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Research Article
Turkish Journal of Maritime and Marine Sciences

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A Comprehensive Genome Mining Analysis of Biosynthetic Gene Clusters in *Pseudomonas* sp. SXM-1

Pseudomonas sp.'deki Biyosentetik Gen Kümelerinin Detaylı Genom Madenciliği Analizi

Türk Denizcilik ve Deniz Bilimleri Dergisi

Cilt: 11 Sayı: 2 (2025) 82-94

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ABSTRACT

Very resistant pathogenic microorganisms have been reported to current antibiotics in the last decade. Therefore, there is a great need to understand not only resistance metabolism but also secondary metabolites of pathogenic microorganisms. Genome mining tools have so far been improved to understand secondary metabolites from biosynthetic gene clusters. Microorganisms whose genomes and secondary metabolites are predicted by these tools are widely used in the pharmaceutical and industrial studies. *Pseudomonas* spp. are widely used in recombinant DNA technology to produce commercial products. Bioinformatics-based *in silico* tools significantly contribute to the discovery of new bioactive compounds for pharmacy and medicine. This study aims to conduct a comprehensive gene cluster analysis of the *Pseudomonas* sp. SXM-1 strain isolated from the coastal seawater of Xiamen Bay using antiSMASH (7.0.1). The accession number of *Pseudomonas* sp. SXM-1 strain was retrieved from NCBI. 14 regions were found, including non-ribosomal peptides metallophores (NRP-metallophore), nonribosomal peptide-synthetase (NRPS), NRPS-like, ribosomally synthesized and post-translationally modified peptide-like (RiPP-like), betalactone, nonribosomal peptide-synthetase (NRPS), ectoine and N-acetylglutaminylglutamine amide (NAGGN). Analysis of all 14 regions revealed secondary metabolites with potential applications in diverse fields. Microbiologists are strongly advised to conduct wet-lab experiments to validate the secondary metabolites discussed in this study.

Keywords: antiSMASH, biosynthetic gene cluster, genome, *Pseudomonas* sp. SXM-1

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ÖZET

Son on yılda mevcut antibiyotiklere karşı çok dirençli patojen mikroorganizmaların olduğu rapor edilmiştir. Bu nedenle patojenik mikroorganizmaların sadece direnç metabolizmasını değil aynı zamanda sekonder metabolitlerini de anlamaya büyük ihtiyaç vardır. Günümüze kadar biyosentetik gen kümelerindeki sekonder metabolitleri ortaya çıkarmaya yönelik genom madenciliği araçları geliştirilmiştir. Bu araçları kullanarak genomları ve sekonder metabolitleri tahmin edilen mikroorganizmalar, farmasötik ve endüstriyel çalışmalarda yaygın olarak kullanılmaktadır. *Pseudomonas* spp. ticari ürünler üretmek için rekombinant DNA teknolojisinde yaygın olarak kullanılmaktadır. Biyoenformatik tabanlı *in silico* araçları, eczacılık ve tıp için yeni biyoaktif bileşiklerin keşfedilmesine önemli ölçüde katkıda bulunmaktadır. Bu çalışma, AntiSMASH (7.0.1) kullanılarak Xiamen Körfezi'nin deniz suyundan izole edilen *Pseudomonas* sp. SXM-1 suşunun kapsamlı bir gen kümesi analizini yapmayı amaçlamaktadır. *Pseudomonas* sp.'nin erişim numarası NCBI'dan alınmıştır. Ribozomal olmayan peptitler metaloforlar (NRP-metalofor), ribozomal olmayan peptit sentetaz (NRPS), NRPS benzeri, ribozomal olarak sentezlenmiş ve translasyon sonrası modifiye edilmiş peptit benzeri (RiPP benzeri), betalakton, ribozomal olmayan peptit sentetaz (NRPS), ektoin ve N-asetilglutaminilglutamin amid (NAGGN) dahil olmak üzere 14 bölge bulunmuştur. 14 bölgenin genom analizi, farklı alanlarda potansiyel uygulamalara sahip sekonder metabolitleri ortaya çıkarmıştır. Mikrobiyologlara bu çalışmada tartışılan sekonder metabolitleri doğrulamak için laboratuvar deneyleri yapmaları şiddetle tavsiye edilir.

Anahtar sözcükler: antiSMASH, biyosentetik gen kümesi, genom, *Pseudomonas* sp. SXM-1

1. INTRODUCTION

The development of *in silico* tools for genome mining paves the way for improved prediction of secondary metabolites. Simple chemical substances known as antibiotics have the ability to specifically and selectively destroy infectious bacteria. Natural products, whether natural, synthetic, or semi-synthetic, have potential to treat infectious diseases in their original or modified forms. Macromolecules are also obtained from various microorganisms and plants (Arulprakasam and Dharumadurai, 2021). Fungal and bacterial secondary metabolism has potential pharmaceutical applications such as cholesterol-lowering drugs, antitumor drugs, and antibiotics (Keller, 2019; Ramírez-Rendon *et al*., 2022). *In silico* tools are good options for genome mining because it takes time and effort to find each set of genes experimentally. antiSMASH is one of these tools and provides *in silico* analysis related to secondary metabolite compound clusters as terpenes, polyketides, non-ribosomal peptides, siderophores and others (Medema *et al*., 2011). *Pseudomonas* genus is a non-fermentative, gram-negative, gamma proteobacteria (Ye *et al*., 2013). The widespread presence of these microorganisms is indicative of the diversity of secondary metabolites of fluorescent *Pseudomonas* spp. Guo *et al*. (2021) isolated *Pseudomonas* sp. SXM-1 from the seawater of Xiamen Bay (China). They fully characterized a siderophore using antiSMASH technology. However, a new version of antiSMASH (7.0.1) revealed novel biosynthetic gene clusters and related secondary metabolites. This study presents a comprehensive biosynthetic gene cluster analysis of *Pseudomonas* sp. SXM-1.

2. MATERIALS AND METHODS

The NCBI accession number of *Pseudomonas* sp. SXM-1 strain is CP038001.1. The antiSMASH tool is used to identify biosynthetic gene clusters or secondary metabolite biosynthesis gene clusters (Blin *et al*., 2021). The default parameters were used for the antiSMASH analysis with relaxed detection strictness.

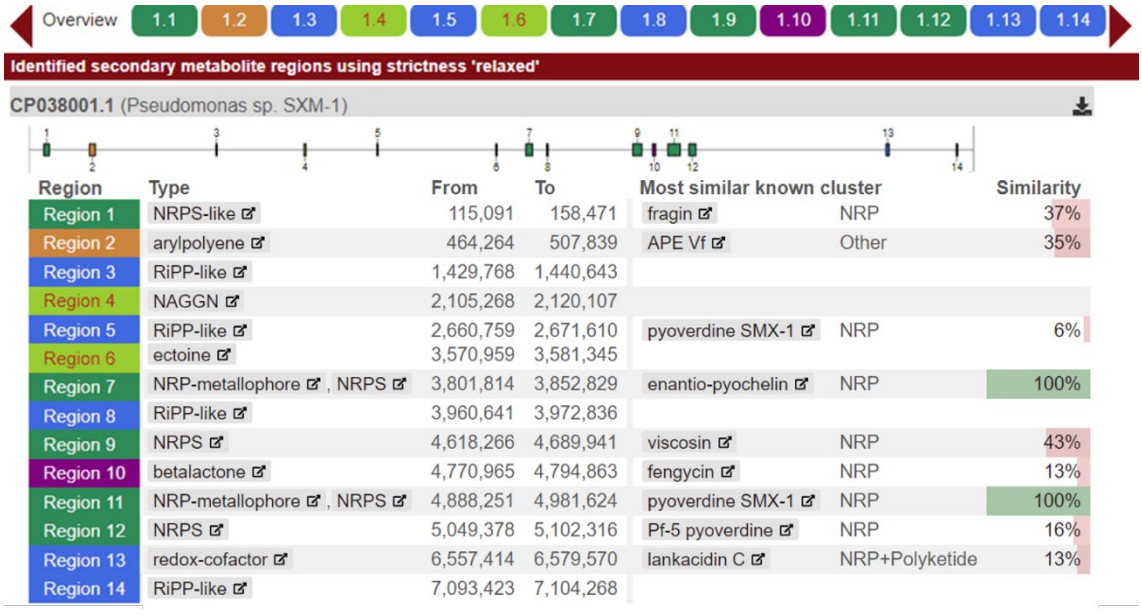
3. RESULTS

AntiSMASH analysis was used to determine secondary metabolites of *Pseudomonas* sp.

SXM-1 genome. Biosynthetic gene regions were identified as Non-ribosomal peptides metallophores (NRP-metallophore), nonribosomal peptide-synthetase (NRPS), NRPS-like, ribosomally synthesized and post-translationally modified peptide-like (RiPP-like), betalactone, nonribosomal peptide-synthetase (NRPS), ectoine and N-acetylglutaminylglutamine amide (NAGGN). NRPSs are modular mega enzymes that function via multiple covalent-linked domains. Adenylation (A), thiolation (T), and condensation (C) are minimal set for biosynthesis of non-ribosomal peptides. Adenylation results in hydrolysis of ATP. The C domain mediates the formation of peptide bonds in two adjacent modules. NRPS-like enzymes catalyze various reactions such as Dieckmann cyclization, reduction, and Claisen condensation (Shi *et al*., 2021). RiPPs are a large group of structurally diverse natural products (Ortega and van der Donk, 2016). Betalactone is a four-membered heterocyclic compound with a high ring strain, high electrophilicity, and good reactivity. Actinobacteria and fungi are responsible for a large portion of its natural products and many of them have powerful medicinal properties (Wang and Yao, 2022). Ectoine, as a highly water-retaining compound that stabilizes biomolecules and entire cells, can be used in scientific studies, cosmetology, and medicine (Reshetnikov *et al*, 2011).

According to Figure 1, 14 genomic regions were obtained from *Pseudomonas* sp. SXM-1 genome based on antiSMASH analysis.

In Figure 2, it is shown that region 1.1 includes NRPS-like gene proteins that have many functions in primary and secondary metabolism. It is located between 115,091 -158,471 nt. There are transcriptional regulator GcvA, acyl-CoA dehydrogenase gene, CoA transferase, TonB-dependent siderophore, sigma-70 family RNA polymerase sigma factor, aminobenzoate oxygenase, TauD/TfdA family dioxygenase, ABC transporter ATP-binding protein, ABC transporter permease, LysR family transcriptional regulator, MFS transporter, HlyD family secretion protein, efflux transporter outer membrane subunit and MarR family transcriptional regulator genes in this region.



Region	Type	From	To	Most similar known cluster		Similarity
Region 1	NRPS-like	115,091	158,471	fragin	NRP	37%
Region 2	arylpolyene	464,264	507,839	APE Vf	Other	35%
Region 3	RiPP-like	1,429,768	1,440,643			
Region 4	NAGGN	2,105,268	2,120,107			
Region 5	RiPP-like	2,660,759	2,671,610	pyoverdine SMX-1	NRP	6%
Region 6	ectoine	3,570,959	3,581,345			
Region 7	NRP-metallophore , NRPS	3,801,814	3,852,829	enantio-pyochelin	NRP	100%
Region 8	RiPP-like	3,960,641	3,972,836			
Region 9	NRPS	4,618,266	4,689,941	viscosin	NRP	43%
Region 10	betalactone	4,770,965	4,794,863	fengycin	NRP	13%
Region 11	NRP-metallophore , NRPS	4,888,251	4,981,624	pyoverdine SMX-1	NRP	100%
Region 12	NRPS	5,049,378	5,102,316	Pf-5 pyoverdine	NRP	16%
Region 13	redox-cofactor	6,557,414	6,579,570	lankacidin C	NRP+Polyketide	13%
Region 14	RiPP-like	7,093,423	7,104,268			

Figure 1. Biosynthetic gene clusters related to secondary metabolites in *Pseudomonas* sp. SXM-1 genome.

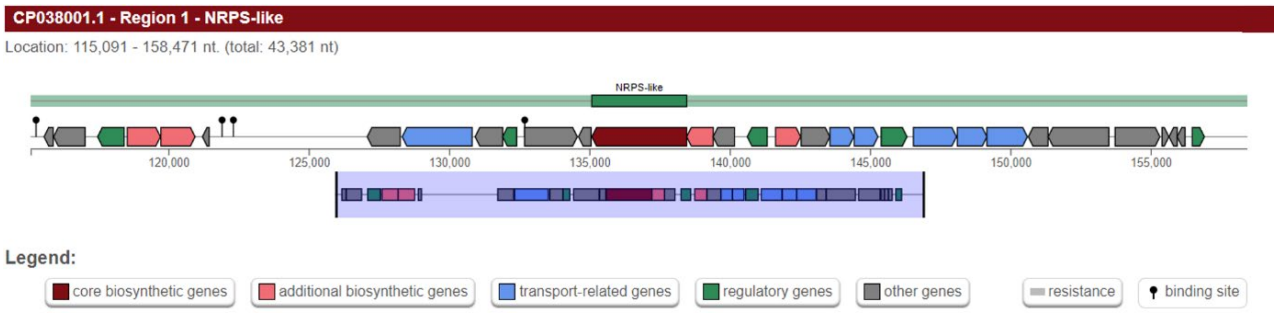


Figure 2. Nonribosomal peptide synthetases like (NRPS-like) gene clusters in *Pseudomonas* sp. SXM-1 genome.

Region 1.2 in the antiSMASH analysis revealed arylpolyene gene clusters (Figure 3). Aryl polyenes are polyunsaturated carboxylic acids (Johnston *et al*., 2021). These gene clusters are located between 464,264 - 507,839 nt. 3-dehydroquinate synthase, glutamate synthase small subunit, MFS transporter, LysR family transcriptional regulator, beta-ketoacyl-ACP synthase, 3-oxoacyl-ACP reductase FabG, beta-ketoacyl-[acyl-carrier-protein] synthase family protein, class I SAM-dependent methyltransferase, glycosyltransferase family 2 protein, AMP-binding protein, acyl carrier protein and 1-acyl-sn-glycerol-3-phosphate acyltransferase genes were also found.

In antiSMASH analysis, ribosomally synthesized and post-translationally modified peptide (RiPP) was detected in region 1.3. These regions were found between 1,429,768-1,440,643 nt (Figure 4). Short chain dehydrogenase, LysR family transcriptional regulator, DUF692 domain-containing protein, ABC transporter ATP-binding protein, high-affinity branched-chain amino acid ABC transporter permease LivM and high-affinity branched-chain amino acid ABC transporter permease LivH genes were also identified within the region 1.3.

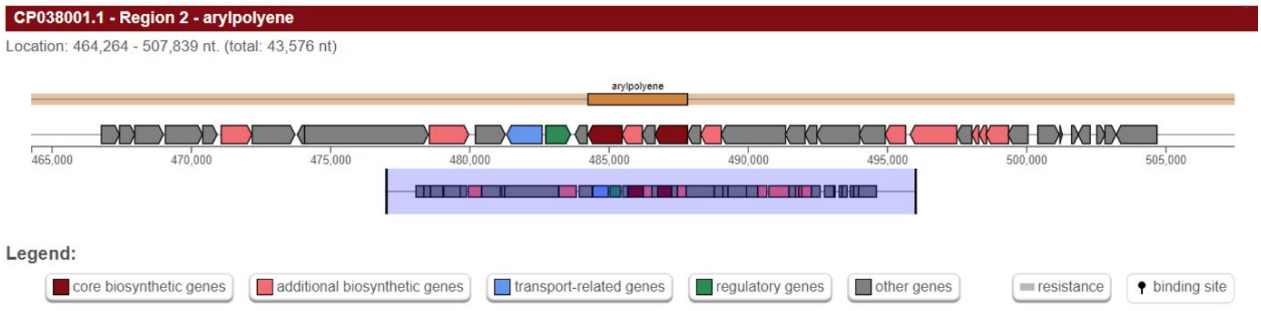


Figure 3. Arylpolyene gene region in *Pseudomonas* sp. SXM-1 genome.

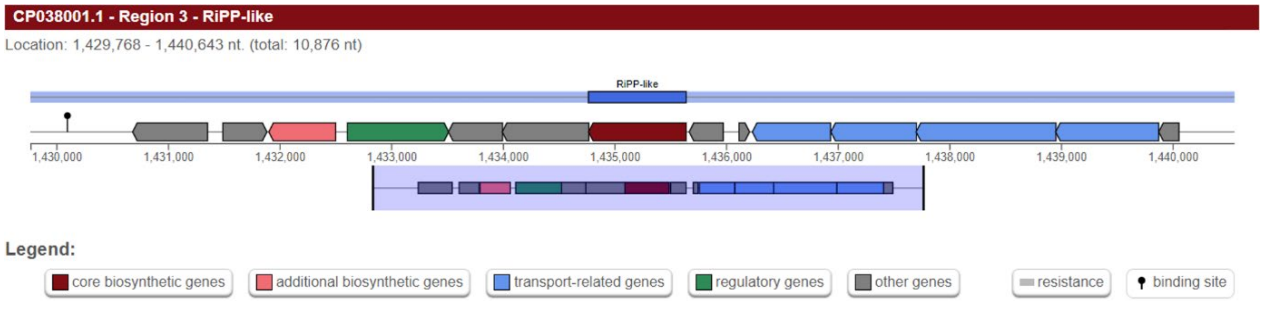


Figure 4. First ribosomally synthesized and post-translationally modified peptides like (RiPP-like) gene clusters in *Pseudomonas* sp. SXM-1 genome.

In Region 1.4, NAGGN related genes were identified (Figure 5). It is located between 2,105,268 - 2,120,107 nt. There are SDR family oxidoreductase, osmoprotectant NAGGN system M42 family peptidase, N-acetylglutaminylglutamine synthetase, N-acetylglutaminylglutamine amidotransferase and bifunctional tRNA (5-methylaminomethyl-2-thiouridine)(34)-methyltransferase MnmD/FAD-dependent 5-carboxymethylaminomethyl-2-thiouridine(34) oxidoreductase MnmC.

Interestingly, to note that we also observed a second region related to RiPP-like biosynthetic gene clusters within region 1.5 (Figure 6). Alpha/beta hydrolase, DUF692 domain-containing protein and MFS transporter genes were identified in this region. The position of region 1.5 is between 2,660,759 - 2,671,610 nt. Ectoine, a solute that prevents osmotic stress in highly saline environments, is located between 3,570,959 - 3,581,345 nt (Figure 7) (Reshetnikov *et al*., 2011). MFS transporter, ectoine synthase, response regulator, HAMP domain-containing protein and class A beta-lactamase-related serine hydrolase genes were identified in region 1.6.

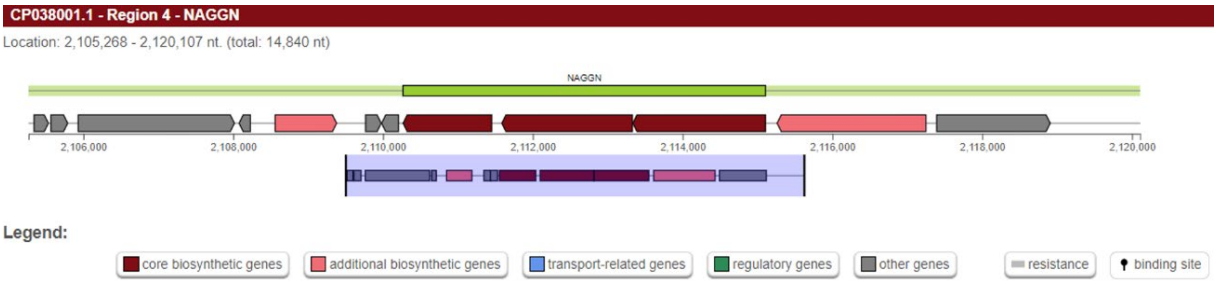


Figure 5. N-acetylglutamylglutamine amide (NAGGN) gene clusters in *Pseudomonas* sp. SXM-1 genome.

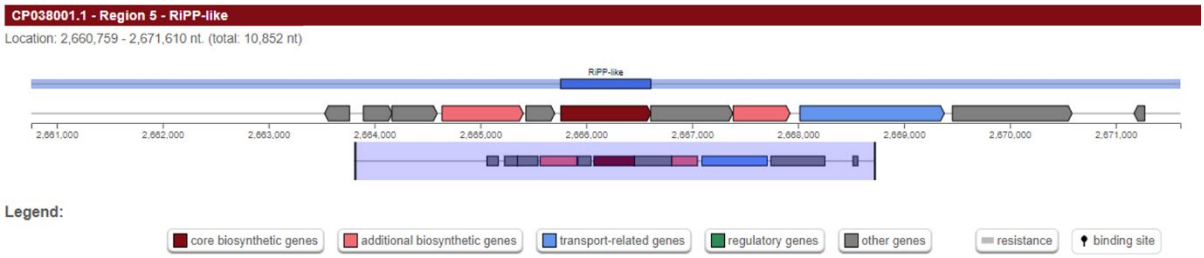


Figure 6. Second RiPP-like gene clusters in *Pseudomonas* sp. SXM-1 genome.

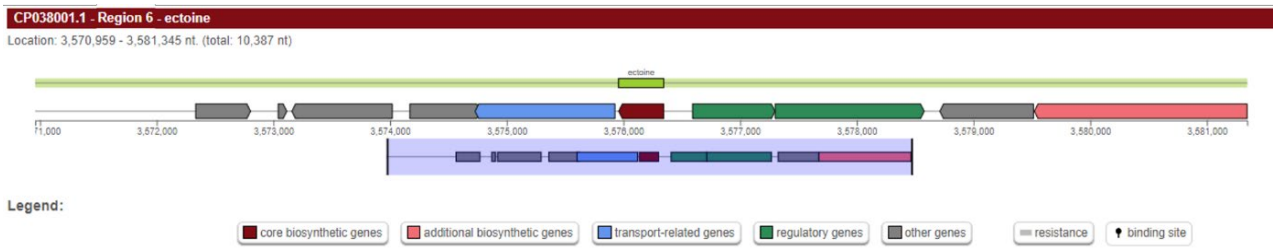


Figure 7. Ectoine gene clusters in *Pseudomonas* sp. SXM-1 genome.

It is shown that region 1.7 includes NRP-metallophore, NRPS genes that are synthesized by multidomain megaenzymes (Figure 8). These genes are located between 3,801,814 - 3,852,829 nt. Sugar ABC transporter substrate-binding protein, cupin domain-containing protein, efflux

RND transporter periplasmic adaptor subunit, efflux RND transporter permease subunit, TolC family protein, glutamate decarboxylase, isochorismate synthase, thioesterase, non-ribosomal peptide synthetase, amino acid adenylation domain-containing protein, ABC transporter ATP-binding protein, 2,3-dihydroxybenzoate-AMP ligase, AraC family transcriptional regulator, TonB-dependent siderophore receptor, iron ABC transporter permease, MFS transporter and TetR/AcrR family transcriptional regulator genes were also found.

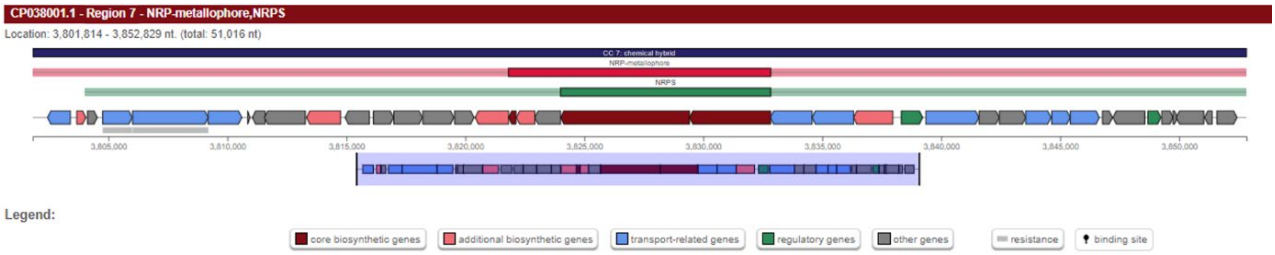


Figure 8. NRP-metallophore, NRPS gene clusters in *Pseudomonas* sp. SXM-1 genome.

In the antiSMASH analysis, a third RiPP-like gene was detected, located between 3,960,641 and 3,972,836 nt. There are HlyD family secretion protein, DHA2 family efflux MFS transporter permease subunit, efflux transporter outer membrane subunit, OsmC domain/YcaO domain-containing protein, alpha/beta hydrolase, HAD family phosphatase, LysR family transcriptional regulator, N-acetyl-gamma-glutamyl-phosphate reductase and epoxide hydrolase in the region 1.8 (Figure 9).

Figure 9. RiPP-like gene clusters in *Pseudomonas* sp. SXM-1 genome.

Figure 10 shows that region 1.9 includes the second NRPS that is located between 4,618,266 - 4,689,941 nt (Figure 10). Sigma-70 family RNA polymerase sigma factor, N-acetyltransferase, EamA family transporter, AraC family transcriptional regulator, GlxA family transcriptional regulator, MATE family efflux transporter, aliphatic amidase, Lrp/AsnC family transcriptional regulator, methionine gamma-lyase, MacB family efflux pump subunit, macrolide transporter subunit MacA, non-ribosomal peptide synthetase, amino acid adenylation domain-containing protein, efflux transporter outer membrane subunit, LysR family transcriptional regulator, glutathione S-transferase, glucose 1-dehydrogenase, L-idonate 5-dehydrogenase, ATP-binding cassette domain-containing protein, metallophosphoesterase and SDR family oxidoreductase were also found.

Figure 11 shows that 1.10 includes a betalactone that is located between 4,770,965 - 4,794,863 nt. Acyl-CoA dehydrogenase, LysR family transcriptional regulator, MerR family DNA-binding transcriptional regulator, hydroxymethylglutaryl-CoA lyase, AMP-binding protein, isovaleryl-CoA dehydrogenase, methylcrotonoyl-CoA carboxylase, gamma-carboxygeranoyl-CoA hydratase and acetyl/propionyl/methylcrotonyl-CoA carboxylase subunit alpha were also identified in the region 1.10 (Figure 11).

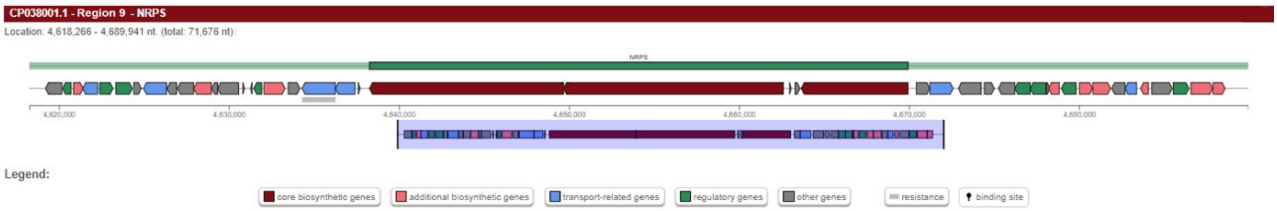


Figure 10. Second NRPS gene clusters in *Pseudomonas* sp. SXM-1 genome.

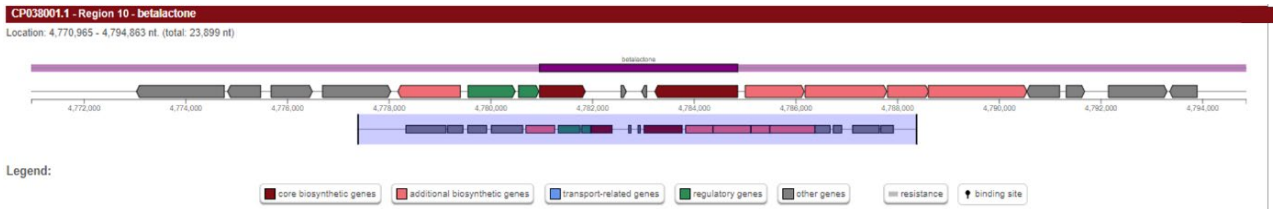


Figure 11. Betalactone genes in *Pseudomonas* sp. SXM-1 genome.

We also observed a second NRP-metallophore, NRPS biosynthetic gene clusters within the region 1.11 that is located between 4,888,251 - 4,981,624 nt (Figure 12). MBL fold metallo-hydrolase, Lrp/AsnC family transcriptional regulator, alpha-ketoacid dehydrogenase subunit beta, dihydrolipoyl dehydrogenase, ornithine cyclodeaminase, ABC transporter substrate-binding protein, ABC transporter permease subunit, histidine ABC transporter permease HisM, ATP-binding cassette domain-containing protein, ornithine monooxygenase, sigma-70 family RNA polymerase sigma factor, efflux RND transporter periplasmic adaptor subunit, MacB family efflux pump subunit, efflux transporter outer membrane subunit, PvdJ/PvdD/PvdP-like protein, aminotransferase class V-fold PLP-dependent enzyme, formylglycine-generating enzyme family protein, cyclic peptide export ABC transporter, TonB-dependent siderophore receptor, alpha/beta hydrolase, amino acid adenylation domain-containing protein, MFS transporter, TetR/AcrR family transcriptional regulator, DHA2 family efflux MFS transporter permease subunit, HlyD family secretion protein, TolC family protein, AraC family transcriptional regulator and SDR family oxidoreductase, GAF domain-containing protein, GlxA family transcriptional regulator and LysE family translocator were found.

In region 1.12, the third NRPS genes were obtained that are located between 5,049,378 - 5,102,316 nt (Figure 13). ABC transporter substrate-binding protein, metal ABC transporter ATP-binding protein, metal ABC transporter substrate-binding protein, MbtH family protein, aspartate aminotransferase family protein, two-component sensor histidine kinase, response regulator, thiol:disulfide interchange protein DsbG, amino acid adenylation domain-containing protein, thioesterase, RNA polymerase factor sigma-70, N-acetyltransferase, TetR/AcrR family transcriptional regulator, SDR family oxidoreductase, acyl-CoA carboxylase subunit beta, acyl-CoA dehydrogenase, enoyl-CoA hydratase/isomerase family protein, acetyl/propionyl/methylcrotonyl-CoA carboxylase subunit alpha, chemotaxis protein CheV, sensor histidine kinase and response regulator transcription factor were found in redox-cofactor gene clusters.

Figure 12. NRP-metallophore, NRPS gene clusters in *Pseudomonas* sp. SXM-1 genome.

