmıştır. Ardından, bu hesaplamalar Marmara Denizi'nin Emisyon Kontrol Alanı (ECA) olarak ilan edilmesi durumu için tekrarlanmıştır. Bölgenin ECA olarak ilan edilmesi durumunda emisyonların mevcut duruma göre % 7,75 azaldığı görülmüştür. Yakıt değişimi nedeniyle toplam yakıt maliyeti % 39,52 oranında artmış, toplam sosyal maliyet ise % 50,56 oranında azalmıştır. Toplam ekonomik kazanç 117.739.686,97 $ olarak hesaplanmıştır. YDA sonuçlarına göre de yakıt değişimi, insan sağlığına, ekosistem kalitesine ve iklim değişikliğine olan zararlı etkileri artırırken ham kaynaklar üzerindeki zararlı etkileri azaltmıştır.

Anahtar Kelimeler: *Gemi Emisyonları, Sosyal Maliyet, Yaşam Döngüsü Analizi.*

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1. Introduction

Parametric roll is uIt is estimated that there are approximately 450 different ship exhaust-gas emissions [1]; however, only a small proportion of these emissions are considered to be a threat to human health and the environment, and some are taken into account because they are produced in large quantities even if they are environmentally harmless. The most environmentally significant components of ship emissions are carbon dioxide (CO2), sulphur dioxide (SO2), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM) and nitrogen oxides (NOx).

Ship-related CO2, NOx and sulphur oxides (SOx) emissions, caused by international shipping, account for 2.6 %, 15 % and 6.5 % of the total global emissions [2-4]. Although the percentage of these emissions have a little ratio comparing the world's total emission production, [5] stated that 70 % of the ships' emissions occurred at a distance of 400 km to the shore.

In this study, firstly, emission estimations for the ferries operating in Istanbul were calculated. Then, the economic, social and environmental results were analysed in case of declaration of the Marmara Sea as ECA.

2. Literature Review

A great number of comprehensive studies have been carried out over the last two decades, in particular on the formation, dispersion and environmental impacts of ship emissions. [6] conducted one of the first studies on the global ship emission inventory and focused mainly on NOx and SOx emissions. Based on the data of 1993, the amount of global NOx and SOx emissions from ship emissions was calculated as 3.08 and 4.24 Tg, respectively. [4], have recalculated global ship emissions based on engine power in their updated study and concluded that the amount of ship-related NOx emissions is 6.87 Tg. [7] calculated global ship-related emissions between 1925 and 2002 and found that ship-related SO2 and CO2 emissions increased by 3.4 and 2.8 times, respectively. [8, 9] reported that ship-related SO2 emissions in the Asian seas accounted for 0.7 % of the total SO2 emissions in the Asian continent and SO2 amount increased by 5.9 % in 1988-1995. [10] calculated ship-related emissions in the Bosphorus and the Dardanelles and found that total emissions in these two regions are 700,386 t. [11] have calculated that the amount of ship-related emissions is 5,680,275 t in the Marmara Sea as of 2003. According to the study conducted by [12], the amount of ship-related emissions in Ambarlı Port of Istanbul is 82,344 tons. [13] calculated the total ship-related emissions in the Gibraltar Strait for the year 2007 and the amount is 1,447,171.77 t. [14] have studied on four Portuguese ports and found that ship-related emissions increased by an average of 20% between 1990 and 2014. [15] have studied on four different ports in different regions of the world and they have found that the total greenhouse gas (GHG) production is 582,000 t as CO2 equivalent.

Besides global and regional studies, International Maritime Organization (IMO) published three significant and comprehensive studies on ship-related emissions. [16] calculated the total ship-related emissions by obtaining the total fuel consumption and investigated the geographic dispersion of these emissions. [17] included the abatement technologies, the future projections of ship-related emissions and the comparative assessment of ship-related CO2 emission with other transportation modes. [2] is the last and the most current publication and it roughly consists of the calculation of ship-related flue gas emissions for 2007-2012 and the future projections for 2012-2050. In addition, IMO has developed emission factors in all three studies.