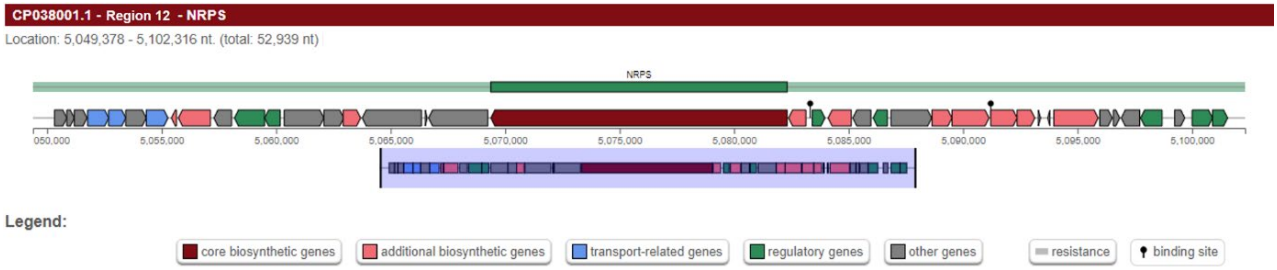


Figure 13. Third NRPS gene clusters in *Pseudomonas* sp. SXM-1 genome.

Figure 14 shows that region 1.13 includes redox-cofactor genes located between 6,557,414 - 6,579,570 nt (Figure 14). Lrp/AsnC family transcriptional regulator, carbon-nitrogen hydrolase family protein, pyrroloquinoline quinone biosynthesis protein PqqF, pyrroloquinoline-quinone synthase PqqC, pyrroloquinoline quinone biosynthesis peptide chaperone PqqD, pyrroloquinoline quinone biosynthesis protein PqqE, aminotransferase class III-fold pyridoxal phosphate-dependent enzyme, LysR family transcriptional regulator, acyl-CoA dehydrogenase and GGDEF domain-containing protein were found in this region.

According to Figure 15, RiPP-like is located between 7,093,423 - 7,104,268 nt. Methyltransferase domain-containing protein and DUF692 domain-containing protein were identified in this region.

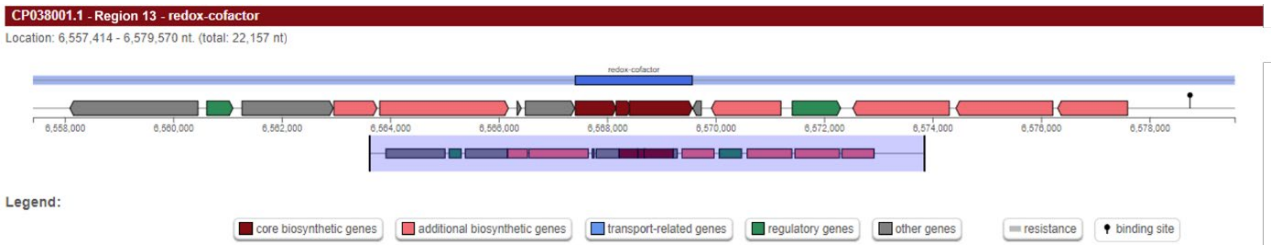


Figure 14. Redox-cofactor gene clusters in *Pseudomonas* sp. SXM-1 genome.

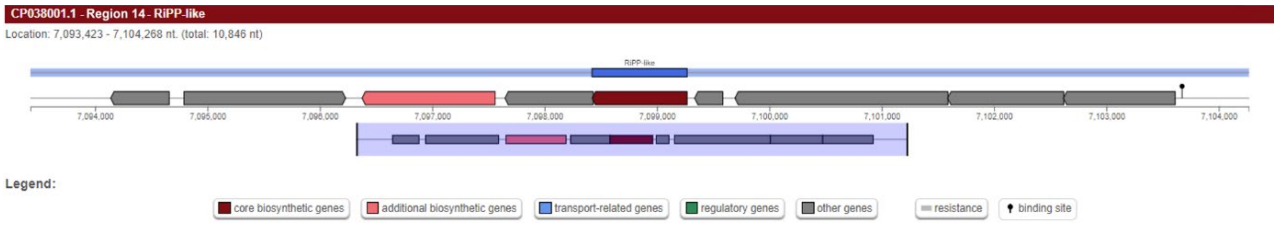


Figure 15. RiPP-like gene clusters in *Pseudomonas* sp. SXM-1 genome

4. DISCUSSIONS

Very resistant pathogenic microorganisms have been reported for the current antibiotics in the last decade. Therefore, there is a great need to understand not only resistance metabolism but also secondary metabolites of pathogenic microorganisms (Martens and Demain, 2017; Anand *et al*., 2020). The latter requires adaptations to new conditions and environments for survival. To be a dominant microorganism, they should synthesize novel secondary metabolites (Palazzotto and Weber, 2018). Recent studies have underlined the importance of the efficacy of novel secondary metabolites of pathogenic microorganisms in the war against other microorganisms under the same conditions (Tiwari *et al*., 2018; Zheng *et al*., 2019). Characterization of secondary metabolites requires wet-lab studies and instrumentation such as HPLC, NMR, FTIR, UV-VIS spectrophotometry and mass spectrometry (Kumar *et al*., 2021; Perruchon *et al*., 2021). However, this process is a time-consuming process. *In silico* tools developed under bioinformatics provide excellent estimation of the novel metabolites. antiSMASH is one of the powerful tools for the characterization of secondary metabolites in the bacterial genome (Blin *et al*., 2021; Medema *et al*., 2011). In this study, a comprehensive analysis of secondary metabolites in *Pseudomonas* sp. SXM-1 found in Xiamen Bay (China) was conducted. The results showed that *Pseudomonas* sp. SXM-1 genome contains not only siderophores, but also other biosynthetic gene clusters of novel secondary metabolites. The secondary metabolites revealed in this study may open a new avenue for fully understanding biosynthetic gene cluster functions in the bacterial genome.

In recent years, *Pseudomonas* spp. have been used in plant growth-enhancing studies. Goswami *et al*. (2013) used *Pseudomonas* spp. isolated from a marine ecosystem as a plant growth-promoting bacterium (PGPB). PGPBs can directly or indirectly affect plant growth. In the direct mechanism, there is the production of plant growth hormones and fixation of nitrogen by attaching to plant's roots, while the indirect mechanism is the production of metal chelating compounds such as siderophores. Because siderophores compete with pathogenic microorganisms for metal binding, they can neutralize these pathogens by chelating iron, which is essential for growth.

Pseudomonas spp. have also been used in agriculture as biocontrol agents against plant pathogens in agriculture. The study by Jin *et al.* (2013), the antagonistic property of *Pseudomonas* spp. against plant pathogens. *Pseudomonas* spp. was used as a biocontrol agent for root disease in Jerusalem artichoke. Jerusalem artichoke has low production cost and it is used in many fields, including production of alcoholic beverages. Therefore, the biocontrol of these plant pathogens is of great importance in agriculture and industry.

Riccardi *et al*. (2021) mentioned that *Pseudomonas* sp. TAE6080 inhibits biofilm formation of *Staphylococcus epidermidis*, which is a pathogen (Accession number of *Pseudomonas* sp. TAE6080 is JAHIDY010000002). *S. epidermidis* is a permanent member of the human microbiota, located on the skin and mucous membranes (Sabaté Brescó *et al*., 2017). They used the antiSMASH tool for the complete genome analysis and they found the gene clusters that have effects on the biofilm formation. Gene clusters related to biofilm formation were found as RiPP-like, NRPS, terpene, NAGGN, arylpolyene, redox-cofactor and betalactone. As a result of this study, it was observed that the formation of *S. epidermidis* RP62A biofilm decreased significantly. When compared with our study, it was seen that the gene regions of arylpolyene, RiPP-like, NRPS, betalactone, NRPS-like and redox-cofactor were common. Sabaté Brescó *et al.* (2017) used antiSMASH 5.0 version and their results were observed in 11 regions. However, when the same accession number was used with the antiSMASH 7.0.1 version, the results occurred in 14 regions.

Girard *et al.* (2023) investigated the phylogenetic trees and metabolic potentials of the *Pseudomonadaceae* family. They used antiSMASH 6.0 and ClusterBlast for the identification of biosynthetic gene clusters. In their study, gene clusters such as NRPS and RiPP-like were identified. In addition to those,

the presence of CLP (cyclopentadecanolide polymer) in the genomes of the strains *Pseudomonas* sp. SXM-1, *P. carnis* J380, and *P. aylmerense* B29B was revealed. Both Girard *et al.* (2023) and the present study utilized antiSMASH for analysis. However, while Girard *et al.* (2023) used antiSMASH 6.0, present study used antiSMASH 7.0.1. In the present study, the specific nucleotide regions of each gene and the associated genes have been analyzed in detail, and their potential effects have been discussed. Girard *et al.* (2023) demonstrated through phylogenetic and biosynthetic gene cluster (BGC) studies that most strains thought to belong to the *Pseudomonadaceae* genus are actually members of the *Halopseudomonas* or *Stutzerimonas* genera. Their work also identified 26 new species. While their study shares features such as MarR family transcriptional regulators, arylpolyenes, RiPPs, NAGGN, ectoine, NRPS, and PvdJ/PvdD/PvdP-like proteins with this study, advancements in antiSMASH versions allowed new gene clusters to be identified, including NRP-metallophores, redox-cofactor genes, and RiPP-like regions, which were not mentioned in the Girard *et al.* (2023) study.

In another study by Wu *et al*. (2016), the antibiofilm properties of *Pseudomonas* stutzeri 273 were studied. In this study, inhibiting the biofilm formation of *Pseudomonas aeruginosa* by another *Pseudomonas* genus, *P. stutzeri* 273 was studied. *P. aeruginosa* is a pathogenic bacterium that causes urinary tract infections, food poisoning and marine antifouling via biofilm formation. It has been found that exopolysaccharide EPS273 obtained from the marine bacterium *P. stutzeri* 273 prevents the formation of biofilm and disperses the formed biofilm.

Pan and Hu (2015) studied the new strain *Pseudomonas* sp. 10B238 which has the potential to produce antibiotics from deep-sea sediments, isolated from the South China Sea. They used the antiSMASH tool to determine antibiotics and secondary metabolites. A total of 11 potential sets of secondary metabolite biosynthetic genes have been predicted. NRP (siderophore), terpenes, arylpolyene, ectoine, bacteriocin were found.

Zeng *et al*. (2020) investigated the *Pseudomonas* sp. DMSP-1 genome. *Pseudomonas* species break down dimethylsulfoniopropionate (DMSP), the algal metabolite necessary to produce dimethyl sulfide (DMS). The results showed that while the genome contains 5510 protein-coding genes, enzyme-coding genes associated with DMSP catabolism were not found. Jain *et al*. (2023) studied the polyamine metabolizing rhizobacteria *Pseudomonas* sp. GBPI_506. 79 strains of the *Pseudomonas* sp. were compared with phylogenomic analysis. The common gene between *Pseudomonas* sp. strain GBPI_506 and *Pseudomonas* sp. SXM-1 is pyrroloquinoline quinone (PQQ) that is related to phosphorus availability, transport and also known as a redox cofactor (Wang *et al*., 2021). In this study, some parameters such as fresh shoot weight, leaf area, and root length were studied. It is clear that there is a difference between controlled plants and *Nicotiana benthamiana* threatened with *Pseudomonas* sp. strain GBPI_506. Currently, there is an increasing resistance to antibiotics because of the indiscriminate use of drugs. Fe *et al*. (2023), studied the effects of phase HZ2201 against *P. aeruginosa*, a clinically used gram-negative bacterium, were investigated. It was observed that HZ2201 has an inhibitor activity on the *P. aureginosa.*

Genome mining tools have been improving and they are widely used methods for *in silico* analysis. Microorganisms with known secondary metabolites are widely used in pharmaceutical and industrial studies. *Pseudomonas* spp. is one of these microorganisms and they are used in areas such as antifouling, agriculture and antibiotic production. Therefore, predicted secondary metabolites of *Pseudomonas* sp. SXM-1 were investigated in our study. Guo *et al*. (2021) also studied this species, but they focused on a single siderophore gene in the whole genome. In our study, all 14 regions of *Pseudomonas* sp. SXM-1 and almost all the secondary metabolites were examined. Thus, a much more comprehensive study was carried out compared with the study by Guo *et al* (2021). By examining all 14 regions, secondary metabolites that can be used in various fields were observed. Wet-lab characterizations of the secondary metabolites mentioned in this paper are strongly

recommended to microbiologists for confirmation.

AUTHORSHIP CONTRIBUTION STATEMENT

Levent Cavas: Conceptualization, Methodology, Validation, Writing - Original Draft, Writing-Review and Editing, Software, Visualization, Supervision, **Yağmur Bilgin:** Conceptualization, Methodology, Validation, Writing - Original Draft, Writing-Review and Editing, Software, Visualization, **İbrahim Kırkız:** Conceptualization, Methodology, Validation, Writing - Original Draft, Writing-Review and Editing, Software, Visualization,

CONFLICT OF INTERESTS

The authors declare that for this article they have no actual, potential or perceived conflict of interests.

ETHICS COMMITTEE PERMISSION

No ethics committee permissions is required for this study.

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China's Belt and Road Initiative: Motivations for Strategic Decision-Making in Global Transport Operations from a Maritime and Marine Engineering Perspective

Çin'in Kuşak ve Yol Girişimi: Küresel Ulaştırma Operasyonlarında Denizcilik ve Deniz Mühendisliği Perspektifinden Stratejik Karar Alma Motivasyonları

Türk Denizcilik ve Deniz Bilimleri Dergisi

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ABSTRACT

China's Belt and Road Initiative (BRI), announced in 2013, is a mega project designed to enhance global transportation infrastructure and stimulate economic development. This study aims to identify and prioritize the key motivational sources driving China's BRI, with a particular focus on economic, political, and strategic considerations. Using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) systematic literature review and focus group methods, we identified 26 motivational factors, 16 of which are primarily economic in nature. Among these, 'New business opportunities for Chinese investors' emerged as the most significant driver. In addition to economic motivations, this study highlights the critical importance of marine engineering, ship risk management, and ship machinery innovations in the success of BRI's maritime routes. Safe, efficient maritime transportation is identified as a crucial element for ensuring the operational effectiveness of the Maritime Silk Road. The study further emphasizes the role of maritime safety protocols, infrastructure modernization, and risk mitigation strategies in achieving China's broader geopolitical and economic ambitions through the BRI. Our findings suggest that China's internal motivations, particularly those related to economic growth and maritime transport infrastructure, play a more prominent role than external factors. This underscores the need for policymakers, marine engineers, and transport operators to align their long-term strategies with China's ambitions, focusing on maritime safety, operational efficiency, and the global competitiveness of China's maritime technologies. The insights gained from this study contribute to a deeper understanding of the strategic importance of maritime infrastructure in shaping the future of global transportation systems under the BRI.

Keywords: Maritime Transportation, Belt and Road Initiative, ANP, PRISMA, Marine Engineering.

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ÖZET

Çin'in 2013 yılında duyurduğu Kuşak ve Yol Girişimi (BRI), küresel ulaşım altyapısını geliştirmek ve ekonomik kalkınmayı teşvik etmek amacıyla tasarlanmış dev bir projedir. Bu çalışma, Çin'in BRI'sini yönlendiren ana motivasyonel kaynakları, özellikle ekonomik, politik ve stratejik unsurlar açısından tanımlamayı ve önceliklendirmeyi amaçlamaktadır. PRISMA sistematik literatür taraması ve odak grup metotları kullanılarak, 26 motivasyonel faktör belirlenmiş olup, bunların 16'sı esas olarak ekonomik niteliktedir. Bu faktörler arasında 'Çinli yatırımcılar için yeni iş fırsatları' en önemli itici güç olarak ortaya çıkmıştır. Ekonomik motivasyonlara ek olarak, bu çalışma, BRI'nin deniz yollarının başarısında deniz mühendisliği, gemi risk yönetimi ve gemi makineleri inovasyonlarının operasyonel etkinliğini sağlamak için hayati bir unsur olarak tanımlanmıştır. Çalışma ayrıca, Çin'in daha geniş jeopolitik ve ekonomik hedeflerine ulaşmasında deniz güvenliği protokolleri, altyapı modernizasyonu ve risk azaltma stratejilerinin rolünü vurgulamaktadır. Bulgularımız, özellikle ekonomik büyüme ve deniz taşımacılığı altyapısına yönelik olan Çin'in iç motivasyonlarının dış faktörlerden daha önemli bir rol oynadığını göstermektedir. Bu durum, politika yapıcılar, deniz mühendisleri ve ulaştırma operatörlerinin, uzun vadeli stratejilerini Çin'in hedefleriyle uyumlu hale getirmeleri gerektiğini, deniz güvenliği, operasyonel verimlilik ve Çin'in deniz teknolojilerinin küresel rekabet gücüne odaklanmaları gerektiğini ortaya koymaktadır. Bu çalışmadan elde edilen bilgiler, BRI kapsamında deniz altyapısının küresel ulaştırma sistemlerinin geleceğini şekillendirmedeki stratejik önemine daha derin bir anlayış kazandırmaktadır.

Anahtar sözcükler: Deniz Taşımacılığı, Kuşak ve Yol Girişimi, ANP, PRISMA, Deniz Mühendisliği.

1. INTRODUCTION

BRI (Belt and Road Initiative) was first suggested in 2013 to promote cooperation and connectivity among nations through trade, investment, and infrastructure initiatives (Zhao, 2019; Han *et al*., 2022; Zhang and Chen, 2022; Wu, 2022). BRI was launched by China, and covers three-quarters of nations (Huang, 2016), accounting for approximately thirty percent of the global Gross Domestic Product and more than fifty percent of the world population (Chan, 2017; Li *et al*., 2022). Geographically, SREB (Silk Road Economic Belt) is divided into three main directions. China is connected to the Europe region via Central Asia and Russia on the first route (Baltic Sea). The second route, which passes via the Central Asia area and West Asia, connects China with Europe through the Mediterranean and the Persian Gulf. The third route, which passes via South Asia region and Southeast Asia, connects China with the Indian Ocean area. The MSR (Maritime Silk Road) also links China's coastal ports with the area of the Indian Ocean, which stretches from Africa to Europe, as well as the Pacific Ocean (Huang, 2016; Hafeez *et al*., 2018; Peng *et al*., 2022).

Regional collaboration is one of the initiative's primary objectives between China's authorities and the initiative's member states based on present and prospective bilateral and multilateral organizations along the route (Cieślik, 2020; Wu *et al*., 2021; Wang and Lin, 2022). The SREB is China's attempt to link its underdeveloped western part to Europe via the area of Central Asia. The second part of the Chinese authorities' strategy is to construct a sea part of the initiative that will connect Southeast Asia -one of the fastest-growing regions- to provinces of China's south via ports and railroads (Hsu and Chien, 2022). The Chinese government's BRI program aims to provide access to important trading nations and areas in the Southeast Asia and the Middle East. By recreating ancient BRI, the project may also boost connectivity and economic cooperation among the participating countries along the route of the initiative as demonstrated in Figure 1. (Chen *et al*., 2019; GFD, 2022; Bakhsh *et al*., 2022).

In the detailed literature review, it was found that the background of the initiative and motivation of China was mentioned by Huang (2016), Kang

(2018), and Chan (2019), however, comprehensive studies related to motivation sources of China were not reached. The accomplishment of this enormous undertaking is well beyond comprehension given that China has a massive economy and production line (Huang, 2016). Figure 1. indicates that participation in the project is constantly growing, and the project idea is receiving worldwide attention. By March 2022, 147 countries have signed a Memorandum of Understanding (MoU) with China to be part of the initiative.

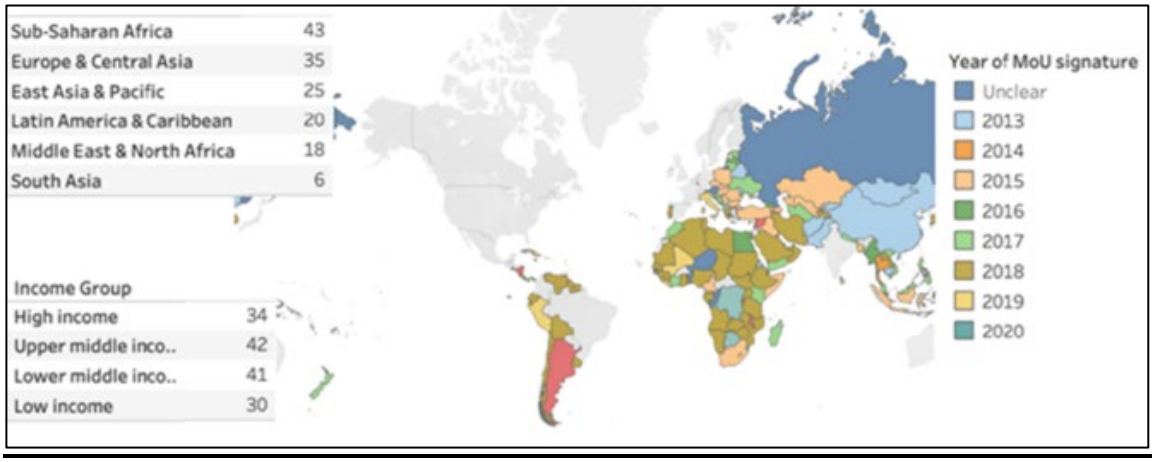

Figure. 1. Member Countries of the BRI (GFD, 2022)

The global transport network may change under Chinese leadership if China completes the project. Since the effort of the initiative has already had an impact on the economic conditions of various nations both member and non-member countries, it is clear that the project has the potential to alter more than just the world transportation order (Laurenceson *et al*., 2019; Lin, 2019; Drysdale and Armstrong, 2021). Policymakers, logistics managers, and transport operators must understand China's motivation for developing this project in order to decide how to respond to recent developments relating to the program.

The study first examines the Strategic Management Process, the Concept of the Study, and the Theoretical Framework. The third section details the Research Methodology, followed by the Systematic Literature Review using PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), Focus Group Studies, and the ANP (Analytic Network Process) method, with validation provided in the fourth section. In the fifth section, the focus shifts to Marine Engineering, Maritime Transportation Efficiency, and Maritime Safety. Finally, the Discussion and Conclusion summarize the study's key findings, emphasizing the strategic implications for policymakers, engineers, and transport operators within the BRI framework.

2. THEORETICAL FRAMEWORK

In order to identify crucial success determinants in the internal and external contexts of firms, the practice of strategic management was first made popular half a century ago (Porter, 1980; Murcia *et al*., 2022). The term "strategic management" described both the function of management and the possibility of strategic decision-making (Taylor, 1947; Simon, 1947; Koseoglu, 2022). Strategic management is a commonly preferred tool by researchers (Kazemi and Szmerekovsky, 2015; Elia *et al*., 2015; de Fátima Teles and de Sousa, 2017; Elrahman and Al, 2017) for identifying internal and external challenges for transportation companies (Chandler, 1962; Andrews, 1971). In order to build the company's strategic posture, which is expressed via the statement of values, vision, purpose, and strategic objectives, the manager must be able to monitor and analyze the reality of the organizational context, both internal and external. The general corporate strategy may then be defined, and afterward, goals and particular activities can be suggested. As a result,

it is clear how crucial strategic alignment is throughout the entire procedure (Hit *et al*., 2002; Bora *et al*., 2017; Barbosa *et al*., 2020). Strategic management is seen to be greatly facilitated by managers having a stronger awareness of current economic trends and the changing business environment, particularly in relation to consumers, rivals, financial needs, and regulatory bodies (Ju *et al*., 2020; Murcia *et al*., 2022).

The strategic management process is an iterative process with a number of phases, such as scanning the present environment and situation, strategy formulation, putting those strategies into action, and evaluating strategies Fig. 2. indicates that environmental scanning is the first phase of the strategic management process (Hitt *et al*., 2016). To ascertain the evolution and projections of factors that will impact the success of the organization, both the internal and external environments should be examined (Choefreh *et al*., 2021). The term "environmental scanning" means the possession and use of data on occurrences, relationships, patterns, and trends in the organization's environments.

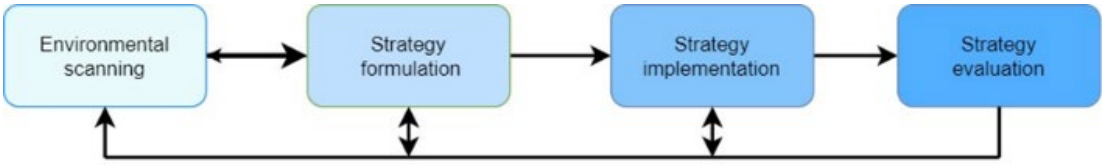

Fig. 2. Strategic management process (Chofreh *et al*., 2021)

The transportation operators are immediately impacted by the BRI progress, the transportation investments made along the route, and the attitudes of the governments regarding the project. A clear understanding of China's view of the project will allow transport operators to make more coherent future decisions about the project. This study both explained the motivational sources of China and prioritized the motivational sources among themselves. Gathering information about events, trends, and external environment data required by the transportation businesses will be ensured within the framework of the BRI during the environmental scanning process, which is the initial step of the strategic management process in the study.

The idea of the survival-based theory consists the framework of the study and is used as a starting point of the research. The method employed by a company to prevent being wiped out by rivals is known as the survival-base theory (Gibcus, 2003). The core element of a survival strategy is that a company must constantly adjust to its competitive environment in order to survive. New paradigms for thinking about and behaving in the business world seem to emerge every decade (Brian, 1996). If transportation companies along the route of the BRI have been affected directly or indirectly by BRI transactions, they should adapt to the changes in the transportation sector related to the project. In the literature on strategic planning, it is assumed that businesses would revise their plans in response to significant changes in the world economy and transportation sector. In this regard, the BRI is among the topics that have to be discussed and researched in the long-term plans for the ensuing ten to thirty years.

3. RESEARCH METHODOLOGY

Expert knowledge, existing literature review, survey, or any mix of the three are all viable options for developing the ANP (Analytic Network Process) model. In the first scenario, a group of experts debates and/or offers the ANP research elements and linkages for the choice. In this situation, to construct a reliable model, the study needs to specify who the selected experts are, their job titles, or provide any other justification to explain their 'expert' qualifications. Based on the second option to develop the ANP model, researchers can evaluate the existing literature and develop decision factors based on it (Mu *et al*., 2020). As shown in Fig. 3 to determine the main motivation sources and develop the ANP model, as a data collection tool, focus group study and PRISMA

systematic literature review methods were preferred in the first part of the methodology. Step one demonstrates that pairwise comparison matrices were answered by the expert team and the weight of each subfactor was identified. To reach the output of the study, supermatrix calculations were presented in the second step of the study. The last part of the methodology involves prioritizing the main motivational sources of the BRI.

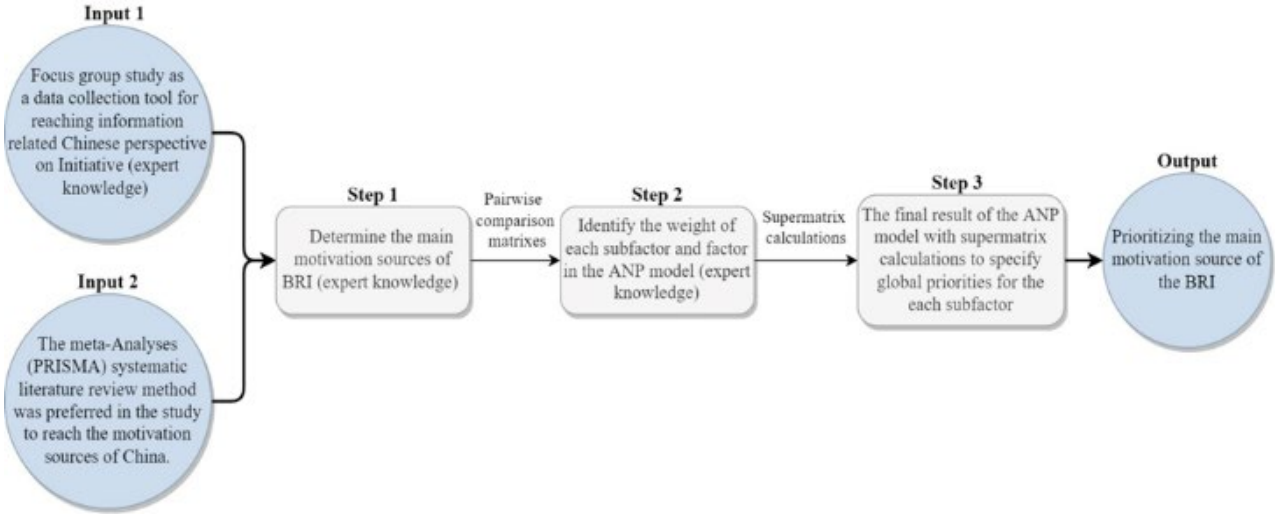

Figure. 3. Research methodology

3.1. Systematic Literature Review approach as a Data Collection Tool

The systematic literature review technique was used to gather information from the literature in order to determine China's motivations to establish BRI. The PRISMA technique was used in the study to reach the motivation sources of China. The PRISMA approach is commonly preferred by researchers (Kalanlar, 2021; Frost *et al*., 2022; Kim *et al*., 2022; Innocenti *et al*., 2022) applying a systematic literature review.

3.1.1. Inclusion-exclusion criteria with search strategies

Three literature databases were searched; Web of Science, Scopus, and Taylor & Francis to gather information from BRI-related studies. In the study, to reach more publications, keywords were determined from a more general perspective as "belt and road'', and "one belt one road'' keywords were preferred. The search technique used combinations of chosen words and phrases that were adapted for each database. The first announcement of the project was in 2013, therefore a sample of full-text articles in English covered between September 2013 and December 2022 were chosen. Meeting abstracts, letters, grey literature, editorial materials, and proceedings papers were excluded from the sample of the review. The study includes only articles written in English.

3.1.2. Search procedure

The direction of the search process was determined using the PRISMA technique, which stands for recommended reporting items for meta-analyses and systematic literature review (Page *et al*., 2021; Kalanlar, 2021). Fig. 4 indicates that the PRISMA systematic literature review.