In the past two decades, generally conventional estimation methods have been used to calculate ship-related emissions; however, the emissions are strongly depend on the ship motion and some other dynamic variables. Thus, innovative estimation methods are needed to achieve more accurate results. One of the first studies, which is based upon Automatic Identification System (AIS) data, was developed by [18]. The authors named the developed systems as Ship Traffic Emissions Assessment Model (STEAM) and it can calculate the ship-related emissions by using ship speed, engine load, fuel sulphur content, abatement technologies and wave effect. [19] used ship speed, engine revolution per minute (RPM), mean draft, trim, cargo amount, wind effect and sea effect as inputs in order to calculate fuel consumption. The authors developed an Artificial Neural Network (ANN). [20] developed some formulas by using nine bulk carriers' noon reports in order to estimate ship-related emissions as a function of deadweight (DWT) and block coefficient (CB). [21] developed an ANN methodology to calculate ship-related emissions as a function of voyage duration, engine RPM, ship speed, displacement, weather condition, sea condition and mean draft. It was found out that the difference between the real and estimated data is 1.57 %. The author has also concluded that there is a strong correlation between weather and sea conditions and emission amounts.

Additionally, some studies have focused on the geographic dispersion of ship-related emissions. [22] used satellite images and found that ship-related nitrogen dioxide (NO2) emissions were concentrated in the Persian Gulf, the Malacca Strait and the North China Sea. In a similar study, [23] found that NO2 emissions increased by 86 % from 2003 to 2008 and decreased by 24 % in 2008-2009 due to slowing ship traffic because of the global crisis. [24] studied on global dispersion of ship-related CO2 emissions for 2015. According to the results, container vessels are mostly concentrated in East Asia, tankers in East Asia and the Arabian Peninsula, cruise ships in the Caribbean region and fishing vessels in the North Atlantic.

Although the estimation of ship emissions by conventional or innovative methods, emission inventory preparation and geographical distribution of ship emissions provides very useful information on the control of these emissions, the financial statements generated by ship-related emissions should be examined separately and in detail. Social costs of the emissions includes the impacts of emissions to the human health and the environment. [25] describes the social cost as "changes in net agricultural productivity, human health, property damages from increased flood risk and the value of ecosystem services". [26] calculated that the amount of ship emissions from ship operations in some ports of Greece is 2742.7 t and emissions yielded a cost of € 18 million to public health. [27] concluded a similar study for the Port of Bergen in Norway and concluded that ship emissions accounted for around € 16 million. [28] examined the Shanghai Port of China, and the total amount of emissions in the port is 598,460 t, while the total cost of the emissions calculated as $ 286,748,496 million. [29] conducted studies for the port of Kotor (Montenegro) and Dubrovnik (Croatian), and found that ship emissions for the Port of Dubrovnik and Kotor were $ 7.9 and $ 3.6 million, respectively. [30] conducted a study on Piraeus Port of Athens, Greece and it was found that the external costs of shipping emissions is approximately € 51 million, annually. [31] calculated the economic cost of NOx and SO2 in the United States for 1993-2001. The results show that the externalities for NOx and SO2 are $ 256 and $ 412 million, annually and respectively. [32] examined the externalities of shipping emissions in the Gulf of Finland. The authors estimated that the average externalities except CO2 is approximately $ 52,143,709 for 2007-2015. [33] indicated that total externalities of Greek shipping emissions reached € 3.1 billion and this value corresponds 1.7 %, 6.8 % and 28.8 % of the costs incurred globally, within the European seas and the Mediterranean, respectively. [34] have also investigated the total external costs of shipping for different pollutant categories such as marine pollution, air quality and GHG's.

3. Regulations on Reducing Ship-Related Emissions

While environmental, economic and health risks of ship emissions are a major problem today, it is obvious that in case of not taking adequate measures, more serious problems will be faced in the future. Important steps have been taken to control ship emissions through international and national studies.

[35] realized a future projection based upon the Special Report on Emission Scenarios (SRES), which was prepared by Intergovernmental Panel for Climate Change (IPCC), and estimated that the total fuel consumption of ships will increase from 280 t to 536 t, at least. In addition, Table 1 presents the future projections of IMO for different emissions.

As it can be seen in Table 1, the general trend of the emissions is to increase by years. CO2, NOx and CO emissions are estimated to increase by 78 %, 46 % and 126 %, respectively in 2050 according to the base value of 2012. On the other hand, it is estimated that SOx and PM emissions are estimated to decrease by 75 % and 30 % in the same period. It is because of Emission Control Areas (ECA).

Table 1. *IMO Projections for Different Pollutant Types [2]*

Pollutant Types	2012 Index (2012=100)	2020 Index (2012=100)	2050 Index (2012=100)
CO_2	100	107	178
NO_x	100	103	146
SO_x	100	60	25
PM	100	71	70
CO	100	118	226

ECA's are identified by IMO based upon Regulation 13 (NOx) and 14 (SOx and PM) of International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI. ECA's are special sea areas in which stricter regulations are in force especially on sulphur content of marine fuels. While current sulphur content limit is 3.5 %mass for other sea areas, the current limit for ECA is 0.1 %mass. While the West and East Coasts of United States and Canada and the coasts of Hawaii are identified ECA for both Regulation 13 and Regulation 14, the Baltic Sea and the North Sea areas are identified as ECA for only Regulation 14. Besides, Regulation 12, Regulation 15, Regulation 16 and Regulation 18 of MARPOL Annex VI are about ozone depleting substances, volatile organic compounds, shipboard incineration and fuel oil availability and quality, respectively. The NOx limitations indicated in Regulation 13 are presented in Table 2.

The first studies of European Commission (EC), which was prepared on the sulphur content of certain liquid fuels, was published in 1993 with the name of Directive 93/12/EEC. This directive was completely about Greek fleet and it is briefly mentioned that Greek fleet must obey the rules which are determined by the port state. Directive 1999/32/EC brought some new rules for sulphur content of marine fuels and it was indicated that the regulations of EC must be in unison with MARPOL restrictions. Directive 2005/33/EC is the first comprehensive publication of EC on marine fuels. The directive firstly

Table 2. *NO_x Limitations*

Tier	NO_x Limit	RPM
Tier I (01.01.2001-01.01.2011)	17 g kWh-1 45 x n-0.2 g kWh-1 9.8 g kWh-1	n<130 130<n<2000 n>2000
Tier II (After 01.01.2011)	14.4 g kWh-1 44 x n-0.23 g kWh-1 7.7 g kWh-1	n<130 130<n<2000 n>2000
Tier III (After 01.01.2016)	3.4 g kWh-1 9 x n-0.2 g kWh-1 3 g kWh-1	n<130 130<n<2000 n>2000

identifies the general information and potential threats of marine fuels and explains solution proposals in general. The directive is generally in unison with MARPOL requirements and defines an exception for military vessels. Rules on trial and use of new emission abatement technologies are also determined. Directive 2012/33/EU includes some amendments and additional substances to Directive 1999/32/EC. According to the directive, the sulphur content of ship fuels cannot exceed 0.5 % in the European Economic Zone after 2020. The last study of European Union (EU) on shipping emissions was published with the name of Directive (EU) 2016/802, which includes some new identifications and regulations. It is important to see that EU directives have generally strong bounds with MARPOL and it can be said that EU follows IMO to determine its own regulations [36].

As a result of these preventive rules, [37] stated that the SO2 release in European ports decreased by 66 %, but no such reduction was observed in the Tunisian ports which were not subject to any restrictive directive. On the other hand, [38] and [39] stated that the issue of emission reduction could have hidden effects and that the financial dimension of these studies should be well investigated.

4. Materials and Methods

In this study, passenger ships, which are actively operated in Bosphorus and Istanbul shores of the Marmara Sea, are investigated for the years 2011-2016. The ships had a total of 9882 trips during the six-year period. The data was obtained from the database of the company. Besides, the fuel consumption of the ships were also obtained from the company.