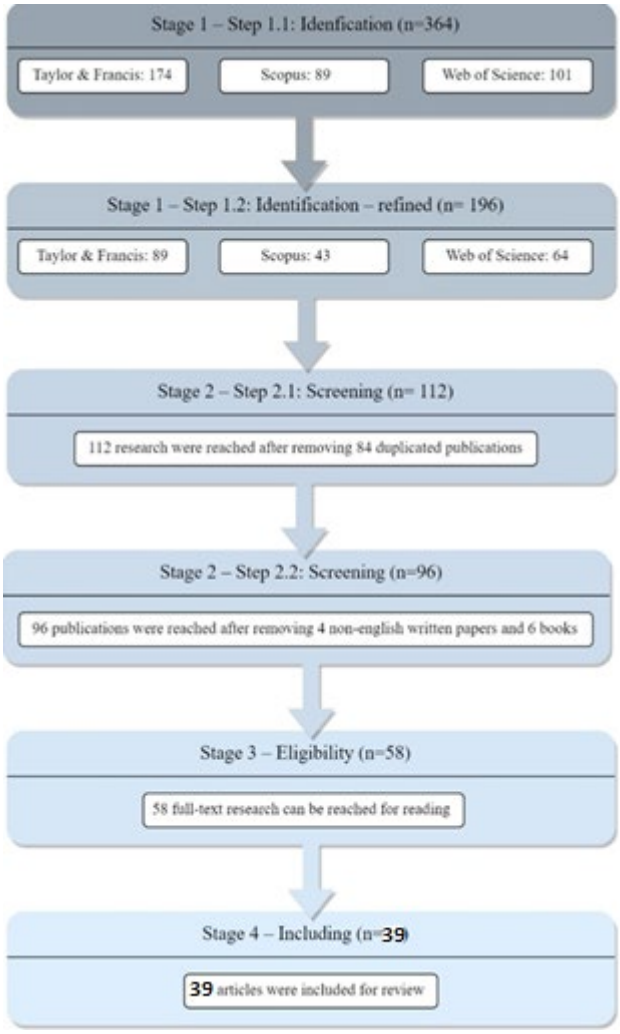

Figure. 4. PRISMA methodology for systematic literature review

The method includes four steps; 1- Identification; 2- Screening; 3- Eligibility; and 4- Including (Ortiz-Martinez *et al*., 2019). Selected articles help to reach the main motivation sources of BRI from the perspective of China. As a result, 364 relevant research articles were reached in the databases at end of the first step. To reach the objective of the study, the research was narrowed down by using the keywords of "China", "motivation", "motivation of China", "China's motivation", "China's perspective", and "perspective of China". In social sciences papers containing these chosen keywords, there were 196 publications overall. In the second stage of the method, publications that are not written in English, duplicate publications, and research that has only an abstract were subtracted from the total list. Consequently, 96 articles were reached at the end of second stage. In the eligibility part of the research method which covers stage 3, publications were separated by their subject, abstract, and title to remove irrelevant papers from the sample. 58 full-text articles were determined at the end of stage 3. In the last part of the PRISMA method, the eligibility of the complete texts of these publications was evaluated; as a consequence of this final step evaluation, there were 39 papers total in the review.

3.1.3. Findings

Considering the criteria of the study, 39 articles satisfied the requirements, as shown in the PRISMA diagram in Fig. 4. Table 1 lists the authors, motivation sources for China, year of publication, and ANP model code. PRISMA's systematic literature review process helped identify 15 Chinese motivational sources from the literature.

The Initiative's avowed goals are to maintain deeper economic relations, support understanding of mutual perspective, ensure world peace, increase cultural collaboration between participating countries, and strengthen political agreements and goodwill among member countries (Chang, 2016; Yu *et al*., 2019) (Code E15).

Collaboration in energy transportation between participating countries of BRI and China has also become a critical subject between participating countries on the route and Chinese authorities (Wang and Lin, 2022; Huang *et al*., 2021; Blah, 2018) (Code EN1).

By creating a multilevel intergovernmental structure for macro-policy discussions, this initiative realizes China's omnidirectional peripheral diplomacy (Cheng, 2016, Huang, 2016) (Code S2).

Trade and financial integration are designated as essential pillars of the BRI's economic agenda, with significant regional and global implications. The economy of China has slowed down after more than 30 years of exceptionally rapid expansion. The manufacturing sector in the country has a high level of excess capacity particularly in heavy sectors like steel, cement, and aluminum, owing to diminishing local and international demand, mostly from wealthy

nations. Despite the fact that China slashed over more than one billion job opportunities from 2016 to 2017 to cope with manufacturing excess capacity, growing foreign demand, or exports, are regarded as effective and urgent strategies to support China's continued economic development. (Huang, 2018; Yu *et al*., 2020; Dai and Zhu, 2022; Nugent and Lu, 2021; Clarke, 2018; Deng, 2021; Yu *et al*., 2019) (Code E2).

Table 1. Determining China's motivation sources to create BRI from the PRISMA systematic literature review

Author	Year	Motivation Source of China	ANP Model Code
Wang and Lin	2022	Ensuring China's energy security with alternative transportation routes	EN-1
Huang *et al*.	2021		
Blah	2018		
Cheng	2016	Improving economic and cultural relations between countries	E-15
Yu *et al*.	2019		
De Soyres *et al*.	2019	Reducing transport times	E-10
Blah	2018		
Chang	2016	Improving diplomatic relations	S-2
Huang	2016		
Cheng	2020	Leveraging initiative against claimant states in the South China Sea	S-3
Yu *et al*.	2020	Overcapacity problem	E-2
Dai and Zhu	2022		
Nugent and Lu	2021		
Clarke	2018		
Deng	2021		
Huang	2018	China's willingness to use its cultural soft power	S-4
Clarke	2018		
Rolland	2017	Combating terrorism, separatism, and religious extremism	G-2
Callaghan and Hubbard	2016		
Rehman and Noman	2021		
Kong *et al*	2021	The desire for economic growth	E-1
Haider *et al*	2021		
Clarke	2018		
Deng	2021		
Flint and Zhu	2019	Reducing American influence in Asia	S-1
Rolland	2017		
Clarke	2018		
Zhou and Esteban	2018		
Deng	2021		
De Soyres *et al*	2019	Reducing transport costs	E-9
Zhang *et al*	2017	Desire to make the renminbi (RMB) a global currency in the world market	E-8
Eichengreen and Lombardi	2017		
Blah	2018		
Rolland	2017	China's desire to ensure its border security	G-1
Callaghan and Hubbard	2016		
Rehman and Noman	2021		
Zhou and Esteban	2018	Desire to have the largest economy in the world to be the rule maker	E-13
Sharma	2019		
Cheng	2020	Helping global prosperity	E-14

The initiative was regarded as the top-level strategy for China's opening to the outside world since it attracted the interest of many nations across the world. China views the project as a lever to boost its recent low trend in growth rate and catch up to its previous economic growth rate (Haider *et al*., 2021; Clarke, 2018; Deng, 2021; Kong *et al*., 2021) (Code E1).

BRI is part of Beijing's geopolitical strategy of connectedness and cooperation, and project intent of diminishing the USA hegemony effect in Asia particularly (Flint and Zhu, 2019; Rolland, 2017; Clarke, 2018; Zhou and Esteban, 2018; Deng, 2021) (Code S1).

The initiative might strengthen Beijing's maritime dominance, potentially resolving the South China Sea (SCS) issue to some extent (Cheng, 2020) (Code S3).

It is anticipated that the project's planned investments will be finished by the time the transit times are reduced by, on average, 1.2 to 2.5 percent. However, due to this decline, trade expenditures will fall by 1.1 to 2.2 percent. While trade prices and transit times are anticipated to drop by an average of 1.7 to 3.2 percent among initiative member nations, this rate is anticipated to fall between 1.5 and 2.8 percent among non-member nations. In terms of transport expenses and time schedule, member nations are anticipated to gain more benefits from the initiative (De Soyres *et al*., 2019; Blah, 2018) (Code E9, Code E10).

The rise of China's economic importance in recent decades has sparked a passionate debate about the position of the RMB (Renminbi) in international commerce. Since roughly 2005, Beijing has launched a number of measures purposed at increasing the global usage of RMB. These attempts intensified after the global economic crisis of 2008, and they have advanced significantly since 2009 (Zhang *et al*., 2017; Blah, 2018; Eichengreen and Lombardi 2017) (Code E8).

Maintaining economic development is critical for the Chinese leadership's social harmony and regime security. As a result, improving living standards through economic growth is considered as a mean to address the difficulties linked with the "three evils" of extremism, separatism, terrorism, and extremism both in China and outside. The initiative will assure the growth of the participating countries and assist in reducing the number of terrorist events near China's borders by investing in their economic development and transportation infrastructure (Callaghan and Hubbard, 2016; Rolland, 2017; Rehman and Noman, 2021) (Code G2, Code G1).

Under the umbrella of "soft power", China's strategy of constructing the project on win-win ties with all member nations in peace, development, and cooperation is an effort to instill trust in the area and in all states (Clarke, 2018) (Code S4).

Through an infrastructure-building program in China's bordering areas, this project intends to reinforce Beijing's economic leadership. Overall, the initiative is a crucial maneuver for Beijing to maintain security and advance its power standing in the international system, allowing it to transition from a rule-taker to becoming a rule-maker (Zhou and Esteban, 2018; Sharma, 2019) (Code E13).

Not only does the initiative assist the economic development process of the member countries but also project aims at ensuring global prosperity (Cheng, 2020) (Code E14).

3.2. Focus group study

The research's second part is a focus group study to complete the identification of BRI's motivating sources from China's standpoint. In the study, an online focus group study is preferred due to the Covid pandemic and international participants by using www.focusgroupit.com. The study started on 2 December 2022 and the completion date of the focus group study is 5 December 2022. The online model of the focus group studies is a virtual version of a face-to-face one, with the researcher able to control talks (Dichabeng *et al*, 2021). Participant group of online studies can read and comment on each other's replies at their leisure using online discussion boards (Williams, 2012). Since the research was asynchronous, participants were able to think about their replies more carefully than they could in real-time sessions, and they may even use web searches or other methods to help them decide. In comparison to the standard version of the focus groups (face-to-face), online focus group studies

usually need more participants. A standard focus group consists of 6–12 people who meet face-to-face to talk about a certain issue (Bloor *et al*., 2001).

3.2.1. Preparation and organization

The systematic literature review in the preceding section of the study provided a certain point of view of China on the project, but a focus group study is required to complete the major motivating sources of the BRI. In the review section of the study, 15 incentive sources were identified, and this list provides the experts with a starting point for debate. A focus group is usually formed by six to twelve people (Fern and Fern, 2001; Stewart and Shamdasani, 2014; Kamberelis and Dimitriadis, 2013). The more participants involved in the focus group studies the more accurate information could be taken (Carspecken and Dennis, 2012). Participants of the focus group were selected based on their expertise. Table 2 indicates that eleven participants were selected with experiences ranging from 16 to 32 years. Experts could be categorized into three groups; academicians, BRI consultants, and sector experts. Academicians include three professors and two associate professors, and their publications mainly focus on the BRI-related scientific works. Sector-related experts are international relations and transportation experts. The purpose of selecting business experts is to reach sectoral information in terms of BRI subjects. Four members of the focus group research are Chinese government consultants in BRI organizations, so they may reflect the Chinese perspective on BRI. A week prior to the meeting, detailed information of the appointment was given to the experts. The goal of the focus group study is to verify the literature review data and extend the previous research items (PRISMA study) and reach the background of the Chinese motivations to create BRI.

Table 2. Expert Profile

Job Title	Year of Service	Academic qualifications
Associate Professor	16	PHD
Committee member of BRI organizations	18	Master
Professor	26	PHD
International relation expert	19	PHD
Committee member of BRI organizations	28	PHD
Associate Professor	21	PHD
Committee member of BRI organizations	22	Master
Professor	28	PHD
Transportation expert	22	Master
Professor	32	PHD
Committee member of BRI organizations	26	Master
Associate Professor	16	PHD
Committee member of BRI organizations	18	Master

3.2.2. Discussion of the focus group

The information for the focus group research was gathered by: (1) asking each of the participants to express their views in order to determine China's perspective on the creation of the BRI in terms of external and internal aspects. (2) capturing the participants' spoken discussions; and (3) taking quick notes on the topics addressed. The questionnaire is divided into three parts. The participants were asked to give personal information, such as their employment, academic qualification, and professional background in the first part of the questionnaire. In the second part of the focus group study, the experts examined the data taken from the literature and made comments on each finding. In the last section of the study, participants agreed on 26 incentive

sources including 15 literature review items. Table 3 demonstrates that in the focus group investigation, 11 incentive source items were identified. With an internal and external viewpoint, experts divided the motivation sources into seven groups: Economic, Energy, Security, Economic-2, Political, Security-2, and Military. Experts were encouraged to share additional subjects or comments not covered in the focus group questionnaire and to provide any other suggestions in the final part of the study. The focus group meeting, which lasted three and a half hours with an intermission, included thirteen experts.

Table 3. Based on expert knowledge, China's motivational sources to create BRI

Motivation Source of China	ANP Model Code
New business opportunities for Chinese investors	EN-3
Strengthening the military presence along the project routes	A-1
Preventing piracy in the SCS	G-3
Increasing the international reputation of Chinese banks	E-7
Strengthening the China-Asia-Europe link	E-16
China's desire to increase the welfare level for its citizens	E-5
China's willingness to create an international safety network	G-4
New job opportunities for Chinese citizens	E-6
China's desire to avoid the middle-income trap for its country	E-4
China's desire to develop western regions within its own country's borders	E-11
Preventing immigration from the eastern part of China to the western part	E-12

3.3. Basic Concepts of Analytic Network Process

The Analytic-Network-Process (ANP) is an extension of the Analytic-Hierarchy-Process (AHP) that considers both inner (between components in the same cluster) and outer (between elements in different clusters) dependence when ranking alternatives (Saaty, 2005). The analytic network approach has been determined to be a multi-criteria decision-making strategy for addressing various complicated decision-making problems (Chen *et al.*, 2019). Interconnected clusters and their constituents are the building blocks of an ANP model. It is necessary to compare the model components in pairs in order to evaluate their relative relevance (Saaty and Vargas, 2006). The essential phases of the ANP technique are the calculation of supermatrices and weighted supermatrices. Assume that the ANP structure's control layer has criteria $P_1, P_2, P_3 \cdots P_n$. $C_1, C_2, C_3, \cdots C_m$ and C_i that contains n_i are element groups in the network layer, while P_{i1}, P_{i2}, P_{i3}, $\cdots P_{in_i}$ $(i = 1,2,3,\cdots,m)$ is a factor group in the network layer. Compare the relevance of each factor in C_i to that in $C_j; P_{jl} (j = 1,2,3,\cdots,m; l = 1,2,3,\cdots,n)$, that is, treat P_{jl} as a sub-criterion under the control criterion $P_s\,(s = 1,2,3,\cdots,N)$, and build a judgment matrix. The eigenvector of the judgment matrix is created and expressed as a matrix using the eigenvector approach; that is, an unweighted supermatrix under criteria P_s is generated (Saaty, 2005).

$$W_{ij} = \begin{bmatrix} W_{i1}^{j1} & \cdots & W_{i1}^{jn} \\ \vdots & \ddots & \vdots \\ W_{in}^{j1} & \cdots & W_{in}^{jn} \end{bmatrix}$$

If the two-element sets are mutually exclusive, then $W_{ij} = 0$. Similarly, the supermatrix of each element's effect on the component group C_i under the criterion is determined by comparing components in elements group of other:

$$W = \begin{array}{c} \\ C_1 \\ \vdots \\ C_m \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & \cdots & C_m \end{array} \\ \begin{bmatrix} W_{11} & \cdots & W_{im} \\ \vdots & \ddots & \vdots \\ W_{m1} & \cdots & W_{mm} \end{bmatrix} \end{array}$$

The weight matrix is calculated using the criteria P_s by comparing the relevance of each group of elements to those of the element group C_i (Sun and Bı, 2008; Wan *et al*., 2021; Wang and Wang, 2013; Du *et al*. 2010).

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1m} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mm} \end{bmatrix}$$

By multiplying the weighted matrix of A with the weightless supermatrix $\overline{W}$; that is, $\overline{W} = AW$, the weighted matrix $\overline{W}$ of W is produced. The steady-state supermatrix $\overline{W}^{\infty}$ acquired after n iterations are then computed, and its column vector represents the stable weight of each element in the network layer under the criteria P_s , according to $\overline{W}^{\infty} = \lim_{n\to\infty} \overline{W}$ (Wan *et al*., 2021).

3.3.1. ANP model

The creation of the ANP model requires data from different methods of application. This study preferred PRISMA systematic literature review and Focus group study for data collection to create the ANP model. To determine the motivational sources of China; "Ensuring China's energy security with alternative transportation routes (EN1)", "Improving economic and cultural relations between countries (E15)", "Reducing transport times (E10)", "Improving diplomatic relations (S2)", "Leveraging initiative against claimant states in the South China Sea (S3)", "Overcapacity problem (E2)", "China's willingness to use its cultural soft power (S4)", "Combating terrorism, separatism, and religious extremism (G2)", "The desire for economic growth (E1)", "Reducing American influence in the Asia region (S1)", "Reducing transport costs (E9)", "Desire to make the renminbi (RMB) a global currency in the world market (E8)", "China's desire to ensure its border security (G1)", "Desire to have the largest economy in the world to be the rule maker (E13)", "Helping global prosperity (E14)" items were determined by using PRISMA method. A Focus group study helped to determine other 11 items; "New business opportunities for Chinese investors (EN3)", "Strengthening the military presence along the project routes (A1)", "Preventing piracy in the South China Sea (G3)", "Increasing the international reputation of Chinese banks (E7)", "Strengthening the China-Asia-Europe link (E16)", "China's desire to increase the welfare level for its citizens (E5)", "China's willingness to create an international safety network (G4)", "New job opportunities for Chinese citizens (E6)", "China's desire to avoid the middle-income trap for its country (E4)", "China's desire to develop western regions within its own country's borders (E11)", "Preventing immigration from the eastern part of China to the western part (E12)". In the focus group study, 26 items were categorized into internal and external motivation topics which is shown in Fig. 5 as an ANP model of the study.

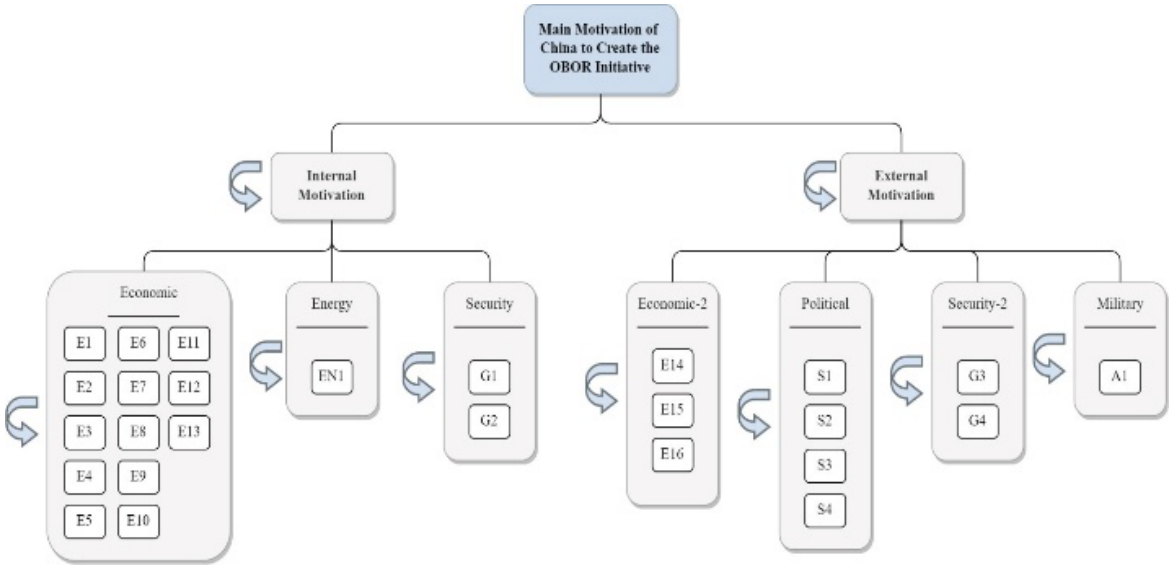

Figure. 5. ANP model of the study

Internal motivation has 16 sub-factors in three different sub-categories as Economics, Energy, and Security. On the other hand, Fig. 5 shows that external motivation has 10 sub-factors under four sub-categories as Economic-2, Political, Security-2, and Military. The weights of the parameters in the ANP model must be compared to each other in order to calculate their weights. Focus group experts answered the comparison matrices based on a 1-9 scale. The 307 pairwise comparisons that comprised 35 comparison matrices under 10 comparison sets were discovered based on the relationships between these parameters.

3.3.2. Relation Matrices of the ANP approach

The second step of the ANP model is the determination of the relation between the clusters and nodes. The Focus group as shown in Table 2 helped in the determination of relation matrices. Based on expert knowledge, there is a direct connection between Internal and External Motivation sources of the China. Relation matrices data were handled with the help of the Super Decision Program as shown in Fig. 6.

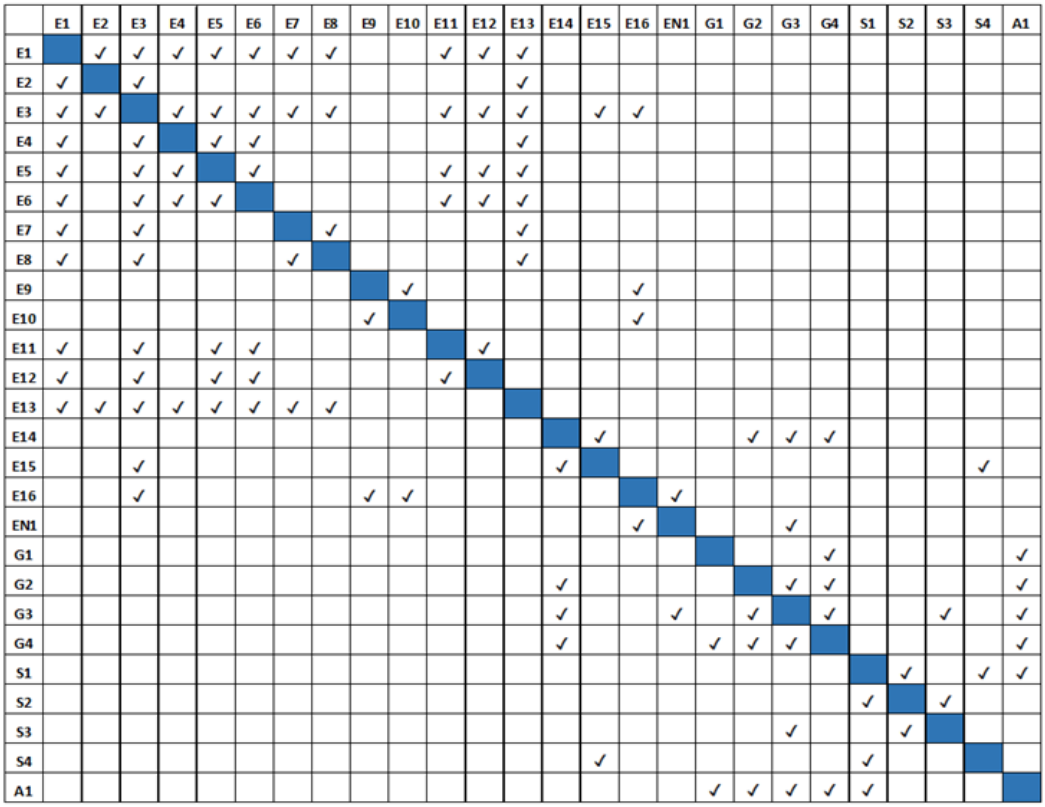

Figure. 6. Relation matrices of the ANP model

3.3.3. Normalized data weight

The normalized weights of criterion and sub-criteria were derived by entering any of the following findings into the Super Decision software. Table 4 shows the pairwise comparison matrix of significant factors in connection to the aim.

Table 4. Matrix of pairwise comparisons of important criteria in relation to the goal

Purpose	Internal Motivation	External Motivation
Internal Motivation	1	5
External Motivation	0.2	1

In all cases, the incompatibility of criteria and sub-criteria was less than 0.1, suggesting that the prioritization of matrix comparisons was acceptable, and the reliability of responses had been confirmed; therefore, the allocated ratings were valid, and paired comparisons can be obtained. Table 5 demonstrate that the internal motivation criterion had the higher weight, with a 0.83 relative weight, while the external motivation criterion had the lower weight, with a relative weight of 0.16.

Table 5. The main criteria normalized weight

Criteria of the Cluster	Normalized-weight	Rank
Internal Motivation	0.83	1
External Motivation	0.16	2

3.3.4. Sub-criteria are compared to the Main criteria in a pairwise comparison matrix

Table 6 shows the results of pairwise comparisons of the "Economic" cluster based on the separation of primary criteria (internal motivations and external motivations). With 0.208 degrees, the "E2- Overcapacity problem" sub-factor has the highest local weight within the "Economic" cluster. The sub-factor "E1- The desire for economic expansion" has a local weight degree of 0.164 and is ranked second in the comparison matrix for the "Economic" cluster. E4- China's desire to avoid the middle-

income trap for its country' has the lowest local weights among the matrices of pairwise comparisons for the "Economic" cluster. The pairwise comparison matrices have a consistency ratio of 0.08, as an acceptable ratio for ANP comparison matrices.

Table 6. Matrix of pairwise comparisons of sub-criteria in the 'Economic' cluster

	E.1	E.2	E.3	E.4	E.5	E.6	E.7	E.8	E.9	E.10	E.11	E.12	E.13	Local weights
E.1	1	0.5	1	4	3	5	4	6	6	6	5	7	1	0.164
E.2	2	1	2	5	6	5	6	7	4	4	5	6	3	0.208
E.3	1	0.5	1	4	5	4	5	5	4	4	3	4	2	0.148
E.4	0.25	0.2	0.25	1	0.5	0.5	0.5	0.5	0.33	0.33	0.5	0.5	0.25	0.021
E.5	0.33	0.16	0.2	2	1	2	0.2	0.5	2	0.33	0.33	0.33	0.2	0.032
E.6	0.2	0.2	0.25	2	0.5	1	0.33	0.5	0.33	0.5	4	0.33	0.2	0.030
E.7	0.25	0.16	0.2	2	2	3	1	2	0.33	0.5	3	4	0.25	0.051
E.8	0.16	0.14	0.2	2	2	2	0.5	1	0.5	0.33	0.5	0.5	0.25	0.029
E.9	0.16	0.25	0.25	3	1/2	3	3	2	1	1	2	2	0.33	0.055
E.10	0.16	0.25	0.25	3	3	2	2	3	1	1	3	2	0.33	0.059
E.11	0.2	0.2	0.33	2	3	0.25	0.33	2	0.5	0.33	1	0.5	0.25	0.032
E.12	0.14	0.16	0.25	2	3	3	0.25	2	0.5	0.5	2	1	0.25	0.040
E.13	1	0.33	0.5	4	5	5	4	4	3	3	4	4	1	0.123

3.3.5. Sub-criteria are compared with sub-criteria in a pairwise comparison matrix

Table 7 shows the results of the matrix of comparisons of sub-criteria pairwise to the S1 sub-factors. Table 8 consistency ratio is 0 and it's acceptable for ANP studies. Based on the result of the sub-criteria that were examined using a comparison matrix., other 17 tables for each sub-factor could be demonstrated.

Table 7. S-1 sub-criterion matrix of pairwise comparisons of sub-criteria

	S-2	S-4
S-2	1	2
S-4	0.5	1

3.3.6 Each sub-normalized criterion's weight

Sub-criteria of the ANP model normalized weight were calculated for each cluster. E16 has the highest normalized weight in the "Economic 2" cluster with 0.493 degrees as shown in Table 8.

S1 is the most significant sub-factor in the "Political" cluster with 0.610 degrees. G3 has the highest normalized weight in the "Security 2" cluster with 0.666 degrees. E2 has the significant degree item in the "Economic" cluster with 0.208 degrees. G1 has the highest normalized weight in the "Security" cluster with 0.666 degrees.

Table 8. Normalized weight for each sub-criterion

Motivation Sources	Priority of the Main Motivation Source	Clusters	Cluster comparisons with respect to Internal Motivation	Sub-criteria	Normalized weight
Internal Motivation	0.83	Economic	0.62	E.1	0.164
				E.2	0.208
				E.3	0.148
				E.4	0.021
				E.5	0.032
				E.6	0.030
				E.7	0.051
				E.8	0.029
				E.9	0.055
				E.10	0.059
				E.11	0.032
				E.12	0.040
				E.13	0.123
		Energy	0.23	EN.1	1
		Security	0.13	G.1	0.666
				G.2	0.333
Motivation Source	**Priority of the Main Motivation Source**	**Clusters**	**Cluster comparisons with respect to External Motivation**	**Sub-criteria**	**Normalized weight**
External Motivation	0.16	Economic 2	0.26	E.14	0.195
				E.15	0.493
				E.16	0.310
		Political	0.51	S.1	0.610
				S.2	0.176
				S.3	0.130
				S.4	0.082
		Security 2	0.13	G.3	0.666
				G.4	0.333
		Military	0.09	A.1	1

3.3.7. Overall prioritization of the sub-factors

The last step of the study is to determine the sub-factors overall priority to rank them. The "New business opportunities for Chinese investors (E3)" item has the first rank with 0.146 degrees. Table 9 indicates that "Desire to have the largest economy in the world to be the rule maker (E13)" has the second rank in the sub-factors overall priority. "Preventing immigration from the eastern part of China to the western part (E12)" has the lowest degree with 0.012057 in the motivation sources of China.

Table 9. The sub-factors overall priority

Sub-criteria	The sub-factors overall priority	Rank
E3- New business opportunities for Chinese investors	0.146201	1
E13- Desire to have the largest economy in the world to be the rule maker	0.122252	2
E2- Overcapacity problem	0.107140	3
E1- The desire for economic growth	0.087903	4
S1- Reducing American influence in the Asia region	0.084236	5
S2- Improving diplomatic relations	0.055840	6
A1- Strengthening the military presence along the project routes	0.048126	7
G3- Preventing piracy in the South China Sea	0.030806	8
E8- Desire to make the renminbi (RMB) a global currency in the world market	0.026225	9
S4- China's willingness to use its cultural soft power	0.023740	10
E7- Increasing the international reputation of Chinese banks	0.023477	11
S3- Leveraging initiative against claimant states in the South China Sea	0.022468	12
E16- Strengthening the China-Asia-Europe link	0.022396	13
E9- Reducing transportation costs	0.022191	14
E10- Reducing transport times	0.021294	15
E5- China's desire to increase the welfare level for its citizens	0.021169	16
E15- Improving economic and cultural relations between countries	0.020450	17
G4- China's willingness to create an international safety network	0.018792	18
E6- New job opportunities for Chinese citizens	0.018523	19
E4- China's desire to avoid the middle-income trap for its country	0.013386	20
E11- China's desire to develop western regions within its own country's borders	0.012057	21
EN1- Ensuring China's energy security with alternative transportation routes	0.011860	22
G2- Combating terrorism, separatism, and religious extremism	0.010521	23
G1- China's desire to ensure its border security	0.010081	24
E14- Helping global prosperity	0.009748	25
E12- Preventing immigration from the eastern part of China to the western part	0.009119	26

4. VALIDATION OF THE METHOD

Consistency ratio (CR) is the only measure that verifies the accuracy of the ANP model in contrast to pairwise comparison matrices of the ANP structure based on random index and Consistency Index (CI). A comparison matrix's consistency index for the ANP model is represented by the formula $CI=(\lambda_{max}-n)/(n-1)$. Max denotes the eigenvalue's highest degree, while n denotes the size of the matrix. The formalization of the relationship between the consistency index and random index results in the CR ratio of the ANP model (Yuksel and Dagdeviren, 2007). To guarantee a legitimate consistency ratio for the ANP model, the comparison matrix result should have a consistency ratio of less than 0.10. Using Saaty's (2005) Super Decision software, the consistency ratio of the comparison matrices was established in this study. Weighted degrees of all outcomes are based on appropriate consistency ratios since the consistency ratios of all pairwise comparison matrices in the research are less than 0.10 and this parameter shows that all comparison matrices are valid.