There are several methods for estimating ship-related airborne emissions. In this study, fuel consumption (FC) method was used. The formula for FC method was offered by [40] and presented below:

$$E_{Trip,i,j,m}=\Sigma_p(FC_{j,m.p} \text{ X } EF_{i,j,m,p}) \quad (1)$$

E_{Trip} :Total emission (t)
FC :Fuel consumption (t)
EF :Emission factor (g/t fuel)
i :Pollutant type
j :Engine type
m :Fuel type
p :Voyage stages

Emission factors for different pollutants, tiers and different fuel types (Heavy Fuel Oil-HFO and Marine Gas Oil-MGO) are given in Table 3. In the table, the factors of pollutants except NOx are based on the fuel type, while NOx factor also depends on the tier, which is identified by IMO according to the built year, of the engine. The emission amounts were calculated by multiplying the emission factors and fuel consumption.

Table 3. *Emission Factors (t/t fuel) [41]*

Pollutant	Tier	HFO	MGO
CO_2		3.179	3.179
SO_2		0.054	0.002
CO		0.0051	0.0053
HC		0.0009	0.001
PM		0.00233	0.00098
NO_x	No Tier Tier I	0.0617 0.0498	0.0632 0.0549

The emission factors of CO2 for both fuels are the same due to the same carbon content of the fuels [41]. The ferries currently use HFO; however, if fuel switching would be mandatory in order to be in accordance with ECA regulations, the ferries should switch their fuels to MGO. Table 4 presents the HFO and MGO average annual prices for 2011-2016 period.

Table 4. *HFO and MGO Prices for Years ($/t fuel) [42]*

Years	HFO	MGO
2011	467.48	665.49
2012	606.56	915.77
2013	686.00	986.06
2014	632.44	946.55
2015	614.81	920.75
2016	367.55	589.53

The social cost of the emissions can be calculated as follows:

$$\textit{Social cost} = \Sigma_i\ \textit{Emission}_i \times \textit{Cost Factor} \quad (2)$$

Table 5 presents the estimated average social costs of ship-related emissions. The average values of cost factors were taken from [28], in which the author utilized a very wide range of previous studies. The average of social costs of previous studies is selected due to the difficulty to decide the most suitable cost factors for different studies. Because there are significant constraints and due to the different conditions for each region, it was determined to use the average values of previous global studies.

Table 5. *Social Costs of Pollutants ($/t pollutant)*

Years	Value ($/t Pollutant)
2011	28.5
2012	32,688
2013	1,680
2014	2,287
2015	250,395.5
2016	29,284.5

Finally, a Life Cycle Assessment (LCA) were realized for both fuel types to estimate the realistic impacts of utilization of the fuels. The LCA calculations includes the production process of the fuels, mainly. In this study, SimaPro 8.2.3.0 package program, Ecoinvent 3 library and IMPACT 2002+ method were used for LCA calculations. IMPACT 2002+ Developed in 2002 by the Swiss Federal Institute of Technology, it was designed to establish a link between the 14 categories and 4 damage categories. Damage categories are defined as human health, ecosystem quality, climate change and resources. Although the middle categories provide comprehensive information on LCA analysis, there are difficulties in expressing the potential losses in an understandable and simple manner. Damage categories make it possible to understand the damages of products, systems or services to human health and the environment. The LCA calculations processes were based upon the ISO 14040:2006 standards. First, a functional unit was defined in order to determine the restrictions of the system. Then, the Life Cycle Inventory Analysis (LCI) was determined and defined. Finally, the Life Cycle Impact Assessment (LCIA) calculations were realized in accordance with the definitions in the standard.

The functional unit used in LCA is fuel in tons. The calculations were restricted with the production of the fuels due to the lack of utilization process in SimaPro program. The LCA was used to calculate the impacts of the total fuel consumption between 2011-2016.

5. Results and Discussion

In the first part of the study, the current and projected emission inventory was calculated for the years 2011-2016 via fuel consumption data of the ships and assuming that the ships used HFO. In case of declaration of the Marmara Sea as ECA, the ships will have to use MGO as fuel. The emissions calculated according to the years are presented in Table 6.