5. MARINE ENGINEERING, MARITIME TRANSPORTATION, AND MARITIME SAFETY PERSPECTIVES

The Belt and Road Initiative (BRI) is an ambitious global infrastructure development strategy by China, with far-reaching economic and geopolitical implications. The sub-factors identified in Table 9 of the analysis can be interpreted through the lenses of marine engineering, maritime transportation, and maritime safety, as these fields play a crucial role in supporting the project's maritime components, specifically the Maritime Silk Road. This section focuses on how key motivational sub-factors align with the goals and challenges of marine engineering, maritime transportation, and maritime safety.

5.1. Marine Engineering and Technological Advancements

Several of the economic and strategic priorities highlighted in the sub-factor rankings directly impact marine engineering, particularly the development of advanced technologies for shipbuilding, navigation, and energy efficiency. For instance, the following sub-factors are crucial in this context:

E3 - New Business Opportunities for Chinese Investors (0.146201, Rank 1): This sub-factor emphasizes the potential for Chinese companies to invest in marine engineering innovations. New business opportunities could drive advancements in ship machinery, propulsion systems, and alternative energy sources (e.g., LNG or hybrid engines), which would increase operational efficiency and reduce environmental impact in maritime routes.

E16 - Strengthening the China-Asia-Europe Link (0.022396, Rank 13): Enhancing connectivity between these regions would necessitate major upgrades in maritime infrastructure, where marine engineering plays a key role in designing ports, dredging channels, and ensuring that ships can navigate efficiently.

E1 - The Desire for Economic Growth (0.087903, Rank 4): The focus on growth aligns with the need for improvements in marine engineering to handle larger and more sophisticated vessels, thus supporting China's broader economic goals.

5.2. Maritime Transportation Efficiency and Infrastructure Development

Maritime transportation is central to the BRI's success, as it forms the backbone of international trade along the project's oceangoing routes. Several sub-factors highlight China's goals in enhancing maritime logistics and transportation infrastructure:

E9 - Reducing Transportation Costs (0.022191, Rank 14): To achieve this, China would likely invest in more efficient port operations, better cargo handling technologies, and improved logistical networks. Maritime transportation systems must integrate advanced navigation technologies to reduce shipping times and fuel consumption, thereby cutting transportation costs.

E10 - Reducing Transport Times (0.021294, Rank 15): Minimizing transport times is another critical objective that marine engineers and transportation planners must address.

Investments in larger, faster, and more fuel-efficient ships will allow China to achieve this goal, further improving global trade connectivity.

E8 - Desire to Make the Renminbi (RMB) a Global Currency (0.026225, Rank 9): A strong maritime transportation network underpins this goal by facilitating international trade in Chinese currency. Efficient and safe shipping operations would be crucial to ensure that trade remains steady and reliable, thus boosting the RMB's global status.

5.3. Maritime Safety and Security Challenges

Ensuring safety is vital for the BRI's maritime routes, which traverse regions prone to piracy, geopolitical tensions, and environmental hazards. The following sub-factors underline the importance of maritime security and safety:

G3 - Preventing Piracy in the South China Sea (0.030806, Rank 8): The South China Sea is a strategically significant yet contentious area. Preventing piracy and ensuring the safety of ships passing through these waters requires the deployment of sophisticated maritime surveillance systems, improved shipboard security measures, and international collaboration to patrol these regions effectively.

A1 - Strengthening the Military Presence Along the Project Routes (0.048126, Rank 7): China's strategic interest in fortifying its military presence along BRI maritime routes aims to protect its vessels and ensure the security of key maritime chokepoints. This military presence can also deter potential security threats, including piracy and territorial disputes.

G4 - China's Willingness to Create an International Safety Network (0.018792, Rank 18): Establishing a cooperative maritime safety framework among BRI countries would enhance overall maritime safety. This would involve not only military cooperation but also agreements on search-and-rescue operations, environmental protection, and accident prevention protocols.

The analysis of sub-factors in the BRI project from marine engineering, maritime transportation, and maritime safety perspectives reveals that these fields are essential to the success of China's maritime ambitions. Marine engineering advancements will play a crucial role in supporting efficient and safe transportation routes, while maritime transportation systems must focus on reducing costs and improving global connectivity. Meanwhile, ensuring the safety and security of shipping lanes, especially in regions prone to piracy and geopolitical tension, is vital for the project's sustainability. By addressing these issues, China can ensure that the Maritime Silk Road—an integral part of the BRI—remains as a safe, secure, efficient, and economically viable route for global trade.

6. DISCUSSIONS AND CONCLUSION

China's motivation for the Belt and Road Initiative (BRI) has often been viewed narrowly, but this study expands on all significant motivational sources. It is evident that the project has the capacity to transform more than just the global transportation system, as its implementation has already impacted the economic conditions of numerous member and non-member countries. In addition to economic motivations, it is essential for policymakers, logistics managers, marine engineers, and transport operators to understand China's rationale behind this initiative to effectively respond to the program developments.

This study employs the Analytic Network Process (ANP), which, through several steps, yields diverse insights into China's motivations. Researchers require comprehensive data to construct an ANP model, often collected through a variety of techniques. In this case, the PRISMA systematic literature review identified fifteen key sources of Chinese motivation. An integrated focus group study further highlighted eleven factors influencing China's decision to create the BRI. The primary objective of this PRISMA-Focus group combination was to fully comprehend China's internal and external motivations.

Twenty-six motivational sources were identified and then prioritized, showing China's internal motivations as more significant than external ones. The "Economic" cluster in the ANP model stands out, with the "Overcapacity problem (E2)" holding the highest degree among the thirteen economic sub-factors. Furthermore, the

study introduces other key clusters: “Energy”, “Security”, and “Marine Engineering”. The findings highlight that China's maritime ambitions, supported by advanced ship machinery and marine engineering innovations, are critical to maintaining the operational efficiency of the Maritime Silk Road—a core component of the BRI.

From the perspective of marine engineering, maritime transportation, and maritime safety, the BRI represents not only an economic and political endeavor but also a significant investment in infrastructure. The development and maintenance of safe, efficient shipping routes along the Maritime Silk Road are paramount to the success of the initiative. China's emphasis on maritime infrastructure, including port development, ship machinery innovations, and risk mitigation strategies, demonstrates the critical role these elements play in global trade.

In terms of external motivations, four additional clusters were identified: “Economic 2”, “Political”, “Security 2”, and “Military”, with the “Political” cluster receiving the highest importance. According to ANP analysis results, the “New business opportunities for Chinese investors (E1)” emerged as the highest priority motivation. However, to realize this potential, China must not only focus on economic development but also invest in reducing shipping risks and preventing maritime accidents. This focus on maritime infrastructure is pivotal for China’s capacity to dominate global transportation systems.

China's drive for global leadership is closely linked to the goal of becoming the world's largest economy and rule maker. To achieve this, the country must establish a robust and sustainable maritime infrastructure. The BRI focuses on modernizing seaports, shipping fleet incl. ship machinery, investing in marine engineering, and developing protocols to improve maritime safety and efficiency. The “Desire to have the largest economy in the world to be the rule maker (E13)” emerged as the second most important motivation in the analysis, further illustrating China's ambitions on the global stage.

The role of transport operators is increasingly significant in this context, as managers must be able to assess both internal and external factors to develop a strategic posture that aligns with the dynamic business environment. This includes keeping pace with advancements in maritime technology, engineering, monitoring ship performance, and implementing best practices to mitigate ship-related risks. The BRI is a subject that must be continuously discussed when formulating long-term strategic decisions, especially in the areas of maritime transportation, which are central to the initiative's success over the next ten to thirty years.

Moreover, the integration of marine engineering with China's broader geopolitical and economic objectives provides critical insights into how transport operators, marine engineers, and policymakers can align their long-term plans with China’s ambitions. Key considerations include improving maritime safety protocols, ensuring the reliability of maritime infrastructure, and enhancing the global competitiveness of Chinese maritime technologies.

Economic goals are the primary driving force behind China's creation of the BRI, followed by political and security motivations, with military concerns ranking lower. Although the initiative is framed as a global, win-win project, internal motivations related to economic growth and maritime transport infrastructure are significantly more critical than external ones. The results of this study offer valuable insights into how transport operators, marine engineers, and policymakers can align their long-term plans with China's ambitions, considering the critical role of maritime safety, ship reliability, and the broader implications for the global maritime economy.

In future research, further analysis can be conducted for each cluster in the ANP model using a variety of methodologies to explore the intricate connections between China's internal and external motivations. This is especially relevant in addressing the technical and operational challenges in maritime infrastructure development, marine engineering, and ship risk management which will be pivotal in ensuring the success of the Maritime Silk Road and the broader Belt and Road Initiative.

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Mehmet Serdar ÇELİK: Conceptualization, Methodology, Validation, Formal Analysis, Resources, Writing - Original Draft, Writing-Review and Editing, Data Curation, Software, Supervision, Project administration.
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CONFLICT OF INTERESTS

The author(s) declare that for this article they have no actual, potential or perceived conflict of interests.

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Author(s) declare that this study was conducted in accordance with ethics committee procedures of human or animal experiments.

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Green Transformation in Maritime Industry: The Role and Impact of Regulations

Denizcilik Sektöründe Yeşil Dönüşüm: Düzenlemelerin Rolü ve Etkisi

Türk Denizcilik ve Deniz Bilimleri Dergisi
Cilt: 11 Sayı: 2 (2025) 118-135

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ABSTRACT

As concerns over climate change and environmental sustainability continue to grow, the shipping industry faces increasing pressure to reduce its carbon footprint and adopt greener practices. In alignment with the United Nations Sustainable Development Goals (SDGs)—particularly SDG13 (Climate Action), SDG7 (Affordable and Clean Energy), and SDG9 (Industry, Innovation, and Infrastructure), this study aims to review the role and impact of green shipping regulations on the maritime industry, focusing on their effects on operational efficiency, financial structures, and technological innovation. By examining both target-based (e.g., Energy Efficiency Design Index, Carbon Intensity Indicator) and market-based (e.g., EU Emissions Trading System) regulatory measures, the study evaluates how these policies shape industrial productivity and competitiveness. It also highlights the challenges and opportunities stakeholders encounter while adapting to these regulations. The review provides critical insights for ship operators, policymakers, and researchers in developing effective strategies for a sustainable maritime industry.

Keywords: Maritime Sustainability, Decarbonization Efforts, Maritime Trade

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ÖZET

İklim değişikliği ve çevresel sürdürülebilirlik konusundaki endişeler artmaya devam ederken, denizcilik sektörü karbon ayak izini azaltma ve daha çevreci uygulamaları benimseme konusunda artan bir baskıyla karşı karşıya bulunmaktadır. Bu çalışma, Birleşmiş Milletler Sürdürülebilir Kalkınma Amaçları (SDG) -özellikle SDG13 (İklim Eylemi), SDG7 (Erişilebilir ve Temiz Enerji) ve SDG9 (Sanayi, Yenilikçilik ve Altyapı) ile uyumlu olarak, yeşil denizcilik düzenlemelerinin denizcilik sektörü üzerindeki rolünü ve etkisini, operasyonel verimlilik, finansal yapılar ve teknolojik yenilikçilik üzerindeki etkilerine odaklanarak incelemeyi amaçlamaktadır. Çalışma, hem hedef bazlı (örn. Enerji Verimliliği Tasarım Endeksi, Karbon Yoğunluğu Göstergesi) hem de piyasa bazlı (örn. AB Emisyon Ticaret Sistemi) düzenleyici tedbirleri inceleyerek, bu politikaların sektörel verimliliği ve rekabet gücünü nasıl şekillendirdiğini değerlendirmektedir. Ayrıca, paydaşların bu düzenlemelere uyum sağlarken karşılaştıkları zorlukları ve fırsatlar vurgulanmaktadır. Bu inceleme, sürdürülebilir bir denizcilik sektörü için etkili stratejiler geliştirmede gemi işletmecileri, politika yapıcılar ve araştırmacılar için kritik bilgiler sağlamaktadır.

Anahtar sözcükler: Denizcilikte Sürdürülebilirlik, Karbonsuzlaşma Çabaları, Deniz Ticareti

1. INTRODUCTION

Maritime transportation, the leading choice for intercontinental trade, facilitates the transport of diverse commodities efficiently while reducing logistics costs through economies of scale (Tran and Haasis, 2015). Maritime transportation is vital for international trade. Initially powered by oars or wind, ships transitioned to coal and later petroleum-based fuels, especially in the 19th century. Over the past 40 years, maritime trade has grown by 250%, driven by containerization and globalization, matching global GDP growth while outpacing energy consumption (170%) and population growth (90%) (Bouman *et al*., 2017). However, since 2020, the industry has been undergoing significant transformation due to the enforcement of green maritime regulations (Balcombe *et al*., 2019).

The global imperative to combat climate change has led to a significant shift towards green practices in industries worldwide. As countries strive to meet ambitious emission reduction targets in international agreements such as the Paris Agreement, regulatory authorities aiming to reduce greenhouse gas emissions are adapting and evolving rapidly. As a vital component of global trade, the maritime industry finds itself at the forefront of these regulatory changes. Because ships emit less CO_2 per ton-mile than other modes but have a more significant ecological impact due to their scale, they use bunker fuel, a cheap but highly toxic and polluting tar-like liquid (Akgül, 2024). Shipping emissions contribute to global warming by trapping heat, causing rising sea levels and extreme weather. Combustion of maritime fuel also releases SO_X, NO_X, and PM, leading to ocean acidification, marine biodiversity loss, and respiratory issues in coastal populations (Feng *et al*., 2024). As an international regulatory organization, the International Maritime Organization (IMO) has taken stringent measures to comply with the provisions of the Paris Agreement (Ampah *et al*., 2021). These measures are directly aligned with the United Nations Sustainable Development Goals (SDGs), particularly SDG13 (Climate Action), SDG7 (Affordable and Clean Energy), and SDG9 (Industry, Innovation, and Infrastructure) to provide a comprehensive framework for addressing global environmental, economic, and social challenges. In addition, the additional rules introduced by the European Union for maritime trade activities within its geographical borders, in addition to or independently of IMO rules, show that green shipping is being taken seriously from a supranational perspective (European Commission, 2020). Given that all industry stakeholders, particularly ship operators and ports, will be impacted by these developments, they must reassess their business models, adapt operations, and invest in necessary measures.

While green shipping regulations are often seen

as a burden on maritime trade, they are also expected to influence countries' macroeconomic outlook (Lee and Nam, 2017). Just as the post-COVID-19 period saw disruptions in maritime transport, logistics costs, and trade due to container shortages—triggering global inflation—regions struggling with green shipping compliance may face similar trade impacts, affecting market supply. Therefore, maritime stakeholders must take necessary action.

Considering that maritime businesses face both challenges and opportunities in complying with stringent emission standards and adopting sustainable practices while trying to transition towards a low-carbon future, this study aims to review the role and impact of environmental regulations in shaping the green transformation of the maritime industry. Specifically, it seeks to review the effects of international and regional regulations (e.g., IMO decarbonization targets, EU-ETS) on the maritime industry, assess the implications for industrial productivity, operational strategies, and financial sustainability, identify challenges and opportunities that industry stakeholders face in adapting to these policies and provide recommendations for policymakers, ship operators, and industry leaders to navigate the green transition effectively. By addressing these objectives, the study contributes to the existing literature on maritime sustainability, offering a comprehensive evaluation of regulatory impacts and potential adaptation strategies.

The second part of the study examines post-Paris Agreement maritime regulations, emphasizing environmental sustainability and eco-friendly ships. The third section explores target-based and market-based measures in green transformation, highlighting related industrial threats and opportunities. The fourth section examines the industrial impact of regulations, focusing on productivity mechanisms, financial and regional aspects, contractual frameworks, and emerging opportunities. The study ends with conclusion.

2. GREEN SHIPPING REGULATIONS

Maritime trade made great progress in the 19th century when steam engines and large steel-hulled ships were built, and offshore cable networks and global transportation networks were established. In the early years, steamships struggled to compete with sailing ships due to inefficiency, but technological advancements eventually phased out sailing ships from maritime trade. With the rise in maritime trade demand, larger and more versatile ship designs with propulsion systems using petroleum-derived fuels began to dominate the maritime trade (Stopford, 2009). Both coal and petroleum, derived from ancient organic matter, contain carbon, leading to inevitable carbon-based gas emissions during combustion. Unfortunately, these carbon emissions are not even the tip of the iceberg.

Ships consume around 4 million barrels of heavy fuel oil per day, equivalent to 4% of total global oil production (Fridell, 2019). From a cost analysis perspective, the proportion of fuel costs in a ship's daily operational and capital expenditure is quite high (Stopford, 2009). However, the environmental impacts of the fuels consumed are now more frequently emphasized, as well as their cost. Given the highly polluting nature of these fuels, characterized by high levels of toxic chemicals, shipping does not fit seamlessly with environmental sustainability goals. Considering the emphasis on green transformation and stringent regulations implemented by the International Maritime Organization (IMO) and the European Union (EU), the goal of reducing greenhouse gas emissions to zero by 2050 has led to a significant shift in the maritime industry (IMO, 2023a). As of 2018, ships calling at EU ports are required to disclose their fuel and CO_2 emissions, and the regulation on the payment of carbon tax by ships calling at EU ports has also come into force, making it inevitable for shipping companies to take urgent measures in this regard (European Commission, 2024b).

2.1. Regulations for Reducing SO_X and NO_X Emissions

One of the biggest global environmental concerns today is air pollution from maritime transportation, and IMO, an international regulatory authority, updated the International Convention for the Prevention of Pollution from

Ships (MARPOL) 73/78 version in 1997 (IMO, 2024a). This update, which added the sixth annex to MARPOL, introduced rules for the Prevention of Air Pollution from Ships. With MARPOL Annex VI, Nitrogen Oxides (NOx) and Sulphur Oxides (SO_X) were initially taken into consideration as the main factors of pollution, and it was aimed to reduce emissions by developing rules and processes for the use of clean fuel in Emission Control Areas (ECA) (IMO, 2023b). On the other hand, measures such as Ship Energy Efficiency Management Plan (SEEMP) and Energy Efficiency Design Index (EEDI) have been implemented to ensure fuel and energy efficiency. However, IMO did not include marine greenhouse gas (GHG) emission reduction in its regulatory framework until 2011. MARPOL Annex-VI Chapter 3 Rule-13 and Rule-14 contain restrictions on NO_X and SO_X emissions, respectively. Looking at the restrictions for NO_X emissions under Rule-13, ships are divided into three classes according to the years of production of their machinery. Tier-I refers to machinery manufactured between 2001-2011; Tier-II refers to machinery manufactured between 2011-2016; and Tier-III refers to machinery manufactured after 2016. There are different NO_X calculations according to the engine operating speeds (rpm) of the ships. All ships built between the specified dates must comply with these restrictions, and machines built before 2001 are not required to comply with these restrictions (IMO, 2024b). The strictest of these, 'Tier III', applies to main engines installed on ships built in 2016 or later operating in ECA regions (NECA) where NO_X is controlled. From January 2021, all ships in these regions must use mandatory main engine standards or equivalent NO_X emission reduction technologies to comply with NO_X emission levels. In 2016, IMO also included the Baltic Sea and the North Sea under NECA (Pape, 2020). Considering the fuel-sulfur content restrictions that must be complied with under Rule-14, two different types of restrictions are seen for the whole world and for the ECA regions. Before 01.01.2012, the sulfur content of fuel could not exceed 4.5% by mass worldwide. This was reduced to 3.5% as of January 1, 2012, and then to 0.5% as of January 1, 2020. In the ECA regions where SO_X is controlled (SECA), this ratio is even lower, and while oil sulfur content was limited to 1.5% before July 1, 2010, it has been limited to 1% since then and to 0.1% since January 1, 2015 (IMO, 2020). The European Union has also enacted IMO SO_X limits (Directive EU/2016/802) and has mandated the use of marine fuels with a maximum sulfur content of 0.1% in the EU SECA regions and set the same limit for ships calling at its ports. NO_X emission limits for EU countries are instead set under EU air quality standards for pollutants in ambient air (Pape, 2020). SO_X emissions are recognized to contribute to the formation of fine particles, which are harmful to humans due to their inorganic content. In this context, market participants have various alternatives to comply with the above-mentioned limits. These alternatives include the continued use of conventional heavy fuel oil (HFO), if scrubber technology that filters out Sulphur is installed on ships, synthetic fuels such as low Sulphur fuels (VLSFO, ULSFO) that are largely free of Sulphur, as well as alternatives such as Liquefied Natural Gas (LNG), Marine Diesel Fuels MDO, MGO (Al-Enazi *et al*., 2021). However, Sulphur emissions are the tip of the iceberg and stringent regulations are aimed at reducing greenhouse gas (GHG) emissions.

2.2. Regulations for Reducing GHG Emissions

Greenhouse gases, defined as gases that trap heat in the atmosphere and increase the earth's temperature, include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and other fluorinated gases. These gases can increase with human activities (e.g. fossil fuel use, industrial processes, agriculture) and increase the greenhouse effect, leading to problems such as climate change (Dong *et al*., 2022). The Paris Agreement was adopted in 2015 at the 21st Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change. At COP21, all countries on a global scale committed to greenhouse gas emission reductions after 2020. The Agreement entered into force on November 4, 2016, with the ratification of at least 55 parties, accounting for 55% of global greenhouse gas emissions. It is the

first global agreement to enter into force just one year after its adoption (Republic of Turkey Ministry of Foreign Affairs, 2024).

As with the measures taken against other pollutants, the EU has taken its place among the parties taking the first steps as a "first mover" for CO_2 emissions. In this context, in 2015, it adopted a system for monitoring, reporting and verification of CO_2 emissions for maritime transport ("MRV Regulation" 2015/757/EU) and required reporting from ships over 5000 GRT calling at ports in the European Economic Area (EEA). Despite plans to harmonize with IMO measures, double reporting has continued since the launch of the global IMO DCS in 2019 (European Commission, 2024b). In 2019, the European Commission introduced the "European Green Deal (EGD)" to address climate challenges with the goal of a carbon-neutral EU by 2050. The EGD, a comprehensive strategy adopted by the European Union to tackle climate change and environmental sustainability, aims to reduce the EU's greenhouse gas emissions to net zero by 2050. However, the EGD also includes far-reaching objectives such as promoting economic growth, investing in green technologies, creating jobs and ensuring social justice. The EGD is one of the EU's key commitments to sustainability and combating climate change, with various instruments such as budget, legislation, incentive mechanisms and innovation to achieve these goals (European Commission, 2020). To turn the political commitment to the EU's carbon-neutral target into a legally binding obligation, the European Climate Act was adopted on June 30, 2021 (Presidency of the European Union, 2024). In July 2021, the European Commission presented a set of complementary and interlinked proposals as part of the "Fit for 55" package to align the EU's climate, energy, land use, transport and taxation policies to reduce net greenhouse gas emissions by at least 55% by 2030 (European Commission, 2021). This package includes the Emission Trading System (ETS), the Carbon Border Adjustment Mechanism (CBAM), the Energy Taxation Directive (ETD), and the Renewable Energy Directive (RED). includes a number of EU regulations affecting maritime transport, such as the Alternative Fuels Infrastructure Regulation (AFIR) and, most recently, the Maritime Fuel Initiative (FuelEUMaritime) (European Commission, 2023a). As visualized in Figure 1, the EU aims to reduce the carbon footprint of the maritime industry by up to 80%, starting with a 2% reduction in 2025 and increasing every five years until 2050, and to promote the use of renewable and low-carbon fuels in the industry.

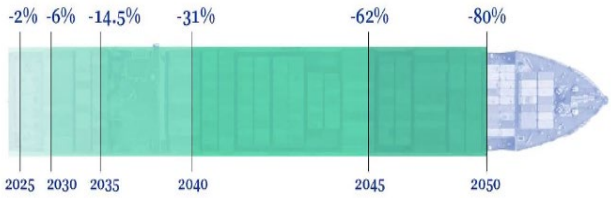

Figure 1. EU GHG Emission Reduction Target

In May 2023, the EU further extended the scope of regulation to transit ports up to 300 nautical miles from its borders, with effect from 1 January 2024. This is intended to prevent illegal voyages to ports outside the EU to avoid ETS payments (DNV, 2023). Achieving this emission limit in the next decade is crucial for Europe to become the world's first climate-neutral continent by 2050, making the "European Green Deal" a reality.

In response to the EU Climate Law requirements to reduce Europe's net greenhouse gas emissions by at least 55% by 2030, the 'Fit for 55' package was prepared in July 2021, then updated to consider renewable energy and energy efficiency issues in the REPowerEU plan to increase Europe's energy security, which emerged with Russia's war in Ukraine. The final legislative package is expected to reduce the EU's net greenhouse gas emissions by 57% by 2030 (European Commission, 2023a). The package aims to establish a common EU regulatory framework to encourage an increased share of renewable and low-carbon fuels in the fuel mix of international maritime transport while ensuring the smooth operation of maritime transport without distorting the internal market. Furthermore, the European Commission is finalizing the EU taxonomy criteria for the decarbonization of ships to classify ships and facilitate compliance checks for sustainable marine fuels and intends to revise the criteria

after 2025 based on industry feedback (European Council, 2023b).

2.3. Green Ship

The term "Green Ship" can be scientifically defined as a vessel designed to minimize environmental impact, characterized by low or zero emissions, and constructed in compliance with international regulations established to mitigate climate change (Sherbaz *et al*., 2015). Beyond its definition, the green ship concept represents a strategic shift in maritime transportation, affecting competitiveness, financial viability, and regulatory compliance (Branza, 2023). Green ships are no longer just an environmental ambition; they have become an operational necessity for ship owners and operators seeking to maintain access to global markets (Shi and Gullett, 2018). Within the scope of making a ship environmentally friendly, being a green ship depends on the operational status of the ship. However, there are ways to improve environmental performance, including reducing fuel consumption per ton-mile by implementing speed strategies (Norlund and Gribkovskaia, 2013). Reducing ship speed can result in significant fuel savings of up to 60% (Chang and Chang, 2013). However, actual savings vary greatly depending on ship type, size and weather conditions (Taskar and Andersen, 2020). Optimizing the hull and propeller design through improvements can also contribute to reducing fuel consumption at optimum speed (Allal *et al*., 2018; Nelson *et al*., 2013). In addition to propulsion, Molland (2014) emphasizes the importance of operational practices such as appropriate trim, speed and weather routing in reducing fuel consumption. Another option is for the industry to use more alternative fuels such as electricity, hydrogen, ammonia, and biofuels to achieve net zero emissions targets (Economist, 2021; IEA, 2024). The transition to environmentally friendly alternative fuels such as liquefied natural gas (LNG) and methanol is an important step towards becoming a green ship. Hydrogen is also expected to emerge as a potential fuel source, offering numerous benefits for the foreseeable future.

From a financial perspective, ship owners investing in green technologies gain preferential access to green financing mechanisms such as sustainability-linked loans and green bonds (Rebelo, 2020). Also, evidence confirms a price premium for eco-ships in the second-hand container market, with financial investors showing a stronger inclination toward these vessels compared to operational buyers (Jia *et al*., 2024). In contrast, vessels failing to meet emission criteria may experience higher operational costs, restricted port access, and declining asset values due to non-compliance. Furthermore, cargo owners and charterers are increasingly integrating environmental performance metrics into contractual agreements, making sustainability a key factor in business decisions (Pereira, 2025).

3. SIGNIFICANT MEASURES WITHIN THE SCOPE OF GREEN SHIPPING REGULATIONS

Regulations based on environmental, social and corporate governance (ESG) principles that have come into force in recent years stand out as a key factor shaping the strategies and operations of shipping companies worldwide. In addition to the obligations imposed by these regulations, as these principles have become a priority in the global business environment, shipping companies have started to focus more on ESG principles to create more value and reduce risks in the long term (Tsatsaronis *et al*., 2024).

Environmental sustainability is at the forefront of ESG initiatives in the maritime industry. As the maritime industry accounts for a significant portion of global carbon emissions, shipping firms are under increasing pressure to reduce their environmental footprint. It can be stated that the regulations mentioned in the previous section for the maritime industry within the scope of combating climate change have become a serious tool in the process of compliance with the environmental dimension of ESG principles. In this adaptation process, companies are investing in renewable energy technologies such as hybrid propulsion systems and wind-assisted technologies to increase fuel efficiency and reduce emissions. In particular, the adoption of alternative fuels such as biofuels, hydrogen,

LNG, methanol, etc., holds promise for further reduction of GHG emissions in the maritime industry. Shipping companies are exploring collaborations with stakeholders across the value chain, including fuel suppliers, shipbuilders and port authorities, to accelerate the transition to cleaner energy sources and achieve ambitious decarbonization targets. This section outlines what these measures entail.

3.1. Goal-Based Measures: EEDI, EEXI and CII

To achieve the zero-emission target, IMO has developed methods to measure technical and operational performance. Energy Efficiency Design Index (EEDI), Energy Efficiency Index of Existing Ships (EEXI) and Carbon Intensity Indicator (CII) are among the important measures developed within the framework of decarbonization efforts in the maritime industry. While EEDI is an international regulation established by the International Maritime Organization (IMO) to encourage the adoption of energy-efficient ship designs and is a criterion required for new-build ships contracted after January 1, 2013 (Tokuşlu, 2020), effective from January 1, 2023, all existing ships of 400 GRT and above, regardless of the delivery date, are required to calculate EEXI as an energy efficiency indicator. The main purpose here is to encourage ships to be designed in a way to reduce carbon emissions (Bayraktar and Yuksel, 2023). Firstly, the EEXI values of existing ships are calculated, and then this value is compared to the required EEXI value according to a certain formula. Ships that meet or exceed the EEXI requirements are considered more environmentally friendly and receive favorable treatment under international regulations. With the EEXI regulation, ship operators are expected to assess the energy efficiency of their ships and take measures to improve performance and reduce emissions to comply with the prescribed EEXI requirements. Measures may include retrofitting existing ships with energy-saving technologies, optimizing operational practices and improving propulsion systems to achieve greater fuel efficiency (ClassNK, 2022).