Table 6. *Current and Projected Emission Inventory (t)*

CostCase/Pollutant Types	CO_2	SO_2	CO	HC	PM	NO_x
Current Emissions (2011-2016)	199,372.97	3,386.64	319.85	56.44	146.13	3,659.01
Projected Emissions	186,766.25	117.50	311.37	58.75	57.57	3,575.43

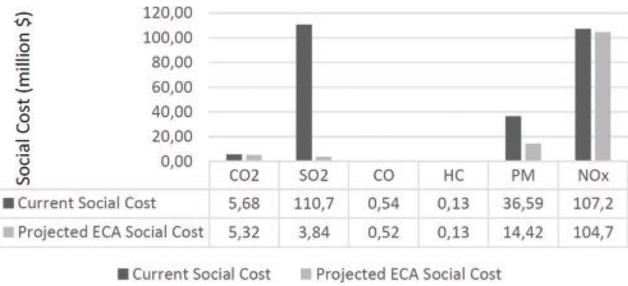
It is clearly seen in Table 6 that if the Marmara Sea have been declared as ECA, a significant emission reduction would be observed except for the HC Emissions. Possible reduction rates for CO2, SO2, CO, PM and NOx were found as 6.32 %, 96.53 %, 2.49 %, 60.6 % and 2.28 %, respectively.

[43], in his calculations for the North Sea, stated that after the ECA announcement of the region, there was a significant decrease in SO2 and sulphate (SO4) emissions but nitrate (NO3) emissions increased. [44] also found that the SO2 emissions in the Rotterdam Port, which is located in the ECA region, were at very low rates as expected. [37] stated that the SO2 reduction in European ports operated in accordance with EC rules is at 66 %, but no such reduction has been observed in Tunisia Port, which is not subject to any emission reduction rules.

The declaration of the Marmara Sea as ECA would provide a significant reduction in ship-related emissions; however, as noted by [38] and [39], emission reduction processes have several other effects.

While the current total social costs are $ 260.8 million for HFO usage, it would be reduced to $ 128.9 million in case of declaration of ECA. On the other hand, while the total cost of HFO was $ 35.7 million, the total cost for switching to MGO was calculated as $ 49.8 million. Thus, the total benefit of fuel switching due to ECA regulations in the Marmara Sea is estimated as $ 117.7 million. Figure 1 presents the comparison of social costs in case of fuel switching for different pollutants.

Compared with the previous studies



	CO2	SO2	CO	HC	PM	NOx
Current Social Cost	5,68	110,7	0,54	0,13	36,59	107,2
Projected ECA Social Cost	5,32	3,84	0,52	0,13	14,42	104,7

Figure 1. *Current and Projected Social Costs (Million $)*

realized by [26-33], the results show that the social costs of operation of passenger ships could not be underestimated.

The results of the LCA calculations for fuels are given in Figure 2.

Figure 2. *The LCA Results of Fuel Switching*

It is seen in Fig. 2 that 53.3 % of the deleterious impacts of the fuels caused by MGO. Similarly, MGO constitutes the 52.78 % and 54.25 % of the harmful impacts of ecosystem quality and climate change, respectively. Only the impacts on the resources are higher for HFO.

Here, DALY is defined as a healthy life lost due to various processes [45]. In DALY calculations, it is assumed that each individual has a healthy life expectancy. This period may decrease over time due to various factors. DALY is an expression of this loss of wellness [46]. The PDF x m^2 x yr unit is an expression of the species expected to be lost for 1 year in the 1 m^2 piece of earth. Kg CO2 eq is a unit in which the effects of various gases are measured in CO2 in terms of climate change, while MJ is the expression of the energy consumed when extracting or processing resources [47].

It is observed that although the total emission amounts are decreasing, the negative impacts of fuel switching on human health and climate change are increasing. It is because the consideration of LCA calculations of fuel manufacturing processes. Although only a few types of air emissions have been calculated for emission estimations, many pollutants are emitted to soil, water and air during the processes for the production of each type of fuel. Considering the cumulative effects of all these wastes, it is concluded that the total positive effects of fuel switching is actually limited. Furthermore, even negative effects may occur more.

However, since the social costs of all types of pollutants are impossible to calculate, fuel switching is accepted as a partially successful method. Although it is possible to investigate different types of fuels with more comprehensive LCA models, these calculations are out of focus of this study.

6. Conclusions

As one of the largest cities in the world, Istanbul is the centre of a large population movement throughout the day. The unique location of Istanbul, which is considered as an important intersection point of land, sea and air ways, makes the city one of the most dense and especial waterways. Bosphorus, which is a part of Turkish Straits that connects the Black Sea and the Mediterranean, is not only an indispensable waterway for trade ships but also an effective alternative for passengers of Istanbul. Besides, a notable population of Istanbul live in districts which are located near Bosphorus. In this respect, the shipping activities in Bosphorus have importance on social, economic and environmental issues.

In this study, passenger ships that are operating in Bosphorus and the Istanbul shores of the Marmara Sea are investigated and the emission inventory for 2011-2016 is calculated.

Then, the social cost of these emissions is estimated. The estimations are repeated for the potential declaration of the Marmara Sea as ECA.

The obtained results show that ECA declaration increases fuel costs approximately 39.52 %; however, the total social costs decrease about 50.56 %. It is also calculated that the total benefit for fuel switching is $ 117,739,686.97. In addition, the cumulative effect of fuel change on human health, ecosystem quality and climate change appears to be negative;

however, the impossibility of social cost calculations for all types of pollutants makes the realistic calculations unfeasible. Therefore, the fuel switching can be used as a partially appropriate emission abatement technique, at least for now.

The fuel and social cost calculated in this study cover passenger ships, which constitute a small part of the total traffic in the Bosphorus, which is a small part of the Turkish Straits System that consists of the Bosphorus and Dardanelles and the Marmara Sea. Besides, these calculations did not cover the direct impacts on human health and some other costs to the environment. Therefore, considering that the total shipping activities are much higher than passenger ship traffic, a holistic approach (in terms of social, environmental, economic and health) to this issue clearly shows that declaration of the Marmara Sea as ECA would provide countless benefits to Turkish and world economy. This study is a guiding first step for a further study which aims to create an emission and social cost inventory for the Marmara Sea and it is planned to be widened and enriched to cover all shipping activities in the Turkish Straits System. In addition, LCA and Life Cycle Cost (LCC) calculations of alternative fuel types for ships are also planned.

Acknowledgements

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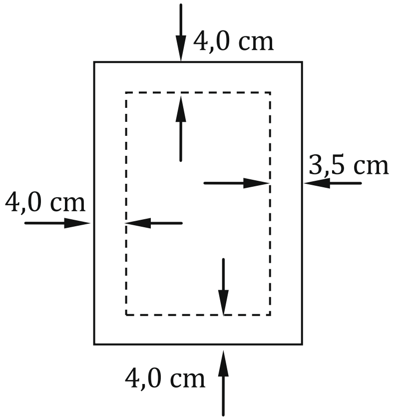

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Table 1. *Sample Table*

Turkish Male Seafarers (n = 131.152)	BMI < 25,0	BMI 25 - 30	BMI ≥ 30	Number of Participants
16-24 Ages Group	74,1%	22,5%	3,4%	34.421
25-44 Ages Group	44,1%	43,3%	12,6%	68.038
45-66 Ages Group	25,6%	51,1%	23,4%	28.693
All Turkish Male Seafarers	47,9 %	39,6 %	12,5%	131.152
Turkish Male Population*1	47,3 %	39,0 %	13,7 %	-

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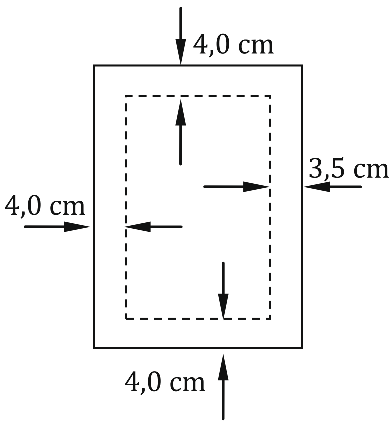

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Tablo 1. *Örnek Tablo*

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Turkish Male Population*1	47,3 %	39,0 %	13,7 %	-

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The objective judgment evaluation is always done by them. The reviewers express their views clearly with appropriate supporting arguments.