An EEXI calculation is required for all ships of 400 GRT and above, except for advanced icebreakers, floating production storage and offloading units (FPSO), non-propeller vessels, diesel-electric, turbine or hybrid propeller vessels without conventional propellers, which are defined as Polar Code Category A. The purpose of this calculation is to calculate how many grams of CO_2 emissions a ship produces while moving 1 ton of cargo 1 nautical mile. According to the formula where a specific value is calculated for each ship, the CO_2 factor of the fuel used, the specific fuel consumption of the main engine and generators when operating at a certain percentage, the kW of the machinery on board, the maximum loading capacity of the ship and the EEXI reference speed are considered. Companies should calculate these five parameters very well and provide them as soon as possible. For specific fuel consumption, it would be appropriate to use the approved values from the parameters in the technical file. Otherwise, reference values published by IMO depending on the ship type and tonnage can also be used, but since these values may cause the EEXI calculation to be lower than expected to a certain extent, it is necessary to access the ship's specific information as much as possible. As a matter of fact, the more accurate the information is, the more accurate the EEXI will be. Similarly, the reference speed can be obtained from the tank test reports from the shipyard where the active ships are built. Otherwise, these data can be obtained by speed trial sailing after the ship is brought to the ideal position after the first drydock. In cases where this is not possible, IMO tables can be taken as reference. If a ship with an EEDI value is above the required EEXI value compared to the value written in the Energy Efficiency Certificate, necessary measures should be taken (ClassNK, 2021).

CII, which is the most emphasized by market players and includes the most stringent measures, stands out as the first measure proposed by IMO within the scope of the Greenhouse Gas Strategy, which aims to reduce the carbon intensity of international maritime transportation (Bayraktar and Yuksel, 2023). The CII indicator, which measures how efficiently a ship transports cargo or passengers, is given in terms of cargo carrying capacity and CO_2/gram emitted per nautical mile. CII is one of the most important metrics for

energy efficiency in maritime activities. As shown in Figure 2, its thresholds are becoming more stringent over time until 2030.

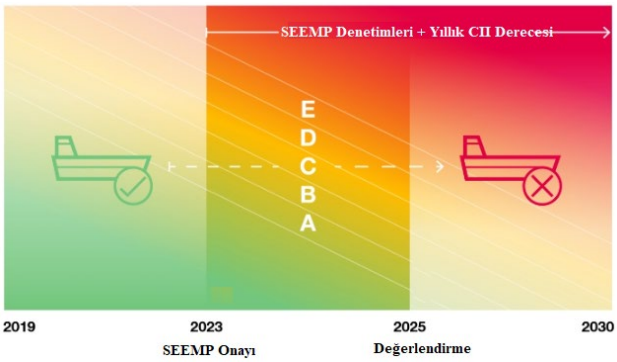

Figure 2. CII Classification and Distribution by Years

In practice, this means that a ship with an A rating may, over time, degrade and become a 'B' rated ship or worse. If the ship is rated 'D' or 'E', the ship operator is required to submit a remedial plan to show how the required index (C or above) will be achieved. This process applies to all ships over 5,000 GT (MAN Energy Solutions, 2024).
While meeting the required EEXI requirement once will be sufficient for the economic life of the ship, CII requires continuous auditing. The main purpose of CII is to check how green the ship's operation is. Unlike EEDI and EEXI, which focus on energy efficiency, CII specifically targets carbon emission intensity by measuring the amount of CO_2 emitted per unit of transport work such as ton-mile or passenger-mile (Garbatov *et al*., 2023). Ship owners and operators are required to monitor and report the carbon intensity of their ships. Indeed, non-compliant vessels will be subject to potential penalties or operational restrictions. The implementation of the CII is expected to incentivize investment in cleaner technologies, alternative fuels and operational practices to reduce emissions and enhance the sustainability of the maritime industry. These measures aim to accelerate the industry's adaptation to the decarbonization process by promoting energy efficiency, reducing GHG emissions and encouraging innovation in ship design, operation and management (Sun *et al*., 2023). Compliance with regulations such as EEDI, EEXI and CII is crucial to ensure the sustainability and competitiveness of the global shipping industry in a carbon-constrained future.

3.2. Market Based Measures

Governments and businesses are increasingly recognizing the importance of carbon pricing for the transition to a low-carbon economy. Carbon pricing is a market-based measure (MBM) used to limit emissions and is gaining momentum worldwide. Currently, 40 national and 25 sub-national jurisdictions are implementing carbon pricing. These initiatives cover 8 gigatons of CO_2 emissions, equivalent to 15 percent of global greenhouse gas emissions. Of the 46 implemented or planned carbon pricing initiatives, 23 are carbon taxes, and 23 are Emissions Trading Systems (ETS). For example, British Columbia implemented a revenue-neutral carbon tax approach covering 70 per cent of total emissions in 2008. In other words, all revenue generated is paid back to taxpayers, including personal income tax, corporate tax and property tax. ETS is also a market-based measure to reduce emissions. In addition to countries' own ETS initiatives, alternatives such as international co-operation and market consolidation are also being examined. In some regions, mixed systems where carbon tax and ETS are used together are preferred (UNFCCC, 2024).
Among the regulations included in the 'Fit for 55' package, which stands out within the scope of 'The European Green Deal', MBM is also considered as a part of the solution. In particular, the inclusion of maritime transport in the EU-Emission Trading System (EU-ETS) stands out as one of the important mechanisms developed in this context (Meng *et al*., 2023; Psaraftis *et al*., 2021). EU-ETS is seen as an effective MBM in combating climate change. MBMs operate according to the 'polluter pays principle' and emitters cover the cost of their emissions (Marrero and Martínez-López, 2023). In summary, in case of a quota exceedance, the carbon tax will be paid per ton until the point where the 'Carbon Allowance' is requested. As shown in Figure 3, according to the EU-ETS, 50 per cent of emissions from voyages starting or ending outside the EU are included in the emissions calculation (allowing the third country to decide on the appropriate action for the

remaining share of emissions), 100 per cent of emissions between two EU ports and 100 per cent of emissions when ships are within EU ports (European Commission, 2023b).

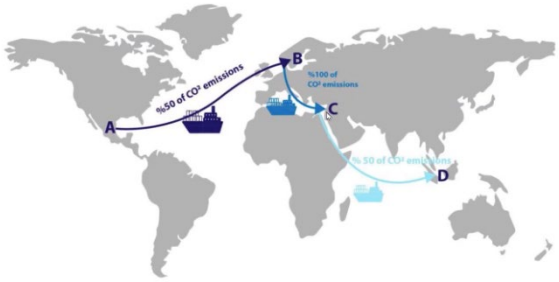

Figure 3. EU-ETS Coverage

There are questions about what the EU-ETS means and how it will be applied to maritime transport in the future. The ETS is not a new regulation but has a history dating back to 2005. Rather, the maritime industry is building on the existing mechanisms according to a specific timetable (European Commission, 2024). In addition, some changes are being made in accordance with the mobility of ships, including the MRV mechanism.

There are very serious costs in this mechanism, which will expand over time. Shipping companies must comply with MRV regulations from today and the financial consequences are estimated at around EUR 10 billion per year until 2026. With disagreements on actual emissions and MRV reporting, existing contracts and long-term lease agreements need to be renegotiated to cover emissions costs. Real-time verified emission data is crucial for recent contractual agreements.

Emissions trading can be explained with an example. Assume that companies A and B both produce 100,000 tones of CO_2 emissions per year. Assuming that the competent authority gives each of them 95.000 tonnes of carbon permits, 'The Cap', both companies will look for ways to close the 5.000 tonnes deficit. In this case, the companies will have the choice to reduce their current emissions by 5000 tonnes, or to buy 5000 tonnes of carbon quotas from the market, or to take a position somewhere between the two alternatives (The Trade). They will need to compare the cost of each before deciding which option to take. Let us assume that the price of carbon in the market at that moment is €20 per tonne of CO_2. Suppose company A calculates that it will cost it €10 per tonne to reduce its emissions. Let's assume that company A decides to reduce 10,000 tonnes, motivated by the low cost compared to the market price. Suppose that company B, on the other hand, calculates that the cost of carbon emission reduction costs is €30 per tonne, i.e. higher than the market price, and therefore decides to buy quotas from the market instead of reducing emissions. In this case, company A will spend €100 000 to reduce its emissions by 10 000 tonnes at a cost of €10 per tonne, but will then sell the 5 000 quotas it no longer needs at a market price of €20/tonne, generating a revenue of €100 000. This would mean that the costs of emission reduction are fully offset by selling quotas. Whereas without the emissions trading system, company B, which would have to incur a net cost of €50,000 assuming that it would reduce emissions by the required 5,000 tonnes, would spend €100,000 to buy 5,000 tonnes of quota at a market price of €20/tonne. Without the flexibility provided by the ETS, it would have to reduce its emissions by 5,000 tonnes at a cost of €150,000. Therefore, emissions trading provides a total cost saving of €100,000 for the companies in this example. Since Company A has chosen to reduce its own emissions, even if Company B has not reduced its own emissions, it will be reduced to the required level with the quota purchased. As seen in this example, with EU-ETS, emissions will be reduced at the lowest possible economic cost (European Commission, 2009).

4. INDUSTRIAL EFFECTS OF GREEN SHIPPING REGULATIONS

The implementation of green shipping regulations has a multifaceted impact on the productivity of the maritime industry. While these regulations aim to drive sustainability, they also introduce operational and financial challenges that influence industrial productivity (Filippopoulos *et al*., 2024).

4.1. Mechanisms of Regulatory Impact on Industrial Productivity

Compliance with stringent environmental regulations necessitates significant financial investments, affecting the cost structures of shipping companies. Regulations such as the IMO's Energy Efficiency Existing Ship Index (EEXI) and Carbon Intensity Indicator (CII), as well as the EU Emissions Trading System (EU-ETS), require vessel owners to adopt cleaner technologies, install energy-efficient equipment, or switch to low-emission fuels. These compliance costs—ranging from retrofitting expenses to the purchase of carbon credits—can lead to short-term productivity declines as firms allocate resources to regulatory adaptation rather than operational efficiency. For smaller shipping firms and those operating older fleets, these financial burdens may reduce their competitiveness, leading to potential market exits. Under target-oriented measures, existing vessels are expected to meet minimum standards set according to their technical characteristics and operational profiles. The CII is more important for market players as it includes the obligation to comply with increasingly stringent levels throughout the economic life of the ship. As a matter of fact, the fact that the required level of energy efficiency is exceeded once and there is no obligation to renew the certificate once it is obtained causes the focus to be mainly on CII. Moreover, while EEXI is based on the theoretical capacity, empty sailing within the scope of CII will have a negative impact. Therefore, the need to minimize ballasted voyages will arise. This may have another negative impact on ship management. Ships in D and E classes will face additional costs such as higher taxes and insurance. Since the average fuel consumption and speed in the current period are taken into consideration while determining the classification, if the ships in these classes cannot take the necessary actions, they also carry the risk of being dropped from these classes and being banned from maritime trade activities with the entry of new construction ships into the market.

4.2. Effects by Ship Tonnage

Regulatory changes influence the competitive landscape of the maritime industry by favoring firms that can adapt more efficiently. Larger shipping companies with greater financial flexibility are better equipped to absorb compliance costs, integrate sustainable technologies, and secure green financing. In contrast, smaller firms with limited capital may struggle to comply, leading to market consolidation as weaker players exit or merge with larger entities. The fact that the EEXI account is mandatory for all ships of 400 GRT and above while the CII account is mandatory for ships of 5000 GRT and above shows that small tonnage ships are exempt, but small tonnage ships will also be indirectly affected by this practice. Considering that small tonnage vessels are below 5000 GRT, although these vessels seem to be exempt from the CII obligation, they face a growing risk of being excluded from chartering opportunities as sustainability-conscious cargo owners and charterers prioritize lower-carbon transportation options. Moreover, stricter environmental policies in key maritime regions, particularly in European Union ports, pose additional challenges for small tonnage ships. Companies required to calculate carbon footprints throughout a product's lifecycle may avoid working with high-emission ships, significantly impacting the industry. Charterers increasingly request emission data from ship operators, a trend expected to grow. Although exempt, small tonnage operators should address CII. Stricter regulations will likely emerge by 2030, a key milestone for EU and IMO targets.

4.3. Effects by Regional Context

The effectiveness of compliance varies across regions and vessel types, with developed maritime hubs better equipped to meet standards (Akac *et al*., 2023). Maritime hubs like Northern Europe, Japan, and South Korea enforce stricter regulations and have better access to technology, ensuring easier compliance with CII and EEXI. Developing regions, such as parts of Africa and Southeast Asia, face significant financial and technical barriers (Baştuğ *et al*., 2024). European ports have made significant progress in adopting various sustainability initiatives compared to North American and Asia Pacific ports (Hossain *et al*., 2021). Ports are increasingly integrating

renewable energy sources, improving energy efficiency, and implementing new infrastructure to reduce environmental impact (Sadiq *et al*., 2021). However, a gap exists between developed and emerging countries in terms of energy management and environmental policies (Durán *et al*., 2022).

4.4. Financial Effects

There is a major financial challenge related to the zero-emission journey of the industry. With the entry into force of the EU-ETS, a price will have to be paid for maritime emissions. Shipping companies must annually report verified emission data for MRV compliance, purchase carbon quotas from the market and submit them to the responsible national authority within the EU. The aim of the EU ETS regulation is to transfer the cost of emissions to the polluter, i.e. the end user. Transport companies are required to ensure that emission quotas are transferred along the value chain in order to avoid the financial burden. Owners must be ready to submit their quotas to national authorities annually and provide verified emissions data to ensure compliance.

The economic dimension is crucial for investment decisions in innovative ship technologies (Raza, 2020). As the transition to cleaner fuels or technologies often requires large initial investments, many shipping companies find it difficult to secure the necessary financing for these initiatives. As environmental requirements tighten and the age of ships increases, it will become increasingly difficult to choose between retrofitting or newbuilding, given that the technical value of ships will decrease and the cost of refurbishment will increase. Besides uncertain returns on investment, other threats include limited access to affordable finance, lack of adequate investment incentives, high development costs for infrastructure, technology-related risks, volatile market and fuel prices, competitive pressures and lack of uniform regulations. While the short-term costs of this transformation are prominent, it is also useful to focus on the long-term benefits of alternatives. Looking at the studies carried out in this context, Bui *et al*. (2021) introduced a life cycle cost analysis (LCCA) for emission-reducing ship machinery, while Yalamov *et al*. (2023) used NPV scenarios to evaluate dual-fuel adoption. A case study on South Korean container shipping suggests that LNG fuel retrofitting may be the most favorable option for meeting EEXI and CII requirements (Ahn *et al*., 2023). Their findings suggest that due to economic uncertainties, LNG price volatility, and CO_2 taxation, shipowners should secure long-term LNG contracts to sustain GHG reduction efforts.

Methanol and LNG are viable alternatives for emission reduction (Lagemann *et al*., 2022), with LNG allowing cost-effective retrofitting to ammonia. These trends align with current vessel orders. Zhao *et al*. (2023) indicate that LNG will dominate in the short term, while ammonia and hydrogen will be key transition fuels. Retrofitting, efficient navigation, and shore power are essential for decarbonization. Liu *et al*. (2022) found LNG's NPV lower than MGO's, recommending MGO retrofitting for maximum economic benefits. Additionally, compliance-driven restructuring extends to port operations and supply chain logistics, as regulatory-compliant firms seek partnerships with green ports and eco-friendly logistics providers. This shift alters the traditional market dynamics and redefines competitive advantages within the industry.

While the EU is often seen as the spearhead of maritime decarbonization efforts, it is important to recognize the vital role that non-EU countries play in shaping the sustainable future of this industry. As significant contributors to shipping emissions, non-EU countries hold the key to steering the industry towards environmentally responsible pathways. However, financing options for shipping decarbonization initiatives present challenges that require innovative strategies. A net zero emissions target has significant financial implications for shipowners and operators, particularly in terms of the large investments required to transition to a greener shipping fleet.

Achieving the set targets will also come at a cost to the end user. Indeed, the cost of using the new fuels will be passed on to shippers who commit to decarbonize their supply chains. Theoretically, if consumers choose Net Zero products, Net Zero

supply chains will be achieved. In practice, consumer choice alone will not be enough. To make green fuels competitive, the cost of heavy fuel oil needs to increase, which will inevitably lead to products becoming more expensive, which means inflation.

4.5. Effects on Charter Contracts

There are concerns about existing contracts in relation to MRV. Long-term charter contracts will need to be renegotiated. Especially in the measurement of actual emissions from a ship, disputes may arise, and the perspective of the charterer and the owner may differ. Although legal compliance with the system will take place according to a specific timetable, data will need to be available in 2024, as the cost of waiting in the commercial world can be high and given that there are contracts that need financial settlement as early as possible. Therefore, the need for real-time verified emission data will increase. Otherwise, there will be problems in contracts with existing partners, it will not be possible to take advantage of new business development opportunities, and ultimately there will be an increase in business and financial risk. Furthermore, the risk of operating some non-compliant vessels may translate into legal implications that need to be addressed for the entire fleet of vessels under management.

4.6. Opportunities

Achieving the net zero carbon emission target for the maritime industry also offers significant opportunities for national economies. For example, newbuilding investments incentivized by emission regulations certainly create a significant economic impact, especially for countries with a large share in the world shipbuilding activities. South Korea, which has highly developed technological competitiveness in the face of high value-added, environmentally friendly shipbuilding orders, has increased its global market share to 37 per cent and has become the leader with a 54 per cent market share, especially in LNG propulsion (MOTIE, 2023). The development of policies that provide added value from all logistics processes, especially transport and storage systems, regarding the supply of these clean fuels will make a significant contribution to the economies of countries.

While studies on various clean fuel alternatives as potential substitutes for dirtier marine fuel continue, new techniques and technologies are also being explored (Bouman *et al*., 2017). It is observed that supply options are shaped depending on demand. In particular, a thriving market is emerging for technology companies dedicated to developing green shipping practices (Md Moshiul *et al*., 2021). In this context, companies working on the development and commercialization of technologies can significantly benefit from the growth of new industry initiatives aimed at reducing the environmental impact of global maritime trade activities with more than 100,000 ships. As highlighted by Schuler (2021), the total cost of modernizing the global merchant fleet to meet 2050 emission targets is estimated to be around USD 2 trillion. There is a total market of USD 3.4 trillion for businesses that can offer clean technology solutions to help maritime companies meet these new regulatory requirements. Therefore, supporting enterprises/initiatives in the direct or indirect industries that will operate in this context with various incentive mechanisms can provide significant gains to the national economies in the long term.

In addition, various financial instruments with a green maritime theme are also being developed. Among the most important developments in this regard, instead of bonds among traditional borrowing instruments, the ‘green bond’ developed to support projects within the scope of green transformation now stands out as an important financial substitute (Rizou, 2023). Green bonds can make significant contributions for countries in increasing the efficiency of financial markets. Especially considering the capital-intensive structure of the maritime industry, it can be stated that it will be an important tool in meeting the external resource needs of market players at affordable costs.

5. CONCLUSIONS

In accordance with the Paris Agreement within the scope of combating climate change, countries

and international regulatory authorities have taken various initiatives and enacted regulations containing strict measures and legal obligations to achieve the targets set. IMO, which has an important mission to bring maritime trade to the desired structure, is also taking important steps in this context. GHG regulations, which came into force after the NO_X and SO_X regulations, have raised the bar one more level. Green maritime regulations mark an important point in the evolution of maritime trade. In response to increasing environmental regulations, this study highlights the critical role of policy, technology, and market-based mechanisms in shaping the green transformation of the maritime industry. While regulatory compliance presents financial and operational challenges, proactive adaptation through sustainable investments and strategic planning can ensure long-term resilience and competitiveness. It seems that all stakeholders of the industry, especially ship operators, will try to exist on a playing field that they have not encountered before. Therefore, it is necessary to understand what is at stake and to take the necessary steps without delay. This study emphasizes the multifaceted impacts of green maritime regulations on various aspects of the maritime industry, from operational practices to economic dynamics.

Within the scope of green transformation, governments need to develop various incentive mechanisms for the maritime industry. Among these, establishing a quota for the maritime industry while granting renewable energy licenses for the maritime industry to be less affected by carbon taxes can make a significant contribution. As a matter of fact, many large manufacturing companies aim to use their quotas in their own production facilities by investing in renewable energy facilities to convert their CO_2 positive quotas into negative quotas. Allocating quotas for the maritime industry can protect it from the high costs of purchasing carbon quotas from the market. Ports may also need to be prepared or incentivized accordingly.

Especially in developing countries such as Türkiye, focusing on some niche areas can be considered as a strategic step. In this context, studies on environmentally friendly engines for special purpose vessels such as fishing motors, recreational boats, tugboats and yachts can be increased. Therefore, scientists should be supported within the scope of R&D studies and support mechanisms should be provided without delay. In this respect, it is especially important for developing countries to receive the highest possible share from the fund to be established at IMO.

It should not be forgotten that there is a serious threat to the maritime trade fleets of the countries. For example, it can be considered that Türkiye's maritime trade fleet mainly consists of old and small tonnage general cargo ships and if this fleet succumbs to the green transformation process, foreign trade companies will incur high costs in transporting their cargoes and will have a negative impact on the sustainability of foreign trade. Therefore, it may provide significant gains for the top management of the companies to take measures rapidly against these developments, to form units within their own organizations, and for small companies, which are in the highest risk group, to act in clusters. In order to make sustainable practices financially viable and desirable for the maritime industry, it will be necessary to address these complex issues and develop supportive government frameworks, industry-wide co-operation and new financing models. The feasibility of such models depends on the financial structure of firms and the regulatory frameworks they operate within. For large shipping firms in developed economies, green bonds, sustainability-linked loans, and government-backed subsidies provide viable funding mechanisms. However, for small and medium-sized enterprises (SMEs) or operators in developing regions, access to capital remains limited. Therefore, financing models should include flexible instruments such as public-private partnerships (PPPs), carbon credit trading schemes, and regional funding pools that reduce the financial burden on smaller market players. These approaches can be tailored to specific regulatory and economic contexts, making them more widely applicable. The generalizability of the proposed solutions is crucial in ensuring that different stakeholders—ranging from policymakers and shipowners to financial institutions—can adapt these strategies to their needs. While some measures, such as

compliance-driven retrofitting and digital optimization, are universally applicable, others, like alternative fuel investments, depend on infrastructure availability, economic incentives, and market readiness. Future research should further explore scalability models for green financing, assess the long-term economic viability of alternative fuels, and analyze how policy interventions can support equitable decarbonization across diverse maritime regions. By integrating regulatory, financial, and technological perspectives, this study provides a structured approach to understanding and addressing the challenges of green shipping. Moving forward, interdisciplinary research and collaboration between industry stakeholders will be essential to refine these strategies and facilitate a sustainable maritime future.

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Ersin Fırat AKGÜL: Conceptualization, Resources, Writing - Original Draft, Writing-Review and Editing, Visualization

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The author(s) declare that for this article they have no actual, potential or perceived conflict of interests.

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Epilithic Diatom Composition of Madra Stream (Türkiye)

Madra Çayı (Türkiye)'nın Epilitik Diyatom Kompozisyonu

Türk Denizcilik ve Deniz Bilimleri Dergisi
Cilt: 11 Sayı: 2 (2025) 136-150

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ABSTRACT

Madra Stream, located in the Northern Aegean River Basin of Türkiye, rises from the southwestern slopes of Madra Mountain (1343 m.) and flows into the Aegean Sea within the borders of Balıkesir province. In this study, we aimed to contribute to the determination of the freshwater algal flora of Türkiye by investigating the epilithic diatom composition of Madra Stream using Water Framework Directive (WFD) methods. For this purpose, seasonal diatom sampling was conducted at seven stations selected within the study area between 2015 and 2016. During the sampling period, a total of 100 epilithic diatom species belonging to 48 genera were identified in Madra Stream. The results of the study revealed that *Navicula* (13 species), *Nitzschia* (5 species), *Cymbella, Gomphonema, Pinnularia* and *Surirella* (4 species of each) were the genera with the highest number of species. The epilithic diatom communities of the Madara Stream were examined in detail for the first time with this study. According to the hierarchical cluster analysis (Bray-Curtis) based on the presence-absence data of epilithic diatoms, the species composition similarity between the selected stations was found to be over 50%. It was concluded that the epilithic diatom composition of Madra Stream primarily consists of species adapted to eutrophic and, to a lesser extent, oligo-mesotrophic running water environments.

Keywords: Biodiversity, Algal flora, Epilithic, Diatoms, Madra stream, WFD.

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ÖZET

Türkiye'nin Kuzey Ege Nehir Havzası'nda yer alan Madra Çayı, Madra Dağı (1343 m.)'nın Güneybatı yamaçlarından doğar ve Balıkesir ili sınırları içerisinden Ege Denizine dökülür. Bu çalışmada, Su Çerçeve Direktifi (SÇD) yöntemleri kullanılarak Madra Çayı'nın epilitik diyatom kompozisyonu incelenerek, Türkiye tatlısu alg florasının belirlenmesine katkılar sağlamak amaçlanmıştır. Bu amaçla, 2015 ve 2016 yılları arasında, araştırma sahamızda seçilen 7 istasyondan mevsimsel diyatom örneklemeleri yapılmıştır. Örnekleme periyodu süresince, Madra Çayı'nda 48 cinse ait toplamda 100 epilitik diyatom türü teşhis edilmiştir. Çalışma sonucunda, *Navicula* (13 tür), *Nitzschia* (5 tür), *Cymbella*, *Gomphonema*, *Pinnularia* ve *Surirella* (4'er tür) görece en fazla türle temsil edilen cinsler olmuştur. Bu çalışma ile Madara Çayı'nın epilitik diyatom toplulukları ilk kez ayrıntılı olarak incelenmiştir. Epilitik diyatomların varlık-yokluk verisi baz alınarak yapılan hiyerarşik kümelenme analizine (Bray-Curtis) göre, seçilen istasyonlar arasındaki tür kompozisyonu benzerliği %50'nin üzerinde bulunmuştur. Madra Çayı'nın epilitik diyatom kompozisyonunun, çoğunlukla ötrofik ve kısmen de oligo-mezotrofik ortamlara uyumlu türlerden oluştuğu değerlendirilmiştir.

Anahtar sözcükler: Biyoçeşitlilik, Alg florası, Epilitik, Diyatomlar, Madra Çayı, SÇD.

1. GİRİŞ

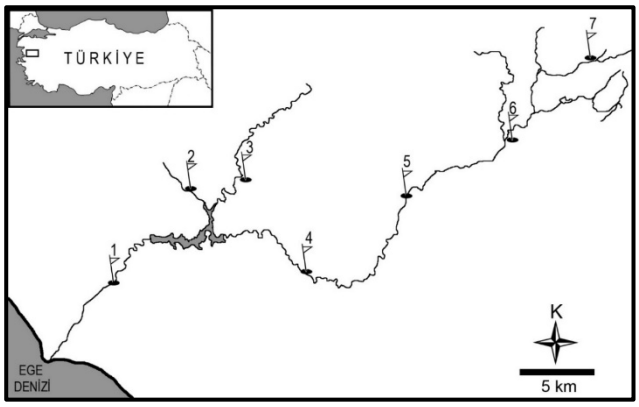
Diyatomlar, tek hücreli, früstül olarak bilinen ve çeşitli formlarda desenler sergileyen silikadan oluşan belirgin hücre duvarları ile karakterize olan, az veya çok su ve ışığın bulunabildiği tüm ekosistemlerde yaşayan, mikroskobik ve birincil üretici organizmalardır (Seckbach ve Kociolek, 2011). Diyatomlar, kutup bölgelerinden tropikal sulara kadar hem tatlı su hem de deniz ortamlarında kolonize olabilirler ve fotosentez yoluyla dünyadaki oksijenin yaklaşık %25'ini üretmekten sorumludurlar (Field *vd*., 1998; Smol ve Stoermer, 2010). Ayrıca, diyatomlar çevresel faktörlere karşı duyarlılıkları nedeniyle su kalitesi ve ekolojik değişikliklerin önemli biyoindikatörleri olarak da hizmet ederler (Lobo *vd*., 2016). Zamanla su tortularında biriken diyatom früstülleri, geçmiş iklim koşulları ve çevresel değişiklikler hakkında değerli veriler sağlar ve bu özellikleri onları paleoklimatoloji ve paleolimnoloji araştırmalarında kullanışlı araçlar haline getirir (Mackay, 2007).

Mann ve Droop (1996) diyatomların 200 binden fazla türünün bulunabileceğini bildirmiştir. Olası bu türler arasından, mevcut olarak bilinen yaklaşık 20 bin tür vardır ve buradan türlerin ancak %10'nun tanımlanabildiği anlaşılmaktadır (Guiry ve Guiry, 2025). Ülkemiz içsularında ise diyatomlar üzerine 300'den fazla çalışma yapılmış ve günümüze kadar Türkiye Alg Florasına 1800'den fazla tür kaydı yapılmıştır (Solak *vd*., 2012; Taşkın *vd*., 2019; Maraşlıoğlu ve Gönülol, 2025). Biyocoğrafik konumu, topoğrafik çeşitliği, iklimsel ve jeolojik değişkenlikleri sebebiyle yüksek endemizme ve biyoçeşitliğe sahip olan ülkemizde (Gemici *vd*.,1992; Atalay, 2008; Keser, 2013), diyatomlar üzerine yapılacak olan yeni çalışmalarla bu sayının artması yüksek bir olasılıktır. Bununla birlikte, sahip olduğumuz biyoçeşitliliğin ortaya çıkarılmasının yansıra, yapılacak floristik çalışmalarla türlerin habitatlara dağılımları ve oluşturdukları topluluk yapılarının belirlenmesi de oldukça önemlidir. Bu çalışma ile Ege Bölgesinde bulunan Madra Çayı diyatom kompozisyonu ayrıntılı olarak ilk kez tespit edilerek, Türkiye tatlısu alg florasının belirlenmesi üzerine bilimsel katkılar yapmak amaçlanmıştır.