Acknowledgement of Sources

Reviewers ought to identify relevant published study that has not been cited by the authors. Reviewers also call to the editor's attention any substantial similarity or overlap between the manuscript and any other published paper of which they have personal knowledge.

D. DUTIES OF AUTHORS:

Reporting Standards

A submitted manuscript should be original and the authors ensure that the manuscript has never been published previously in any journal. Data of the research ought to be represented literally in the article. A manuscript ought to include adequate detail and references to allow others to replicate the study.

Originality

The authors who want to submit their study to the journal must ensure that their study entirely original and the words and sentences getting from literature should be appropriately cited.

Multiple Publications

Authors should not submit the same study for publishing any other journals. Simultaneous submission of the same study to more than one journal is unacceptable and constitutes unethical behavior.

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Convenient acknowledgment of the study of others has to be given. Authors ought to cite publications that have been efficient in determining the study. All of the sources that used process of the study should be remarked.

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Authorship of a paper ought to be limited to those who have made a noteworthy contribution to study. If there are others who have participated process of the research, they should be listed as contributors. Authorship also includes a corresponding author who is in communication with editor of a journal. The corresponding author should ensure that all appropriate co-authors are included on a paper.

Disclosure and Conflict of Interest

All sources of financial support should be disclosed. All authors ought to disclose a meaningful conflict of interest in the process of forming their study.

Fundamental Errors in Published Works

If authors find out a remarkable error in their submitted study, they have to instantly inform it. Authors have a liability to cooperate with editor to provide corrections of errors.

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A. DERGİ İMTİYAZ SAHİBİNİN SORUMLULUKLARI:

Editoryal Bağımsızlık

JEMS, herhangi bir kimse veya ticari ortaklarının etkisi olmadan editoryal kararların bağımsızlığının sağlanmasını taahhüt etmektedir.

Fikri Mülkiyet ve Telif Hakkı

JEMS, dergide yayımlanan makalelerin mülkiyet ve telif haklarını korur ve her makalenin yayımlanmış versiyonunun kaydını sağlamaktadır. JEMS, yayımlanmış her makalenin bütünlüğünü ve şeffaflığını sağlamaktadır.

Bilimsel Suiistimal

JEMS, hileli yayın veya yayıncı intihali ile ilgili olarak daima uygun tedbirleri almaktadır.

B. EDİTÖRÜN SORUMLULUKLARI:

Yayın ve Sorumluluk Kararı

JEMS editörü, dergideki her şeyi kontrol altında tutmaktadır ve okuyucuların ile yazarların ihtiyaçlarına cevap vermek için çaba göstermektedir. Editör ayrıca,

dergiye gönderilen makalelerden hangilerinin dergide yayınlanacağının ve hangilerinin onur kırıcı yayın, telif hakkı ihlali ve intihal ile ilgili yasal gerekliliklere tabi politikalarla karar verilmesinden sorumludur. Editör, yayın kararı verilirken hakemler ile müzakere edebilir. Editör, içerik ve genel olarak yayın kalitesinden sorumludur. Editör adil ve uygun bir hakem süreci sağlamalıdır.

Tarafsızlık

Dergiye gönderilen makaleler daima, herhangi bir önyargı olmaksızın değerlendirilmektedir.

Gizlilik

Dergiye gönderilen bir makale ile ilgili herhangi bir bilgi, editör tarafından yayın kurulu, hakemler ve dergi sahibi dışında herhangi bir kimseye ifşa edilmemelidir.

Çıkar Çatışmaları ve İfşa Etme

JEMS editörü yazarlar, hakemler ve editörler gibi taraflar arasındaki herhangi çıkar çatışmalarına izin vermez. Dergiye gönderilen bir makaledeki yayınlanmamış materyaller, yazarın sarih bir yazılı onayı olmadan herhangi biri tarafından kullanılmamalıdır.

C. HAKEMLERİN SORUMLULUKLARI:

Değerlendirme

Hakemler yazarların kökeni, cinsiyeti, cinsel eğilimi veya siyasal felsefesine bakılmaksızın eserleri değerlendirmektedirler. Hakemler ayrıca, dergiye gönderilen metinlerin değerlendirilmesi için adil bir kör hakemlik süreci sağlamaktadırlar.

Gizlilik

Dergiye gönderilen makalelere ilişkin tüm bilgiler gizli tutulmaktadır. Hakemler, editör tarafından yetkilendirilmiş olanlar dışında başkaları müzakere etmemelidir.

İfşa Etme ve Çıkar Çatışması

Hakemlerin; yazarlar, fon sağlayıcılar, editörler vb. gibi taraflar ile menfaat çatışması bulunmamaktadır.

Editöre Destek

Hakemler, karar verme aşamasında editörlere yardım ederler ve ayrıca metinlerin iyileştirilmesinde yazarlara yardımcı olabilmektedirler.

Tarafsızlık

Objektif bir karar değerlendirmesi, daima hakemler tarafından yapılmaktadır. Hakemler, uygun destekleyici iddialarla, açık bir şekilde görüşlerini ifade etmektedirler.

Kaynakların Referansı

Hakemler ayrıca, kendi bilgileri dahilindeki yayınlanmış diğer herhangi bir makale ile dergiye gönderilen metin arasında herhangi önemli bir benzerlik veya örtüşme ile ilgili olarak editörü bilgilendirmelidir.

D. YAZARLARIN SORUMLULUKLARI:

Bildirme Standartları

Dergiye gönderilen bir metin özgün olmalıdır ve yazarlar, metnin daha önce herhangi bir dergide yayınlanmamış olmasını sağlamalıdırlar. Araştırmanın verileri, makalede tam olarak belirtilmelidir. Dergiye gönderilen bir metin, başkalarının çalışmayı türetmesine izin vermek üzere yeterli detay ve referansları içermelidir.

Özgünlük

Çalışmalarını dergiye göndermek isteyen yazarlar, çalışmalarının tamamen özgün olmasını sağlamalıdır ve literatürden elde edilen kelimeler ile cümleler uygun bir şekilde alıntılanmalıdır.

Birden Fazla Yerde Yayın

Yazarlar, aynı çalışmayı herhangi bir başka dergide yayınlanmak üzere

göndermemelidirler. Aynı çalışmanın birden fazla dergiye eş zamanlı gönderilmesi etik olmayan bir davranış teşkil etmektedir ve kabul edilemez.

Kaynakların Referansı

Başkalarının çalışmalarıyla ilgili olarak uygun referanslar verilmelidir. Yazarlar, çalışmalarının belirlenmesinde etkili olmuş yayınlara referans vermelidirler. Çalışma sürecinde kullanılan kaynakların tümü belirtilmelidir.

Makale Yazarlığı

Makale yazarlığı, çalışmaya kayda değer katkıda bulunan kişilerle sınırlı olmalıdır. Araştırma sürecine katılan başkaları var ise, bu kişiler katkıda bulunanlar olanlar listelenmelidir. Yazarlık ayrıca, derginin editörü ile iletişim halinde olan yazışmadan sorumlu olan bir yazar içermelidir. Yazışmadan sorumlu yazar, tüm yardımcı yazarların makaleye dahil olmasını sağlamalıdır.

İfşa Etme ve Çıkar Çatışması

Finansal destek ile ilgili tüm kaynaklar açıklanmalıdır. Tüm yazarlar, çalışmalarının oluşturulması sürecinde yer alan çıkar çatışmasını ortaya koymalıdırlar.

Yayınlanmış Çalışmalardaki Temel Hatalar

Yazarlar göndermiş oldukları çalışmalarında dikkat çekici bir hata bulduklarında, bu hata ile ilgili olarak derhal dergiyi bilgilendirmek zorundadırlar. Yazarların, hataların düzeltilmesini sağlamak üzere editör ile birlikte çalışma yükümlülükleri vardır.

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