2. MATERYAL VE YÖNTEM

Madra Çayı, Türkiye'nin Kuzey Ege Nehir Havzası'nda, Balıkesir ile İzmir illerinin sınırında ve 39° 07'- 39° 22' Kuzey enlemleri ile 26° 40'-27° 15' Doğu boylamları arasında yer almaktadır. Yükseltisi 1343 m olan Madra Dağı'nın Güneybatı yamaçlarından doğan bu akarsu, Ege Denizi'ne kuş uçumu yaklaşık 45 km'de ulaşmakta ve Balıkesir'in Altınova ilçe sınırları içerisinden denize dökülmektedir.

Epilitik diyatom örneklemeleri için akarsu ağı üzerinde 7 istasyon belirlenmiştir (Şekil 1).



Şekil 1. Madra Çayı ve örnekleme istasyonları

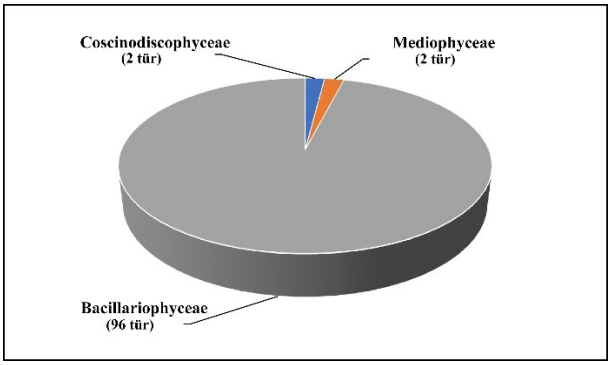
İstasyonların konumları ve karekterstikleri; İstasyon 1: Madra Çayı'nın Balıkesir İli Altınova İlçesi kıyılarından denize dökülmeden önceki ve baraj altı bölgededir. 39°13'58" K enlemi ve 26°49'50" D boylamındadır. Deniz seviyesinden yüksekliği 43 m'dir. İstasyon 2: Balıkesir Ayvalık'a bağlı Karaayıt Köyü mevkiinde bulunan örnekleme istasyonudur. 39°16'02" K enlemi ve 26°52'24" D boylamındadır. Bu istasyona yakın bölgede demir madeni zenginleştirme tesisi ve yerleşim bulunmaktadır. Deniz seviyesinden yüksekliği ise, 158 m'dir. İstasyon 3: Bergama Okçular Köy yolu üzerinde yer alan Esirik Köprüsü'nün yakınlarındadır. 39°16'20" K enlemi ve 26°54'21" D boylamındadır. Debisi düşüktür. Deniz seviyesinden yüksekliği 230 m'dir. İstasyon 4: İzmir'in Bergama İlçesine bağlı olan Kozak Kaplan Köyü'ndedir. 39°12'51" K enlemi ve 26°57'51" D boylamındadır. İstasyona yakın bölgede altın madeni ocağı bulunmaktadır. Deniz seviyesinden yüksekliği 324 m'dir. İstasyon 5: Su seviyesi görece az, akarsu yatağı ise oldukça geniştir. Bu kesimin zemin yapısı daha çok kumludur. 39°15'47" K enlemi ve 27°02'04" D boylamındadır. Deniz seviyesinden yüksekliği 432 m'dir. İstasyon 6: 39°17'36" K enlemi ve 27°06'27" D boylamındadır. İki yan kolun birleştiği bir noktadadır. İstasyon çevresinde hayvan çiftlikleri gibi tarımsal faaliyetler yoğun olarak yapılmaktadır. Deniz seviyesinden yüksekliği 458 m'dir. İstasyon 7: Madra Çayı'nın kaynaklarının bulunduğu bölgededir. İzmir İli Bergama İlçesi Kozak Yaylası'ndaki Çamavlu Köyü yakınlarındadır. 39°20'18" K enlemi ve 27°09'47" D boylamındadır. Deniz seviyesinden yüksekliği 764 m'dir.

Madra Çayı'nın epilitik diyatomları, 2015 ve 2016 yıllarında sonbahar, kış, ilkbahar ve yaz mevsimlerinde örneklenmiştir. Diyatom örneklerinin toplanmasında, kabuklarının temizlenmesinde ve kalıcı preparatların hazırlanmasında, Avrupa Su Çerçeve Direktifi uygulamaları için oluşturulan standart yöntemler tercih edilmiştir (Kelly *vd.,* 1998; CEN 13946, 2003). Bu yöntemlere göre; önceden seçilen her bir istasyon bölgesinde, gölge olmayan alanlar örnekleme noktası olarak seçilmiştir. Yüzeyi düzgün ve pürüzsüz taşlar derinlik en az 20 cm olan bölgelerden toplanmıştır (5 adet). Taşların üst yüzeylerindeki alanlardan diş fırçası yardımı ile toplanan diyatomlar 250 ml' lik örnek kaplarına alınmış ve formaldehitle (sonuç konsantrasyonu %4) ile fikse edilerek laboratuvara getirilmiştir. 15 ml'lik Falkon tüplerine alınan diyatom örnekleri 24 saat çökelmeye bırakılmış ve devamında tüpün üstünde kalan süpernatant sifonlanarak üzeri saf su ile doldurulup örnekler tekrar homojenize edilmiştir (2 tekrar). Diyatomların temizlenmesinde potasyum dikromat ($K_2Cr_2O_7$) ile sıcak hidrojen peroksit (%30) yöntemi kullanılmıştır. Tüplerdeki örneklerin 24 saat bekletilmesi sonrası diyatom materyalinden asit uzaklaştırılması yapılmış ve saf su ile doldurularak örnekler tekrar homojenize edilmiştir (en az 3 tekrar/nörtralize olana kadar). Bu süreç sonunda, organik maddelerden uzaklaştırılmış olan diyatom kabuklarını içeren süspansiyondan bir damla, lamel üzerine damlatılarak ısıtıcı tabla üzerinde 90 °C'de kurumaya bırakılmıştır. Daha sonra lamelin diyatom kabuklarını taşıyan yüzeyi, NaphraxTM damlatılan lam üzerine yerleştirilmiştir. Kalıcı sertleşme için preparat ısıtıcı tabla üzerinde yaklaşık 1 dakika kaynatılmış ve sonrasında soğumaya bırakılmıştır (Blanco *vd*., 2008; Martin ve Reyes Fernández, 2012). Preparatlar Olympus BX53 (DIC) mikroskobu ile 400x ve 1000x büyütmede incelenmiştir. Diyatomların ölçümlerinde ve fotoğraflarının çekilmelerinde 10,6 megapiksel Olympus SC 100 dijital kamera ve cellSens Entry yazılımı kullanılmıştır.

Diyatom türlerinin teşhisinde çeşitli araştırmacıların monografik eserlerinden yararlanılmıştır (Hartley *vd*., 1996; Krammer ve Lange-Bertalot, 1986; 1987; 1988; 1991a; 1991b; 1999; Lange-Bertalot, 2001; Krammer, 2000; 2002; 2003). İstasyonların benzerliklerini belirlemek için, diyatomlarının varlık-yokluk verisine göre Biodiversity Professional, 2.0 ile Bray-Curtis hiyerarşik kümelenme analizi gerçekleştirilmiştir (McAleece *vd*., 1997).

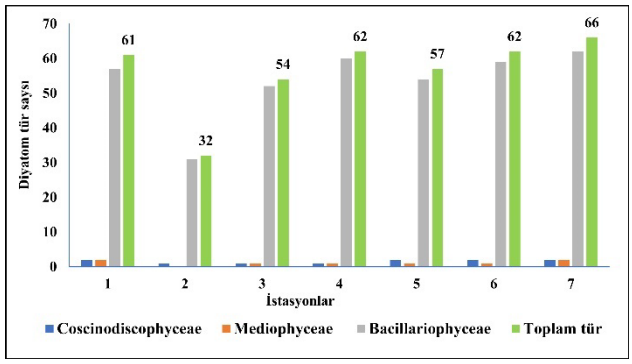
3. BULGULAR

Madra Çayı'nın epilitik diyatomları üzerine yapılan incelemelerde, Bacillariophyta bölümünden 48 cinse ait 100 diyatom türü bulunmuştur (Tablo 1). Sıklıkla gözlenen türlerin bazıları fotoğraflanmıştır (Şekil 5a-c). Bu diyatomların 96'sı Bacillariophyceae, 2'si Coscinodiscophycea ve diğer 2'si de Mediophyceae sınıfındandır (Şekil 2). Türlerin cinslere dağılımı ise; *Navicula* (13 tür), *Nitzschia*, (5 tür), *Cymbella*, *Gomphonema*, *Pinnularia, Surirella* (4'er tür), *Amphora*, *Craticula*, *Fragilaria*, *Encyonema*, *Sellaphora* (3'er tür), *Caloneis*, *Cocconeis*, *Cymatopleura*, *Diploneis*, *Epithemia*, *Eunotia*, *Gyrosigma*, *Halamphora*, *Neidium*, *Placoneis*, *Rhopalodia*, *Stauroneis*, *Staurosira, Ulnaria* (2'şer tür), *Aneumastus*, *Aulacoseira*, *Cyclostephanos*, *Cymbopleura*, *Diatoma*, *Didymosphenia*, *Frustulia*, *Gomphonella, Hannaea*, *Hantzschia*, *Hippodonta*, *Iconella*, *Luticola*, *Melosira*, *Meridion*, *Navigeia, Neidiomorpha*, *Planothidium*, *Pseudostaurosira*, *Paraplaconeis*, *Reimera*, *Rhoicosphenia* ve *Stephanocyclus* (1'er tür) şeklindedir.



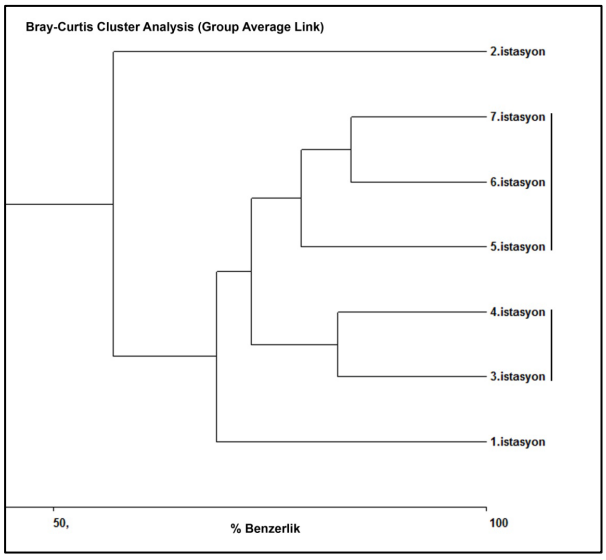
Şekil 2. Madra Çayı epilitik diyatomlarının sınıflara göre dağılımı

Madra Çayı'nda istsyonlar arasında epilitik diyatom tür sayıları en az 32 (2. istasyon), en çok 66 (7. istasyon) olarak bulunmuştur ve tüm istasyonlarda Bacillariophyceae sınıfı diyatomlar yüksek oranda temsil edilmiştir (Şekil 3).



Şekil 3. Madra Çayı epilitik diyatomlarının sınıflara göre dağılımı

Diyatom türlerinin varlık-yokluk durumlarına göre hiyerarşik kümelenme analizi (Bray-Curtis) yapılmış ve istasyonların birbirlerine benzerlik durumları belirlenmiştir (Şekil 4). Kümelenme analizine göre, 3. ve 4. istasyonlar %82,8 benzer; 6. ve 7. istasyonlar %84,4 benzer bulunmuştur. 6 ve 7 istasyonlara en yakın benzerliğe sahip 5. istasyon olmuştur. 1. istasyon ise, diğer tüm istasyonlarla %50'nin üzerinde benzerlik göstermiştir. En farklı olarak görülen 2. istasyonun ise diğer istasyonlara olan benzerliği ise %51,6-%67,4 arasında değişmiştir.



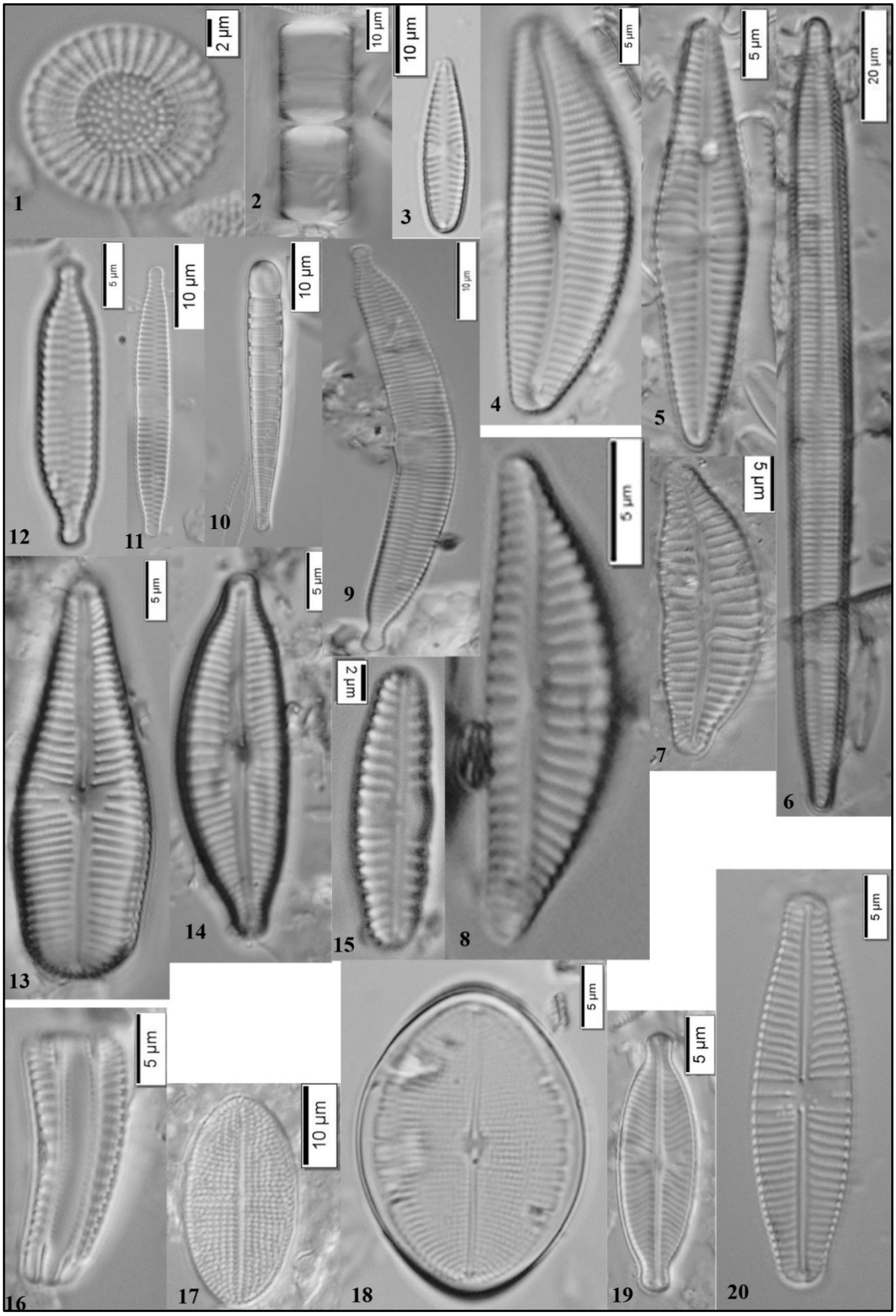
Şekil 4. Madra Çayı istasyonlarının epilitik diyatom türlerine göre benzerliği

Tablo 1. Madra Çayı'nın epilitik diyatomlarının istasyonlara göre dağılımları ve mevsimsel sıklıkları
(▲: % 100, 4 mevsim, ■: % 75, 3 mevsim, ◘: % 50, 2 mevsim, +: % 25, 1 mevsim)

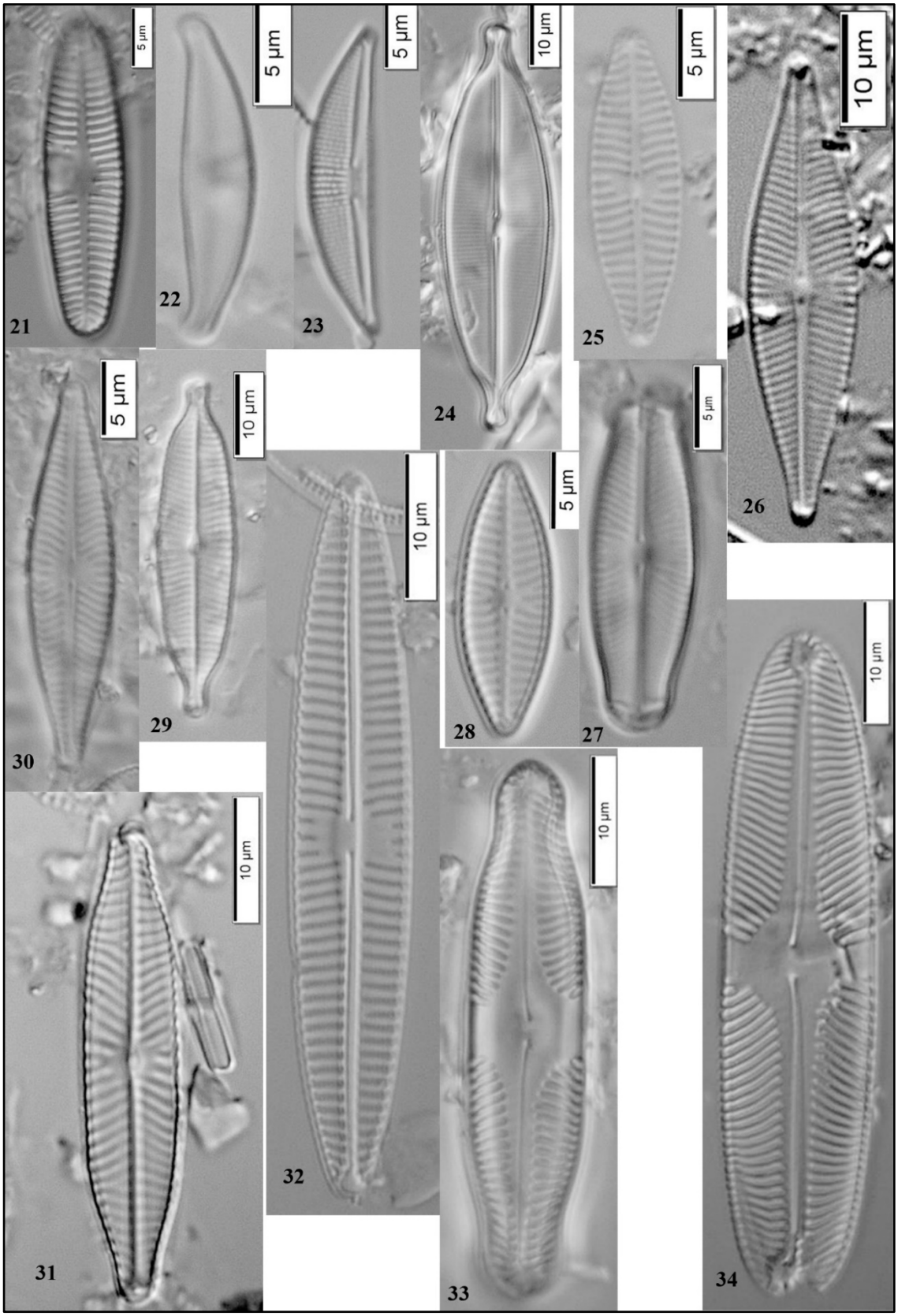
Bölüm: BACILLARIOPHYTA	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Sınıf: Coscinodiscophyceae							
Aulacoseira ambigua (Grunow) Simonsen	+				+	◘	+
Melosira varians C.Agardh	■	◘	▲	■	▲	+	▲
Sınıf: Mediophyceae							
Cyclostephanos dubius (Hustedt) Round	▲						◘
Stephanocyclus meneghinianus (Kützing) Kulikovskiy, Genkal & Kociolek	▲		■	◘	◘	■	◘
Sınıf: Bacillariophyceae							
Amphora copulata (Kützing) Schoeman & R.E.M.Archibald	+						
Amphora libyca Ehrenberg	▲	+	+	◘	◘	■	+
Amphora ovalis (Kützing) Kützing	+						
Aneumastus tusculus (Ehrenberg) D.G.Mann & A.J.Stickle				+	+		
Caloneis bacillum (Grunow) Cleve				+			◘
Caloneis permagna (Bailey) Cleve	+						
Cocconeis pediculus Ehrenberg	▲		◘	◘		+	+
Cocconeis placentula Ehrenberg	▲		▲	▲	■	▲	▲
Craticula accomoda (Hustedt) D.G.Mann					◘	+	+
Craticula ambigua (Ehrenberg) D.G.Mann	+	+	◘	◘	■	+	
Craticula cuspidata (Kutzing) D.G.Mann					+		
Cymatopleura elliptica W.Smith	◘	+	+				
Cymatopleura solea (Brébisson) W.Smith	◘		■	◘			
Cymbella compacta Østrup	◘			■	◘	+	▲
Cymbella cymbiformis C.Agardh	+						+
Cymbella excisa Kützing	■			◘	◘	+	+
Cymbella subcistula Krammer				+			+
Cymbopleura hercynica (A.Schmidt) Krammer	+			+	+	+	◘
Diatoma vulgaris Bory	▲			■			
Didymosphenia geminata (Lyngbye) Mart.Schmidt					+	+	+
Diploneis elliptica (Kützing) Cleve				+		+	
Diploneis ovalis (Hilse) Cleve						+	+
Encyonema caespitosum Kützing	+						
Encyonema leibleinii (C.Agardh) W.J.Silva, R.Jahn, T.A.Veiga Ludwig&M.Menezes	+						
Encyonema silesiacum (Bleisch) D.G.Mann	▲		◘	◘	◘	■	▲
Epithemia sorex Kützing		+	▲	◘			
Epithemia turgida (Ehrenberg) Kützing			■				
Eunotia minor (Kützing) Grunow	+				+	+	
Eunotia sudetica O. Müller				+			
Fragilaria capucina var. *capitellata* (Grunow)Lange-Bertalot	+	◘	■	■	▲	◘	▲
Fragilaria crotonensis Kitton	+		▲	+	+	◘	+
Fragilaria vaucheriae (Kützing) J.B.Petersen		+	▲	◘	◘	■	▲
Frustulia vulgaris (Thwaites) De Toni			+		◘	+	◘
Gomphonella olivacea (Hornemann) Rabenhorst	▲	■	▲	▲	■	▲	■
Gomphonema clavatum Ehrenberg						+	
Gomphonema gracile Ehrenberg	■		▲	+	+	◘	+
Gomphonema parvulum (Kützing) Kützing	▲	▲	▲	■	■	▲	▲
Gomphonema truncatum Ehrenberg	◘		◘	+		+	
Gyrosigma acuminatum (Kützing) Rabenhorst	▲		+	+			+
Gyrosigma attenuatum (Kützing) Rabenhorst	■						
Halamphora montana (Krasske) Levkov		▲	+	◘	+	◘	+
Halamphora veneta (Kützing) Levkov	◘	▲	■	■	■	◘	◘
Hannaea arcus (Ehrenberg) R.M.Patrick			+	◘	◘	■	▲
Hantzschia amphioxys (Ehrenberg) Grunow	■	▲	▲	▲	▲	■	◘
Hippodonta capitata (Ehrenberg) Lange-Bertalot, Metzeltin & Witkowski	■				+		

Tablo 1. devamı

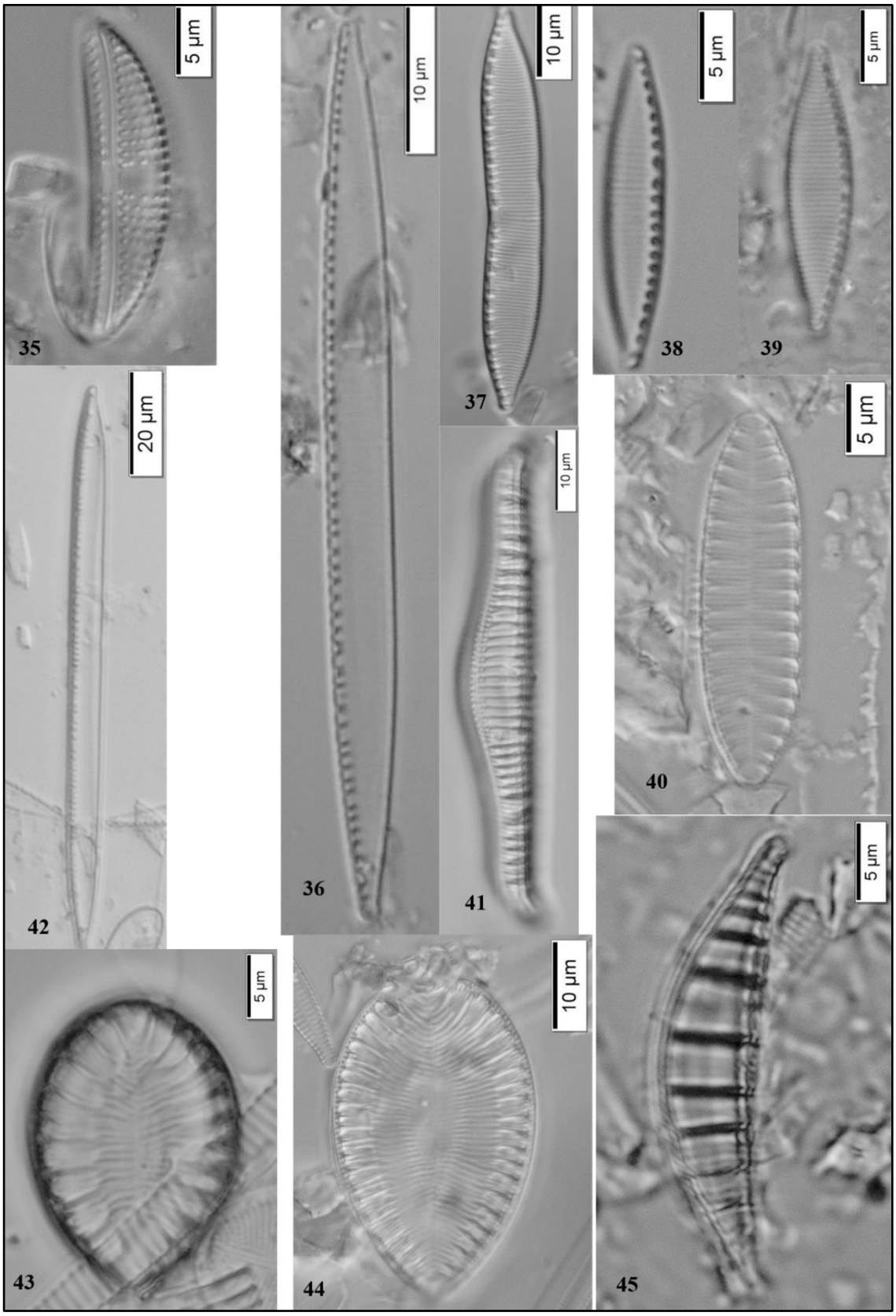
Sınıf: Bacillariophyceae							
Iconella tenera (W.Gregory) Ruck & Nakov	+						
Luticola mutica (Kützing) D.G.Mann			+				
Meridion circulare (Greville) C.Agardh	◘	◘	▲	◘	◘	■	■
Navicula amphiceropsis Lange-Bertalot & U.Rumrich		+		■	◘	◘	◘
Navicula cari Ehrenberg				+	+		+
Navicula cincta (Ehrenberg) Ralfs						+	◘
Navicula cryptocephala Kützing	▲		▲	■	▲	▲	■
Navicula cryptotenella Lange-Bertalot	◘			◘			+
Navicula lanceolata Ehrenberg						+	◘
Navicula menisculus Schumann				■	+	+	■
Navicula slesvicensis Grunow			◘	+	+	+	◘
Navicula tripunctata (O.F.Müller) Bory	▲		▲	▲	▲	▲	▲
Navicula trivialis Lange-Bertalot	+		■	■	■	■	+
Navicula veneta Kützing	◘	◘	▲	▲	■	■	▲
Navicula viridula (Kützing) Ehrenberg	◘						
Navicula viridulacalcis Lange-Bertalot		+	■	▲	◘	◘	▲
Navigeia decussis (Østrup) Bukhtiyarova	▲		◘	▲	▲	▲	▲
Neidiomorpha binodis (Ehrenberg) M.Cantonati, Lange-Bertalot & N.Angeli							+
Neidium ampliatum (Ehrenberg) Krammer							+
Neidium dubium (Ehenberg) Cleve			+				+
Nitzschia acicularis (Kützing) W.Smith	+				+		
Nitzschia amphibia Grunow	◘	◘	■	+	◘	◘	■
Nitzschia fonticola (Grunow) Grunow	■	◘	◘	■	+	■	▲
Nitzschia linearis W.Smith	■	▲	■	◘	▲	■	▲
Nitzschia palea (Kützing) W.Smith	▲	▲	▲	▲	▲	■	▲
Paraplaconeis placentula (Ehrenberg) Kulikovskiy & Lange-Bertalot						+	
Pinnularia borealis var. *sublinearis* Krammer		+				◘	◘
Pinnularia brebissonii (Kützing) Rabenhorst	+	▲	+	+		■	+
Pinnularia microstauron (Ehrenberg) Cleve		+			+	◘	+
Pinnularia subgibba var. *undulata* Krammer					+	+	
Placoneis clementis (Grunow) E.J.Cox			+				
Placoneis elginensis (W.Gregory) E.J.Cox						◘	◘
Planothidium lanceolatum (Brébisson ex Kützing) Lange-Bertalot	▲	▲	▲	■	▲	▲	▲
Pseudostaurosira parasitica (W.Smith) Morales	+						
Reimeria sinuata (W.Gregory) Kociolek & Stoermer	■		+	■	▲	■	▲
Rhoicosphenia abbreviata (C.Agardh) Lange-Bertalot	▲		■	+	◘	◘	+
Rhopalodia gibba (Ehrenberg) Otto Müller	+	◘	■	+		+	◘
Rhopalodia gibberula (Ehrenberg) Otto Müller		+	◘	+			+
Sellaphora bacillum (Ehrenberg) D.G.Mann				◘	+		◘
Sellaphora pupula (Kützing) Mereschkovsky	▲	+	◘	▲	▲	■	■
Sellaphora seminulum (Grunow) D.G.Mann						+	
Stauroneis anceps Ehrenberg			+	◘	◘		
Stauroneis smithii Grunow	▲					+	+
Staurosira construens Ehrenberg	▲		+	◘			
Staurosira leptostauron (Ehrenberg) Kulikovskiy & Genkal					+		
Surirella angusta Kützing	▲	■	▲	■	■	■	▲
Surirella brebissonii Krammer & Lange-Bertalot	+	▲	◘	+			
Surirella ovalis Brébisson	▲	▲	◘	◘	◘	◘	+
Surirella robusta Ehrenberg	▲	▲	▲	■	■	◘	▲
Ulnaria oxyrhynchus (Kützing) Aboal			+	+	◘		
Ulnaria ulna (Nitzsch) Compère	+	▲	▲	■	◘	◘	◘



Şekil 5a. **1**: *Stephanocyclus meneghinianus*, **2**: *Melosira varians*, **3**: *Gomphonella olivacea*, **4**: *Cymbella compacta*, **5**: *Gomphonema gracile*, **6**: *Ulnaria ulna*, **7**: *Cymbella excise*, **8**: *Encyonema silesiacum*, **9**: *Hannaea arcus*, **10**: *Meridion circulare*, **11**: *Fragilaria vaucheriae*, **12**: *Fragilaria capucina* var. *capitellata*, **13**: *Gomphonema truncatum*, **14**: *Cymbopleura hercynica*, **15**: *Reimeria sinuate*, **16**: *Rhoicosphenia abbreviate*, **17**: *Cocconeis placentula*, **18**: *Cocconeis pediculus*, **19**: *Navigeia decussis*, **20**: *Gomphonema parvulum*



Şekil 5b. **21**: *Planothidium lanceolatum*, **22**: *Halamphora montana*, **23**: *Halamphora veneta*, **24**: *Craticula ambigua*, **25**: *Navicula veneta*, **26**: *Navicula trivialis*, **27**: *Sellaphora pupula*, **28:** *Navicula menisculus*, **29**: *Navicula amphiceropsis*, **30**: *Navicula cryptocephala*, **31**: *Navicula viridulacalcis*, **32**: *Navicula tripunctata*, **33**: *Pinnularia microstauron*, **34**: *Pinnularia brebissonii*



Şekil 5c. **35**: *Amphora libyca*, **36**: *Nitzschia palea*, **37**: *Hantzschia amphioxys*, **38**: *Nitzschia amphibia*, **39** *Nitzschia fonticola*, **40**: *Surirella angusta*, **41**: *Rhopalodia gibba*, **42:** *Nitzschia linearis*, **43**: *Surirella ovalis*, **44**: *Surirella brebissonii*, **45**: *Rhopalodia gibberula*

4. TARTIŞMA

Madra Çayı'nda belirlenen 7 istasyonda yapılan örneklemeler sonucunda, Bacillariophyta bölümünden 48 cinse ait toplam 100 epilitik diyatom türü saptanmıştır. *Navicula* (13 tür), *Nitzschia* (5 tür), *Gomphonema* (4 tür), ve *Surirella* (4 tür) en fazla temsil edilen cinsler olmuştur. Türkiye akarsularında diyatom toplulukları üzerine yapılan birçok çalışmada da, bu cinslerin en fazla türle temsil edildiği ve çalışmamızla benzer şekilde çoğunluğunun Bacillariophyceae sınıfından olduğu görülmektedir (Solak *vd.*, 2012).

Madra Çayı'nda 1. istasyon ile diğer istasyonlar arasında diyatom kompozisyonu açısından %50'nin üzerinde bir benzerlik olduğu görülmüştür. Bu istasyonun en baskın cinsi *Navicula* (6) olmuştur. Munda (2005) *Navicula* cinslerine ait olan türlerin epilitik olarak koloni oluşturduklarını kaydetmiştir. 1. istasyona sık ve birlikte rastlanan bazı türler ilgili olan ve bulgularımızı destekleyen çeşitli araştırmacıların çalışmaları incelenmiştir. Akarsuların ekolojik durumlarını değerlendirmek amaçlı bentik diyatomlardan yararlanılan bir çalışmada, kümelenme analizinde, *P. lanceolatum* ve *G. olivacea* akarsuda beraber bulunan türler olmuştur, yine aynı çalışmada, alkalifil türler olan *N. tripunctata* ve *C. placentula* türlerinin yüksek besin konsantrasyonlarında görüldükleri, *G. acuminatum*, *S. meneghinianus* ve *C. placentula* türlerinin de ötrofik durumu net bir şekilde ortaya koyan türler olduğu ifade edilmiştir (Kóvacs *vd*., 2006). Kozmopolit ve esasında planktonik bir diyatom olan *S. meneghinianus*, dünya üzerinde pek çok akarsuda ve acı suda rapor edilmiştir (Finlay *vd*., 2002; Mitrovic *vd*., 2008). Madra Çayı'nın 1. istasyonunda devamlı bulunan diğer bir tür *F. construens* olmuştur ve meso-ötrofik ortamları seven alkalifil bir diyatomdur (Kóvacs *vd*., 2006). *C. dubius* göl ve acı sularda dağılım gösteren yaygın bir tür olup, ötrofik şartlara sahip akarsularda kaydedilmiştir (Hustedt, 1930; Cleve-Euler, 1951; Kalbe, 1982; Hickel ve Håkansson, 1987). Yapılan bir çalışmada *S. pupula* ağır kirlilik şartları altında da görülebilen ve geniş spektrum aralığına sahip bir diyatom türü olarak da değerlendirilmiştir (Taylor *vd*., 2007). *C. pediculus* türünün ise besince zenginleşmiş (ötrofik sular) ve sert su ortamlarında dağılım gösterebilmektedir (Aboal *vd*., 1998). *P. lanceolatum* türü ise oligotrofik ve elektrolitçe zayıf sularda dağılım göstermektedir (Lange-Bertalot ve Krammer, 1989). *G. olivacea* türün baskın saptandığı bir çalışmada, bu türün ötrofik karakterde olduğu (Tokatlı ve Dayıoğlu, 2011), başka bir çalışmada ise çeşitli trofik seviyelerde de bulunduğu değerlendirilmiştir (Krammer ve Lange-Bertalot, 1986). Seyfer ve Wilhm (1977) yapmış oldukları çalışmada, *S. meneghinianus*, *G. parvulum*, *N. cryptocephala* ve *N. palea* türlerinin kirliliğe tolerans gösterdiklerini belirtmişlerdir. Bu istasyonda teşhis edilen *N. palea*, *S. pupula*, *G. parvulum*, *G. olivacea* türleri çalışmamızda, çoğunlukla birlikte gözlenmişlerdir. Weilhoefer ve Pan (2006) farklı ekolojik bölgeler seçerek yaptıkları çalışmada, *N. cryptocephala* ve *P. lanceolatum* türlerini aynı grupta sınıflandırırken, *R. abbreviata* ise ayrı bir grupta sınıflandırmışlardır. Madra Çayı'nda ise geniş bir tolerans aralığına sahip olan *N. cryptocephala* ve *R. abbreviata* türleri (Krammer ve Lange-Bertalot, 1999; Lange-Bertalot, 2001), çoğunlukla birlikte bulunma eğilimi göstermiştir. 1. istasyonda devamlı olarak bulunan diyatomların ekolojileri incelendiğinde, bu türlerin hem oligotrof hem de ötrofik ortamlarda yer alan ve geniş tolerans aralığına sahip oldukları değerlendirilmiştir.

Madra Çayı'nda belirlenen 2. istasyon yerleşim yerlerine ve endüstriyel faaliyetlere yakınlığıyla dikkat çekmiştir. 2. istasyonda diyatom çeşitliliğinin (32 tür) diğer istasyonlara göre oldukça az olduğu da ayırt edici bir bulgudur. Diyatom kompozisyonu bakımından diğer bütün istasyonlara olan benzerliği %51,6 ile %67,4 arasında değiştiği tespit edilmiştir ve bu istasyonun en yaygın cinsi *Nitzschia* (4) olmuştur. Diğer yaygın olarak görülen cinsler *Surirella* (4 tür), *Navicula* (3 tür) ve *Pinnularia* (3 tür)'dır. Özellikle bu istasyonda yaygın olarak görülen *Nitzschia* türlerinin yüksek besin konsantrasyonlarına pozitif tepki gösterdiği bilinmektedir (Kelly ve Whitton, 1995; Kelly, 2003). Bu durum akarsuyun bu bölgesinin çevresindeki baskılardan etkilendiği varsayımını güçlendirmiştir. 1. istasyonun devamlı gözlenen

türleri arasında yer alan *G. parvulum*, *P. lanceolatum*, *N. palea*, *S. ovalis* ve *S. robusta* bu istasyonda da devamlı gözlenen türler olarak saptanmıştır. Madra Çayı'nda çoğunlukla birlikte bulunan *N. palea* ve *G. parvulum* türlerinin bulunduğu bir çalışmada, kirli olan bir istasyonda bu türlere de rastlanmıştır (Soininen, 2002). Bu istasyonda devamlı olarak gözlenen bir başka diyatom olan *H. amphioxys* oligo-ötrofik bir karaktere sahiptir (Kóvacs *vd*., 2006). Yine bu istasyonda devamlı bulunan *H. montana* hem durgun hem de akarsularda bulunan yine alkalifil bir tür olarak bildirilmiştir (Sıvacı *vd*., 2013). Devamlı türlerden *S. brebissonii*, yüksek elektrolit içeriğine sahip tatlısularda yaygın olmakla birlikte, acı su ortamlarında da dağılım gösterdiği belirtilmiştir (Krammer ve Lange-Bertalot, 1987). Meso-ötrofik olarak sınıflandırılan *U. ulna* türünün oldukça düşük nutrient şartlarında da rapor edilmekle birlikte (Kelly ve Whitton, 1995; Soininen ve Niemelä, 2002), yüksek nutrient şartlarında bulunan indikatör bir organizma olduğu da belirtilmektedir (Rott *vd*., 1997).

Madra Çayı'nda epilitik diyatomlara göre yapılan benzerlik analizi neticesinde; 3 ve 4 numaralı istasyonlar kendi aralarında %82,7 benzer bulunmuştur. 3. istasyonda 54 tür, 4. istasyonda ise 62 tür tespit edilmiştir. Her iki istasyonda da ortak olarak yaygın bulunan cinsler; *Navicula*, *Nitzschia*, *Surirella*, *Fragilaria*, *Gomphonema*, *Halamphora* ve *Rhopalodia*, devamlı bulunanlar ise; *G. olivacea*, *C. placentula*, *N. veneta*, *N. tripunctata*, *H. amphioxys* ve *N. palea* olmuştur. *P. lanceolatum*, *S. robusta* ve *S. angusta* ise 3. ve 4. istasyonlarda görece sık görülen diyatomlardır. Bunlardan *S. robusta* türünün orta seviyedeki kirliliklere tolerans gösterdiği belirtilmiştir (Mangadze *vd*., 2015). Madra Çayı'nın 3. ve 4. istasyonlarında farklı sıklıklarla gözlenen *M. varians* ve *N. tripunctata* türlerinin iyi çevresel şarta sahip kirlenmemiş bir sucul ortamda oldukça yaygın bulunduklarını tespit edilmiştir (Pfiester *vd*., 1979). Madra Çayı'nın 3. ve 4. istasyonlarında devamlı gözlenen *H. amphioxys* ve *N. veneta* bir çalışmada akarsuyun alçak bölgelerinde dağılım gösterdikleri ve *H. amphioxys* için yüksek su akışıyla beraber suda yer değiştirdiği belirtilmiştir (Martínez De Fabricius *vd*., 2003). *C. placentula* türü, ülkemizde az kirli veya görece ötrofik akarsularda yaygın saptanmıştır (Kıvrak *vd*., 2012). Bu tür başka bir çalışmada, tarımsal arazi bölgelerinde seçilen iki istasyonda da bol olarak bulunmuştur (Kargıoğlu *vd*., 2012). Kobayasi ve Mayama (1989) yaptıkları bir çalışmada, *N. veneta* ve *N. palea* türlerini kirliliğe yüksek tolerans gösterenler olarak bir grup altında sınıflandırmıştır.

Diyatom kompozisyonuna göre, 6. ve 7. istasyonlar birbirlerine %84,4 benzer bulunurken, bu istasyonlara en yakın benzerliğe sahip 5. istasyon olmuştur. 5. istasyon 6. istasyona %80,7 benzerlikte, 7. istasyona ise %76,4 benzerliktedir. Bu çalışmada, 5. istasyonda 57 tür, 6. istasyonda 62 tür, 7. istasyonda ise 66 tür tespit edilmiştir. Madra Çayı'nda seçilen 7. istasyon akarsuyun kaynağına en yakın bölgede bulunmakta ve görece çevresel baskılardan muhtemelen az etkilenebilecek bir lokasyondadır.

Madra Çayı'nda diğer istasyonlardan farklı olarak, 5. 6. ve 7. istasyonlarda sıklıkla gözlenen diyatomlardan bazıları; *R. sinuata*, *H. arcus*, *E. silesiacum*, *N. decussis*, *M. circulare*, *N. linearis*, *F. capucina* var. *capitellata* ve *N. viridulacalcis* olmuştur. Bunlardan, *R. sinuata* genellikle dağ biyotoplarında, yosunlar üzerinde, kaynak ve akarsularda bulunmaktadır (Taylor *vd.,* 2007). *H. arcus* oligotrofik su kaynaklarında ve hafif asidikten nötüre giden sularda dağılım gösterir (Bixby ve Jahn, 2005). *E. silesiacum* oligo-ötrofik su kaynaklarında bulunan ve aşırı kirlilik koşullarına da uyumlu, kozmopolit bir türdür (Taylor *vd*., 2007). Hafif kirlenmiş ya da kirlenmemiş olan su kaynaklarında bol olarak bulunan ve kozmopolit bir tür olan *N. decussis*, yüksek mezotrofik seviyelerden ötrofik seviyelere kadarki aralıkta da dağılım gösterebilmektedir (Lange-Bertalot, 2001; Taylor *vd*., 2007). Bu çalışmada da olduğu gibi, *N. decussis* ve *E. silesiacum* türlerinin birlikte tespit edildiği başka akarsu çalışmaları da vardır (Vidaković *vd*., 2015). Bir başka çalışmada *H. arcus*, *E. silesiacum* ve *R. sinuata* temiz bir akarsu ortamında birlikte saptanmış olup, *H. arcus* dağlık bölgelerde, *E. silesiacum* ve *R. sinuata* ise görece daha yüksek trofik şartlarda bulundukları bildirilmiştir (Morales *vd*., 2007). *M. circulare* akarsularda bentikte dağılım

gösteren ve alkalifil bir diyatom olup, oligo-ötrofik ortamlarda bulunurken, diğer alkalifil *N. linearis* meso-ötrofik durgun ve akarsu ortamlarından bildirilmiştir (Sıvacı *vd*., 2013). Bentik kozmopolit bir tür olan *F. capucina* var. *capitellata* orta derecede elektrolit içerikli oligo-mezotrofik sularda bulunmaktadır (Taylor *vd*., 2007). Bu tür ile ilgili farklı substratlar üzerinde yapılan bir çalışmada; epiliton, episammon ve epifiton gibi çeşitli substratlarda gelişim göstermişken, epipelonda herhangi bir gelişim göstermediği belirtilmiştir (Ivanov *vd*., 2006). *N. viridulacalcis* genellikle kalsiyum karbonatça zenginleşmiş oligo-mezotrofik sularda dağılım gösteren kozmopolit bir tür olsa da, hafif derecede ötrofik olan ortam koşullarında da yaşayabildiği belirtilmektedir (Lange-Bertalot, 2001; Chudaev *vd*., 2015).

5. SONUÇLAR

Bu çalışmada, Madra Çayı'nın epilitik diyatom kompozisyonunun Türkiye diyatome florasında kozmopolit olarak bulunan türlerden oluştuğu saptanmıştır. Bununla birlikte, sıklıkla gözlenen diyatom türlerinin trofik seviyeleri dikkate alındığında, Madra Çayı'nın çoğunlukla ötrofik kısmen de oligo-mezotrofik sucul ortamlara uyumlu türleri barındırdığı ve bu akarsuyun diyatom kompozisyonunda görece geniş bir spektrumun oluşmasında, kaynağından denize döküldüğü yere kadar çeşitli çevresel etkilerin şekillendirici olduğu değerlendirilmiştir.

ESER SAHİPLİĞİ KATKI BEYANI

Haşim SÖMEK: Kavramsallaştırma, Yöntem Bilimi, Örneklemeler, Tür Doğrulama, Veri iyileştirme, İstatistksel analiz, Yazım- Orijinal Taslak, Yazım-Gözden Geçirme ve düzenleme, Görselleştirme, Denetleme, Proje yönetimi **Gülşah COŞKUNIŞIK MART:** Örneklemeler**,** Tür teşhisi, Fotoğraflama, Yazım- Orijinal Taslak, Yazım-Gözden Geçirme, Kaynaklar, Veri girişi, Görselleştirme

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Galataport Port: Descriptive analysis of the current market in terms of ship owners and cruise lines

Galataport Limanı: Armatör ve kruvaziyer işletmeler açısından mevcut pazarın tanımlayıcı analizi

Türk Denizcilik ve Deniz Bilimleri Dergisi

Cilt: 11 Sayı: 2 (2025) 151-168

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ABSTRACT

It is known that the tour packages purchased by passengers and their expenditures at homeports are making the tourism revenues. In this study, the data of ships and travel tour packages that called at Galataport Port between January 1, 2024 and January 1, 2026 were examined. The data set was obtained from the websites of shipowners and cruise lines. A total of 930 travel tour package data sets were created. Descriptive Analysis was performed by using the SPSS 29 Package program on the obtained data set. Accordingly, shipowners and cruise lines that prefer Galataport were determined through the travel tours offered for sale by Shipowners and Cruise Lines. Inferences were made about the characteristics of travel tours, routes, tour fees and incoming ships. Thus, evaluations were made on the current potential of Galataport through data analysis. It is explained that if he ships arriving Galataport, which is capable of handling three ships – 15000 passengers a day as declared officially by the port to the Turkish Ministry of Transportation, stay for one day or more, passenger expenses will increase and the ship needs will be supplied by the agency in the port city, which will contribute positively to the economy. In the evaluation section, action plans for the acceleration of cruise tourism in Turkiye are included. Evaluations are made and suggestions are included for Galataport to support cruise tourism in Istanbul, an original port city as one of the most well known brand cities in the world.

Keywords: Galataport, Cruise industry, Shipowner and cruise line, İstanbul, Cruise tour packages, Türkiye

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ÖZET

Kruvaziyer yolcuların uğrak yapılan limanlardaki satın aldıkları gezi turları ve yolcu harcamalarının turizm gelirlerini meydana getirdiği bilinmektedir. Bu çalışmada 1 Ocak 2024 ile 1 Ocak 2026 tarihleri arasında Galataport limanına uğrak yapan gemi ve seyahat tur paketleri verileri ele alınmıştır. Veri seti armatörlerin internet siteleri ve kruvaziyer işletmelerin internet sitelerinden elde edilmiştir. Toplamda 930 adet seyahat tur paketi veri seti oluşturulmuştur. Elde edilen veri seti ile SPSS 29 Paket program kullanılarak Tanımlayıcı Analiz yapılmıştır. Buna göre Armatör ve Kruvaziyer İşletmelerin satışa sunduğu seyahat turları üzerinden, Galataport limanını tercih eden armatör, kruvaziyer işletmeler tespit edilmiştir. Seyahat turları, güzergahlar, tur ücretleri ve gelen gemilerin özellikleri hakkında çıkarımlar yapılmıştır. Böylelikle veri analizi üzerinden Galataportun mevcut potansiyeli hakkında değerlendirmeler yapılmıştır. Günde üç gemi - 15000 yolcu kapasitesini resmi olarak Türk Ulaştırma Bakanlığı'na bildirmiş olan Galataport'a gelen gemilerin kalış sürelerin bir veya daha fazla gün olması durumunda yolcu harcamalarının artacağı ve de gemi ihtiyaçlarının liman şehrindeki acenta tarafından karşılanması ile ekonomiye getireceği olumlu katkısı açıklanmıştır. Değerlendirme kısmında ise Türkiye'de ki kurvaziyer turizmin ivmelenmesi için eylem planları içerilmektedir. Galataport'un orjinal bir liman şehri ve dünyanın en iyi bilinen marka şehirlerinden birisi olan İstanbul'u kruvaziyer turizmi ile desteklemesi açısından değerlendirmeler yapılarak önerilere yer verilmiştir.

Anahtar sözcükler: Galataport, Kruvaziyer endüstrisi, Armatör ve kruvaziyer işletmeler, İstanbul, Seyahat turları, Türkiye.

1. INTRODUCTION

Cruise has many definitions in literature. Briefly, cruise is one of the passenger transport sectors in the world (Kendall, 1986). Cruise is a voyage on a ship or boat taken for pleasure or as a holiday and usually calling in at several places (Cambridge Dictionary, 2024**).** Cruise is a global industry, with cruise lines operating in every major world region. Rodrigue and Notteboom identified that a current trend in the cruise industry is a "ship represents in itself the destination, essentially acting as a floating resort with all the related facilities (bars, restaurants, theatres, casinos, swimming pools, etc.)" (Lau and Yip, 2020; Rodrigue and Notteboom, 2013). Cruises are proposed as 'the transportation of pleasure-seeking travellers on ocean voyages offering one or more ports of calls' (Kendall, 1986). Cruise Tourism type is a significant economic added value especially at sea and culture touring destinations (Alkan *et al*., 2015). Tourism strategies that maximize the socio-economic benefits of cruise travel and technologies and innovations in the world. In addition to the economic impacts of cruise tourism (Lau *et al*., 2014), environmental (Johnson, 2002; Davenport and Davenport, 2006; Paiano *et al*., 2020; Han *et al*., 2019; Lloret Romañach *et al*., 2021) and socio-cultural (Niatu, 2007; Brida, 2021; Aras, 2022) impacts have also been mentioned in the literature (Paiano *et. al*, 2020; Niatu, 2007; Lloret Romañach *et. al*.,2021).

The United Nations World Tourism Organization (UNWTO) stated that international tourism has reached an estimated 1.3 billion international arrivals after a strong 2023, countries are on track to return to pre-pandemic levels in 2024 (UNWTO, 2024). Number of Cruise Passengers by Source Regions is given in Table 1. Cruise destinations with the highest percentage increases in travelers include The Mediterranean, North America's West Coast, South America, and Alaska. The 11 regions are South America, Western Europe, Asia Australasia, South America, Eastern Europe, Middle East/Arabia, Scandinavia/Iceland, Africa, Caribbean, and Central America. The Average Cruise Trip Duration and Passenger Ages are given in Table 2. It is shown that the average journey time is 6.5 to 7 days and the average passenger ages are between 46 and 47. The Cruise Lines International Association

(CLIA), the world's largest cruise industry trade association, announced in its 2023 report that world cruise passenger transportation by region reached 31 million in 2023.

Tourism revenues are one of the sectors that directly affect the country's economy directly. $138 billion in total economic impact globally, supporting $43 billion in wages in the world. It is known that the share of cruise passengers in homeports in sightseeing tours and the expenses made by passengers for shopping are included in the revenues obtained from tourism. In the global economy, approximately 910000 jobs were attributable to the industry's global onshore activities, particularly at ports, including direct, indirect, and induced employment effects. Almost 462000 jobs were generated through direct effects, 257000 came through indirect effects, and 191000 through induced employment effects.

Table 1. Number of Cruise Passengers by Source Regions (Thousand, Years) (CLIA, 2021; CLIA, 2023; CLIA, 2024)

Region Years	2018	2019	2020	2021	2022	2023
North America	14240	15408	3008	2218	12592	18103
Western Europe	6731	7226	1223	1671	5433	7722
Asia	4240	3738	497	626	791	2329
Avustralasia*	1460	1351	340	7	471	1339
South America	883	935	458	89	426	997
Eastern Europe	213	263	72	32	161	332
Middle East/Arabia	111	108	8	22	149	229
Scandinavia/İceland	225	218	52	45	131	151
Africa	154	169	68	0	88	150
Caribbean	56	57	7	0	30	48
Central America	47	49	14	0	20	35
Total	28360	29252	5474	4710	20292	31435

***(Avustralia/ New Zealand/ Pacific)**

Table 2. Average Cruise Trip Duration and Passenger Age (CLIA, 2021; CLIA, 2023; CLIA, 2024)

Year	2018	2019	2020	2021	2022	2023
Average Duration (day)	7	7.1	7.2	6.5	7	7.3
Average Passenger Age	46.7	46.8	47.6	47.7	46.5	46.3

In addition, 301000 jobs were provided by Cruise Lines. The sum of jobs linked to cruise lines economic impact at ports economic impact at ports (910000) and employment sustained by the cruise lines directly equates to 1.2 million jobs (CLIA, 2024). The number of ships in cruise industry is 300 and 37 new ships are in the order process by the end of 2028.

Cruise ship owners either operate their ships themselves or allow them to be operated by cruise companies in the world. In the literature, those who have their own fleet are referred to as Cruise Ship Owners and those who carry out the operating activities of the ships are referred to as Cruise Line Operators. In fact, Shipowners can operate their own ships through their own lines or through Cruise Lines.

The ship's arrival port is also known as homeport in maritime literature- it is expressed as a homeport. Moreover, cruise revenues are generated from various business activities such as port services, shipbuilding industry services,

ship supply services, ship agency services, travel tour agency services and public services etc.
Cruise expenditures have a direct impact on countries economy. The passenger expenses, which consist of cruise passengers' expenses for both sightseeing tours and shopping in the port, are much higher in the regions referred to as homeports. Incoming passengers contribute to economic activity by spending their time city sightseeing activities such as visiting historical places, eating delicious foods, and shopping. Additionally, If the ship's itinerary is more than 1 day, passenger' and ship' expenditures are directly increases and therefore revenues are raised.

1.1. Galataport

Karaköy-Salıpazarı port, is known as one of the historical places of Istanbul located in Karakoy village, formerly known as Galata. Istanbul symbolizes the habits from the past as being one of the most known brand cities in the world and city has its own ports. It serves as a docking area for cruise ships coming in from the Mediterranean. Additionally, Galataport attracts cruise tourism with its location and supports other tourism activities. Istanbul has a title of brand port and brand port city in Europe. Accordingly, this positions Istanbul more valuable in the global market.
The Galataport Istanbul Cruise Terminal details are as follows (Galataport, 2024):

- 29000 m^2 underground terminal area
- 176 units of 3-meters high hatches
- Daily 3 ships 15 thousand passenger handling capacity
- 15 thousand luggage storage capacity
- 5 ramps
- Total conveyor length of 1200 meters.

1.2. Istanbul

The touristic and historical places of port cities significantly increase tourism expenditures with the visits of tourists. Istanbul is one of the best examples of this. In the Brand Finance, "Brand Cities in 2024 List" Istanbul is ranked 64th (Londra Aktüel, 2024). Galataport still continues to attract cruise tourism with its location.
"Dolmabahçe Palace" one of the most popular architectural structures in Istanbul, is at the top of the list of important places to visit in Istanbul. "Topkapı Palace" one of the largest palaces in Istanbul built by Fatih Sultan Mehmet, which continues on the list, "Galata Tower" which was included in the UNESCO World Heritage Temporary List in 2013, "Basilica Cistern" Cistern for shopping tourism, "Spice Bazaar" and "Grand Bazaar", "Ottoman Cuisine"; Palace Desserts for gastronomy tourism, "Hagia Sophia Mosque" one of the most magnificent structures in Istanbul in terms of faith tourism, and touristic places such as Aya Yorgi Monastery and Eyüp Sultan Mosque are very close to Galataport and can be reached in about 1 hour via inland transport. Many ship and passenger needs, such as provisions, fresh water supply, and bunker supply, which are included in the agency services, are often served by the port cities on the route.
Istanbul as one of most popular brand cities in the world with its Galataport located in Karaköy-Salıpazarı village, directly affects cruise tourism and supports other tourism activities, giving the existing tourist attraction of cruise vessels if she stay more than one day, this revenue is the income coming from the expenditures made by passengers during sightseeing tours and shopping at homeport, if they stay a day longer at homeport. It has been determined that cruise ships arriving in Galataport port have an average of 3 thousand to 4 thousand people, including the crew. Many ship and passenger needs, such as provisions, fresh water supply, and bunker supply, which are included in the agency services, are often supplied by the port cities on the route.

1.3. Cruise Industry in Türkiye

The revenue items obtained from cruise tourism are among the sectors that directly affects Türkiye. It is known that the share of cruise passengers at homeports, both in the tours and the expenses made by the passengers for shopping are included in the income obtained from tourism, but it cannot be fully monitored.
When the economic effects of the cruise sector are examined, the income obtained from the expenses of individuals should not be considered only, as it is a fact that income is obtained from

various business lines such as port services, shipbuilding industry services, ship supply. services, ship agency services, travel and tour agency services and public services in Turkish territorial waters.

Until the early 2000s, Turkish Maritime Lines (TDI) was both a shipowner and a cruise operator in the market with 9 ships, due to very old aged ships having high renewal costs, they had to withdraw from the market. Today, it has been determined that 1 small-tonnage ship belonging to a Turkish shipowner will be carrying passengers in the Black Sea region as of 2022. On the other hand, multinational and multi-partner shipowner and cruise lines jointly offer cabin capacity from the Turkish Cruise Market and these partnerships largely shape the direction of the Turkish Cruise market as well.

2. METHODOLOGY

In this study, the ships, shipowners, and cruise lines that have called at Galataport between 2024-2025 were analyzed. The data included in the research were taken from the cruise mapper website and the cruise in Türkiye website (Cruiseinturkey, 2024; Cruisemapper, 2024a; Cruisemapper 2024b). In addition, the accuracy of the information from all shipowners and cruise companies' websites was double checked from both sides. In this content, some minor exceptions were ignored.

A data set of travel tours that called at Galataport between January 1, 2024, and January 1, 2026 has been created. 930 travel tour package data sets obtained from shipowners' websites and cruise lines' websites were analyzed. The data were analyzed using the Descriptive Analysis method in the SPSS 29 program. We have following questions raised in the article.

- Which shipowners and Cruise Lines do prefer Galataport?
- Is there a partnership relation between the shipowners and cruise companies who prefer Galataport as a homeport?
- What are the numbers of ships, their carrying capacity, technical specifications, and number of passengers they are bringing to Galataport?
- What is Türkiye's position in Cruise market?
- Is the modernization made with the Galataport meets the requirements of the ships coming into the port?
- Can Türkiye have a tour package in Aegean and Mediterranean seas with its own fleet and what class ships should be owened by Turkiye in this regard?

The limits of this study: Assessment is done over the standard cabin prices per single person declared by tour seller for a certain period of time. The tour prices are checked from both shipowners and cruise lines to obtain the correct values. Accordingly, assessment is done over the current datas provided by shipowners and cruise sellers.

3. RESULTS

It is determined that a total of 90 ships made one or more stops at Galataport at various times of the years 2024 and 2025. In Figure 1; It is understood that 55 ships called at the port in year 2024 and 66 ships called in 2025 are list.

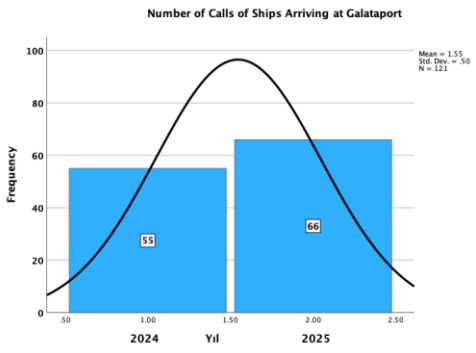

Figure 1. Number of Calls of Ships Arriving port in between 2024-2025.

In Figure 2 and in Figure 3 Cruise Lines and Shipowners names and their fleet codes are given. It's understood that total of 25 shipowners and 33 cruise lines preferred Galataport.

When the distribution of ships of the shipowners coming to Galataport is examined, it is observed that Norwegian Cruise Line Holding operates its ships in the market with a rate of 17.4% and Carnival Corporation & PCL with a rate of 16.5%.

Shipowner	Name of Shipowners	Vessel Code
NCLHltd	Norwegian Cruise Line Holdings Ltd	Grande-NorDawn-NorGeta-NorPear-NorSky-NorViva-OceAllur-OceMari-OceRivi-OceVist-OceVista-RsGrande-RsMarine-RsNaviga-RsSplenda-RsVoyage-Voyager
CC&PLC	Carnival Corporation & PLC	Aidab-Aidas-CArnM-CosDi-CosFor-IsIPRin-MajPrinc-msNisSta-MsOoster-MsVolen-ms-Zuider-QueVic-StarPrinc-SunPrinc
RCCLltd&LEFG	Royal Caribbean Cruise Limited & Lefebvre Family (Rome, Italy)	Briolofsea-CwlebAs-CelebEq-CelebIn-CelebSi-OdyofSea-SeraofSea-VoyofSea
VCltd	Viking Cruises Ltd	VikJupi-VikMars-VikNept-VikSatu-VikSky-VikStar-VikVela-VikVenu-VikVesta
A&KTGvCSltd	A&K Travel Group Ltd (via Crystal Serenity Ltd)	CrystSer-CrystSymp
BoCltd	Bolette Cruise Ltd	FoBol
BCltd	Balmoral Cruise Ltd	FoBal
CC&PLCvSCltd	Carnival Corporation & PLC (via Seabourn Cruise Line Ltd)	SeaboEnc
CoHGmbh	Conti Holding GmbH	SmClmsHam
LGPvCTOLLC	Louis Group Plc (via CRISTAL TRADING OPCO LLC)	CelesCr
LGPvCOASSsa	Louis Group Plc (via OASIS SHIPPING SERVICES SA)	CelesJr
MIH	Mystic Invest Holding (Portugal)	McCMVdgm
MSASC	MS Artania Shipping Company GmbH	PhoeArt
MSCG	Mediterranean Shipping Company (MSC Group)	MscSinf-MscSplen
MSCGv MSCCrS	Mediterranean Shipping Company (MSC Group) via MSC Crociere SpA	MscExp1
RCGvRCCLltd	RCG-Royal Caribbean Group (via RCCL-Ltd)	Moon-Ray-SilvsDawn-SilvMuse-SilvsSpir-Whisper
SCltd	Star Clippers Ltd	StarClip
SeaDYC	SeaDream Yacht Club	SeaDreamI- SeaDreamII
SGa	Scenic Group (Australia)	emerDes-EmerLun-EmerSky-EmerStar
SP	Sycamore Partners	AjaJ-AzaO-AzaP
STA	Scenic Tours Australia	ScenCryst-ScenJade-ScenJasp-ScenOpal
TRclhcllcvCYOPCOLT	The Ritz-Carlton Hotel Company LLC (via Cruise Yacht OpCo Ltd)	RtszEvrima- RtzcIlma
TUI AG-RCCLltd	TUI AG and RCCL (Ltd)	MarDisc-TuiS2-TuiMS4-TuiMS5
TUI AGVTUIcltd	TUI AG (via TUI Cruises GmbH)	HpLmsEu-HPLmsEu2
XP&RI	Xanterra Parks & Resorts Inc	Wlegend

Figure 2. Names of shipowner, shipowner codes, vessel names

Cruise Lines	**Cruise Lines**	**Vessel Codes**
Cdltdbah	Crystal Cruises, LTD (Bahamas)	CrystSer-CrystSymp
FOCLltd	Fred Olsen Cruise Lines Ltd	FoBal- FoBol
PCLltdusa	Princess Cruise Lines Ltd (USA)	IsıPrin-MajPrinc-StarPrinc-SunPrinc
CoC	Costa. Cruises	CosDi-CosFor
HoAL	Holland America Line	msNista-MsOoster-msVolen-MsZuider
SeabC	Seabourn Cruises	SeaboEnc
AIDAC	AIDA Kreuzfahrten (AIDA Cruises)	Aidab-Aidas
Clltduk	Cunard Line Ltd (UK)	QueVic
PlaK	Plantours Kreuzfahrten	SmClmsHam
CaCl	Camival Cruise Line	CamM
CelsC	Celestyal Cruises	CelesJr-CelesJr
SchGmbh(NickoCGrm	Schiffsreisen GmbH (Nicko Cruises Germany)	McCMVdgm
PhRGmbh	Phoenix Reisen GmbH	PhoeArt
NCL	Norvegian Cruies Line	NorDawn-NorGeta,NorPear,NorSky-NorViva
MSCC	MSC Cruises	MscSinf-MscSplen
MSCCvMSCEJ	MSC Cruises (via MSC Explora Journeys)	MScExp1
RSSC	(RSSC) Regent Seven Seas Cruises	Grande-Navigat-RsGrand-RsMarine-RsNaviga-RsSplenda-Rsvoyag-Voyager
Ocinc	Oceania Cruises Inc	msNista-OcAllur-OceMAri-OceNatu-Ocerivi-OceVist-OceVista
SiC	Silversea Cruises	Moon-SilvsDawn-SilvsMuse-SilvsSpir-Whisper
SICltdusa	Silversea Cruises Ltd USA (via Silversea Expeditions)	Ray
CeC	Celebrity Cruises	CelebAs-CelebEq-CelebIn-CelebSi
RCI	RCI-Royal Caribbean International	BrilofSea-OdysofSea-SeraofSea-VovofSea
StCC	Star Clippers Cruises	StarClip
SeaDCL	SeaDream Cruise Line	SeaDreamI-SeaDreamII
EWeETa	Emerald Waterways (Europe), Evergreen Tours (Australia)	EmerDes-EmerLun-EmerSky-EmerStar
AzC	Azamara Cruises	AzaJ-AzaO-AzaP
SceC	Scenic Cruises	ScenCryst-ScenJade-ScenJasp-ScenOpal
TRCYC	The Ritz-Carlton Yacht Collection	Rtzcevrima-RtzcIlma
TUICGmbh	TUI Cruises GmbH	TuiMS2-TuimS4-TuimS5
HLC	Hapag-Lloyd Cruises	HPLmsEu
MaCltdTUIuk	Marella Cruises Ltd (TUI UK)	HPLmsEu2
VOCusa	Viking Ocean Cruises (USA)	VikJupi-VikMars-VikNept-VikSatu-VikSky-VikStar-VikVela-VikVenu-VikVesta
WC	Windstar Cruises	Wlegend

Figure 3. Names of cruise lines, cruise line codes and codes of ship that operated by cruise lines

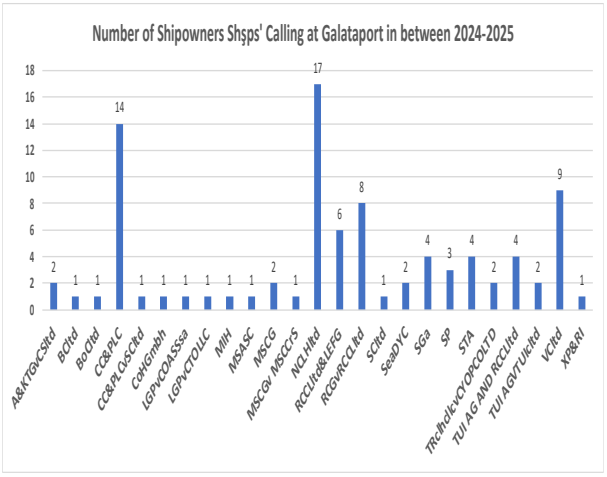

Figure 4. Number of shipowners fleet at calling Galataport in between 2024-2025

In Figure 4 and in Figure 5 the number of shipowners calling at Galataport in between 2024-2025 are shown.
Norwegian Cruise Line Holdings Ltd has 17 ships, followed by with 14 ships from Carnival Corporation & PLC (via Seabourn Cruise Line Ltd) ships and 9 ships from Viking Cruise Limited shipowners.

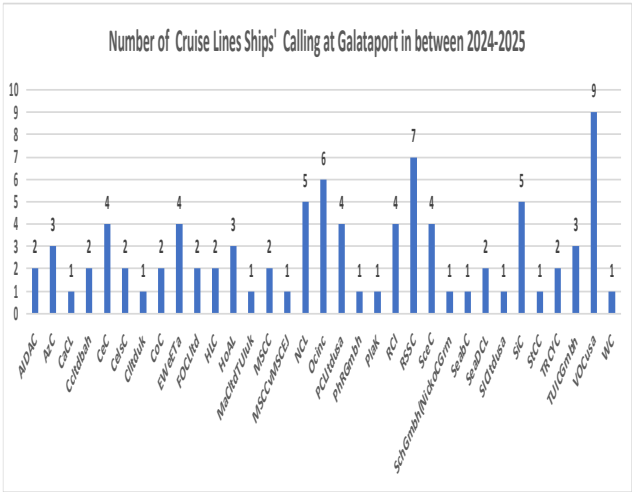

Figure 5. Number of cruise lines ships at calling Galataport in between 2024-2025

It is observed that the cruise lines operate Viking Ocean USA with 9 ships, Regent Seven Sea Cruises with 7 ships and Oceania Cruises Inc with 6 ships.
Accordingly, it is seen that Norwegian Cruise Line Holding is ranked the first carrier with 8 calls in 2024 and 13 calls in 2025. It's seen that number of ships calling at Galataport by shipowners on a yearly basis. In Figure 6; the number of calls of the fleet operated by the shipowners are given.

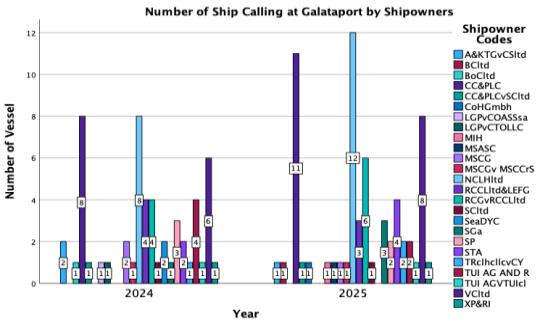

Figure 6. Number of calls at Galataport by shipowner in between 2024-2025

Accordingly, it is seen that Norwegian Cruise Lines is ranked the first with 8 calls in 2024 and 12 calls in 2025.

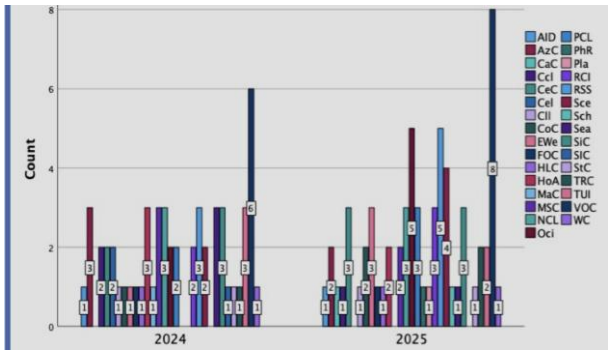

Figure 7. Number of calls at Galataport by cruise lines in between 2024-2025

In Figure 7; the number of calls by the fleet operated by the cruise lines are given. It is observed that Viking Ocean Cruise (USA) is ranked the first with 6 calls in 2024 and 8 calls in 2025.

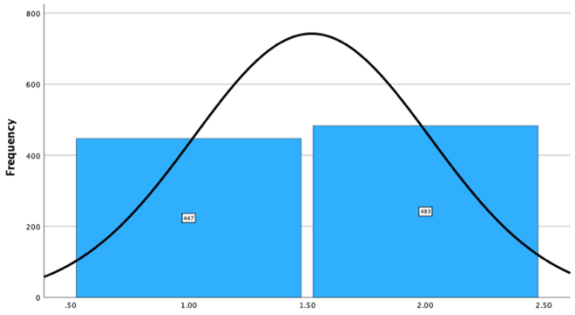

Figure 8. Number of travel tours-packages offered by shipowners

In Figure 8; It's seen that 448 tour packages have been on sale in 2024 and 482 in 2025. It is seen that a total of 930 tour packages were on sale by Cruise Lines and Ship Owners for these ships.

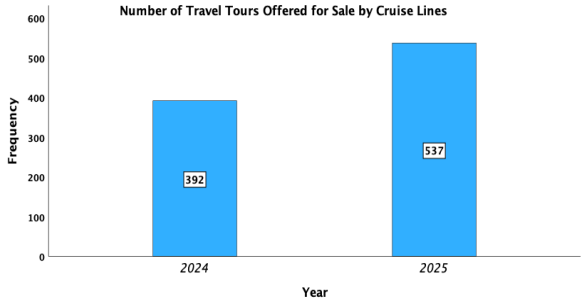

Figure 9. Number of Travel Tours Packaged Offered by Cruise Line

In Figure 9, It is observed that the tour packages on sale by Cruise Lines are 392 in 2024 and 537 in 2025.

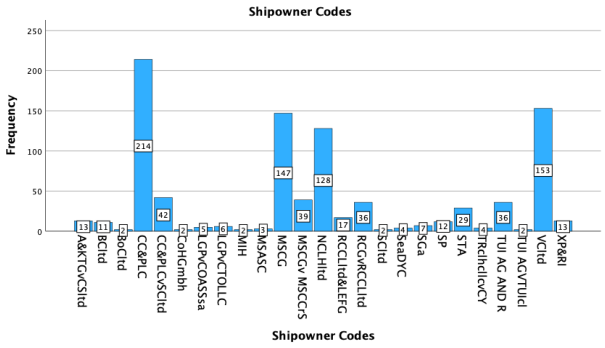

Figure 10. Number of tour packages offered by shipowners

In Figure 10 and in Figure 11; shipowner and cruise line-based tour packages are given. When the tour packages on sale by the shipowners are examined, it is observed that Carnival Corporation & PLC (via Seabourn Cruise Line Ltd) is taking the first place with 214 tour packages, followed by Viking Cruise Ltd with 153 tour packages.

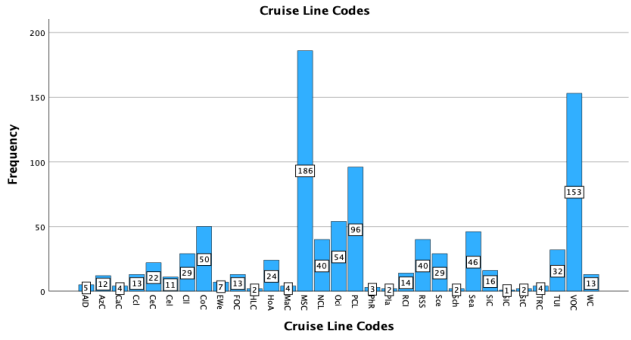

Figure 11. Number of tour packages offered by cruise lines

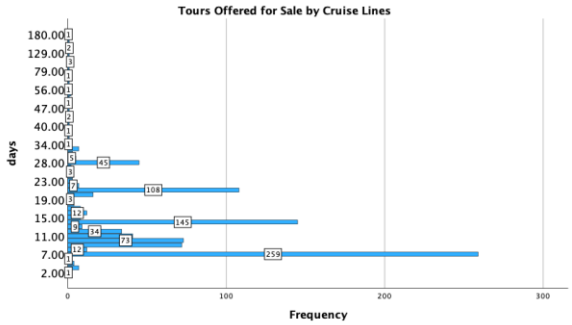

Figure 12. Number of tours-packaged offered for sale by time basis

In Figure 12, it was determined that the package tour durations were 2, 7, 11, 15, 19, 23, 28, 34, 40, 47, 56, 79, 129 and 180 days. It was determined that the travel tour durations for Galataport were the tours covering 7, 15 and 21 days. It is seen that there are a maximum of 401 tours based on homeport Istanbul, 259 tours on sale include 7-day package tours, and it is observed that 145 tours and 15-day tours follow these package tours in the Figure 13.

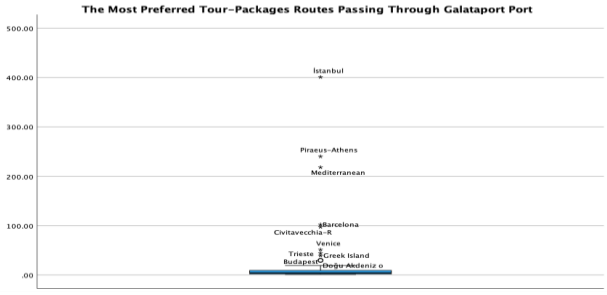

Figure 13. Tour-Packages routes calling Galataport

The most frequent Galataport call tour routes are Istanbul 401, Piraeus-Athens 240, Mediterranean 218, Barcelona 102, Civitavecchia 97, Venice 51, Trieste 44, Greek Islands 39, Eastern Mediterranean 30 and Budapest 29. In addition, Galataport call tour routes with a frequency of less than 5 are shown in Figure 14.

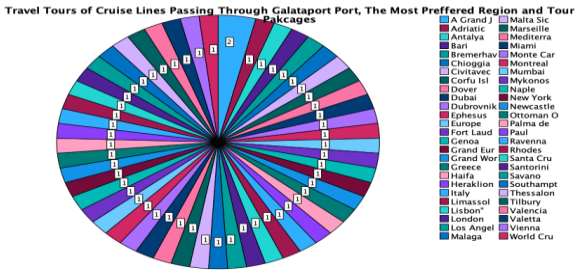

Figure 14. Tour-Packages routes calling Galataport

Vessel Name	Vessel Code	Vessel Name	Vessel Code
AIDAblu	Aidab	Oceania Nautica	OceNatu
AIDAstella	Aidas	Oceania Riviera	OceRivi
Azamara Journey	AzaJ	Oceania Vista	OceVista
Azamara Onward	AzaO	Odyssey of the Seas	Odyofsea
Azamara Pursuit	AzaP	Phoenixline Artania	PhoeArt
Brilliance Of The Seas	Brilofsea	Queen Victoria	QueVic
Carnival Miracle	CarnM	Ray	Ray
Celebrity Ascent	CelebAs	RegentSeven Seas Grandeur	RsGrande
Celebrity Equinox	CelebEq	RegentSeven Seas Mariner	RsMarine
Celebrity Infinity	CelebIn	RegentSeven Seas Navigator	RsNavigator
Celebrity Silhouette	CelebSi	RegentSeven Seas Splendor	RsSplenda
Celestyal Crystal	CelesCr	RegentSeven Seas Voyager	RsVoyager
Celestyal Journey	CelesJr	Ritz-Carlton Evrima	RtzcEvrim
Costa Diadema	CosDi	Ritz-Carlton Ilma	RtzcIlma
Costa Fortuna	CosFor	Scenic Crystal	ScenCryst
Crystal Serenity	CrystSere	Scenic Jade	ScenJade
Crystal Symphony	CrystSymp	Scenic Jasper	ScenJasp
Emerald Destiny	EmerDes	Scenic Opal	ScenOpal
Emerald Luna	EmerLun	Seabourn Encore	SeaboEnc
Emerald Sky	EmerSky	SeaDream I	SeaDreamI
Emerald Star	EmerStar	SeaDream II	SeaDreamII
Fred Olsen Balmoral	FoBal	Serenade Of The Seas	SerSea
Fred Olsen Bolette	FoBol	SilverseaSilver Dawn	SilvsDawn
Grandeur	Gran	SilverseaSilver Muse	SilvsMuse
Hapag-Lloyd ms Europa	HPLmsEu	SilverseaSilver Spirit	SilvsSpir
Island Princess	IslPrin	Small Cruise Lines Cru	SmClmsHam
Majestic Princess	MajPrinc	Star Clipper	StarClip
Marella Discovery	MarD	Star Princess	SunPrin
Moon	Moon	Sun Princess	SunPrinc
ms Nieuw Statendam	msNiSta	TUIMein Schiff 2	TuiMS2
ms Oosterdam	msOoster	TUIMein Schiff 4	TuiMS4
ms Volendam	msVolen	TUIMein Schiff 5	TuiMS5
ms Zuiderdam	msZu	Viking Jupiter	VikJupi
MSC Explora 1	MscExp1	Viking Mars	VikMars
MSC Sinfonia	MscSinf	Viking Neptune	VikNep
MSC Splendida	MscSplen	Viking Saturn	VikSatu
Mystic Cruises CMV Vasco da Gama-Nicko	McCMVdgm	Viking Sky	VikSky
Hapag-Lloyd ms Europa2	HPLmsEu2	Viking Star	VikStar
Norwegian Dawn	NorDawn	Viking Vela	VikVela
Norwegian Getaway	NorGate	Viking Venus	VikVenu
Norwegian Pearl	NorPear	Viking Vesta	VikVesta
Norwegian Sky	NorSky	Voyager	Voyager
Norwegian Viva	NorViva	Voyager Of The Seas	Voyofsea
Oceania Allura	OceAllur	Whisper	Whisper
Oceania Marina	OceMari	WindstarStar Legend	Wlegend

Figure 15. Vessel name and vessel codes

A Grand Journey the Aegean Adriatic	Istanbul to Monte Carlo	Piraeus-Athens to Valletta
A Journey to the Crossroads of Antiquity	Istanbul to Naples	Piraeus-Athens to Venice
A month meandering the majestic Med	Istanbul to Piraeus-Athens*	Rhodes Island to Malaga
Aegean Treasures, Greek Isle Gems Ephesus	Istanbul to Ravenna	Rhodes Island to Southampton
Amsterdam to Piraeus-Athens	Istanbul to Santa Cruz de Tenerife	round-trip Greece, Turkey Italy Cruise
An Extended Journey to Beach Bliss	Istanbul to Savona	San Diego to Miami
An Extended Journey to Sybaritic Beaches	Istanbul to Southampton	Savona to Istanbul
Ancient Kingdoms Turkish Delight	Istanbul to Thessaloniki	Savona to Piraeus-Athens
Ancient Ruins, Stunning Scenery Athens	Istanbul to Trieste	Singapore to London-Tilbury
Antalya to Heraklion	Istanbul to Vienna	Southampton to Civitavecchia-Rome
Athens Piraeus to Athens Piraeus Cruise	Lands Of Legends, Eternal Cities Greek Isles	Southampton to Istanbul
Athens to Istanbul	Legendary Aegean	Southampton to Malaga
AthensnbspPiraeus To AthensnbspPiraeus	Legendary Aegean Ionian	Southampton to Trieste
Barcelona to Civitavecchia-Rome*	Limassol to Southampton	Steps of Paul
Barcelona to Dubai	Lisbon to Monte Carlo	Steps of Paul Cruise
Barcelona to Piraeus-Athens*	Lisbon to Piraeus-Athens	Temali
Barcelona to Southampton	Los Angeles to London-Tilbury	The Best of the Mediterranean
Barcelona to Trieste	Los Angeles to New York	Toulon to Piraeus-Athens
Bari to Istanbul	Malta, Sicily Aegean Jewels Istanbul Overnight	Trieste to Antalya
Bremerhaven to Genoa	Malta, Sicily Eastern Mediterranean Asia Minor	Trieste to Bari
Civitavecchia-Rome to Haifa	Marseille to Piraeus-Athens	Trieste to Civitavecchia-Rome
Civitavecchia-Rome to Malaga	Mediterrane Inseln - AbBis Heraklion	Trieste to Istanbul
Civitavecchia-Rome to Miami	Mediterranean	Trieste to Piraeus-Athens
Civitavecchia-Rome to Naples	Mediterranean from Athens	Trieste to Southampton
Civitavecchia-Rome to Piraeus-Athens	Mediterranean from Barcelona	Turkey Greek Isles
Civitavecchia-Rome to Southampton	Mediterranean from Civitavecchia Rome	Ultimate Mediterranean Atlantic Passage
Civitavecchia-Rome to Trieste	Mediterranean from Istanbul	Valencia to Malaga
Corfu Island to Antalya	Mediterranean from Marseilles	Valencia to Southampton
Desire Greece Turkey Cruise	Mediterranean from Savona	Valletta to Limassol
Discovering Greece, Turkey the Datian	Mediterranean Grand Voyage	Venetian Delight Adriatic Antiquities
Dover to Piraeus-Athens	Monte Carlo to Civitavecchia-Rome	Venice Marghera, Italy to Fusina, Italy
Dubai to Piraeus-Athens	Monte Carlo to Istanbul	Venice to Civitavecchia-Rome
Dubrovnik to Istanbul	Mumbai to Istanbul	Venice to Istanbul
Dubrovnik to Malaga	Naples to Barcelona	Venice to Lisbon
Dubrovnik to Piraeus-Athens	Naples to Piraeus-Athens	Venice to Piraeus-Athens
Dubrovnik to Southampton	New York to Barcelona	Vienna to Istanbul
Epic East Mediterranean Rome to Rome	Newcastle upon Tyne to Southampton	World Cruise - To
Europe	Ottoman Odyssey	
Europe Mediterranean- Piraeus Athens	ouml;Stliches Mittelmeer Intensiv - AbBis Heraklion	
Fort Lauderdale to London-Tilbury	ouml;Stliches Mittelmeer Intensiv - AbBis Heraklion - Doğu Akdeniz yoğun - Kandiye'den gidiş/dönüş	
Fort Lauderdale to New York	ouml;Stliches Mittelmeer Mit Istanbul - AbBis Heraklion	
Grand European Sojourn Lisbon To Lisbon	ouml;Stliches Mittelmeer Mit Kreta	
Grand World Voyage	ouml;Stliches Mittelmeer Mit Kreta Korfu	
Greece Adriatic Antiquities	ouml;Stliches Mittelmeer Mit Malta Kreta	
Greece Turkey	ouml;Stliches Mittelmeer Mit Piraus	
Greece, Italy Turkey	ouml;Stliches Mittelmeer Mit Piraus I	
Greek Isles Santorini, Mykonos Istanbul	ouml;Stliches Mittelmeer Mit Piraus Rhodos	
Greek Isles Turkey Cruise	ouml;Stliches Mittelmeer Mit Zypern I- Doğu Akdeniz ile Kıbrıs I	
Greek Isles Turquoise Coast	ouml;Stliches Mittelmeer Mit Zypern Kreta	
Greek Isles, Ephesus Turquoise Coast	Palma de Mallorca to Antalya	
Haifa to Piraeus-Athens	Palma de Mallorca to Istanbul	
Istanbul	Piraeus Athens - Piraeus Athens Greek charm and trendy Istanbul	
Istanbul And Greek Islands	Piraeus-Athens to Civitavecchia-Rome	
Istanbul to Amsterdam	Piraeus-Athens to Dubai	
Istanbul to Barcelona*	Piraeus-Athens to Istanbul	
Istanbul to Budapest *	Piraeus-Athens to Lisbon	
Istanbul to Chioggia *	Piraeus-Athens to Monte Carlo	
Istanbul to Civitavecchia-Rome *	Piraeus-Athens to Montreal	
Istanbul to Dubai*	Piraeus-Athens to New York	
Istanbul to Genoa	Piraeus-Athens to Savona	
Istanbul to Haifa	Piraeus-Athens to Toulon	
Istanbul to Miami	Piraeus-Athens to Trieste	

Figure 16. Names and routes of tour packages through at Galataport in between 2024-2025

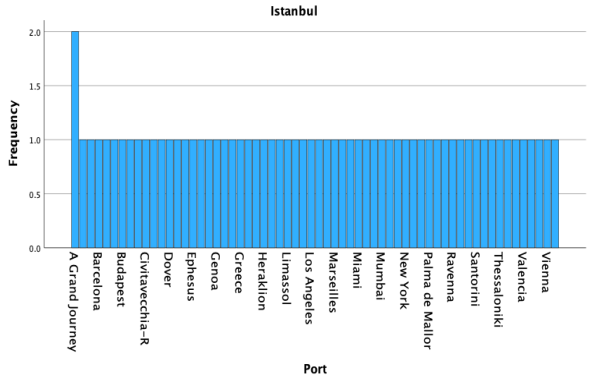

Figure 17. Tour packages with direct route to Istanbul Galataport

Figure 17 shows tour packages with direct Istanbul Galataport routes. Important regions include Barcelona, Budapest, Civitavecchia, Dover, Ephesus, Greece, Genoa Limassol, Los Angeles, Marseilles, Miami, Mumbai, New York, Palma de Mallorca, Ravenna, Santorini, Thessaloniki, Valencia, Vienna, and A Grand journey.

When creating daily cruise data, the lowest price open for sale in the system was taken as the basis. Since the first 4 months of 2024 have already been completed, cruise fees here could not be determined. The calculation is shown as made without applying corrections to missing data.

When the tour packages are observed, it's determined that there is more than a single tour package are sold for the same cruise ship and voyage. Comparing these tour packages with each other, it is seen that the duration of the tour varies from one another. Accordingly, it is determined that same tour packages for different times have the same daily price. However, it is seen that when the standard cabins are sold in ful, deluxe cabins are in sale for some passengers willing to have a more luxurious vacation.

Tour price with a general assessment is obtained by having total tour package price divided by the total time/day of the tour package. 770 tour packages are received from the tour operators and selling offices. Past prices of the tours are strictly classified since the market keep rising and no operator, nor selling office do intend to disclose such information to any party which will

enable buyers to make a thoroughly comparison on the prices yearly. Accordingly, above said simple tour price calculation is used to obtain daily price. Thus, it is seen that the tour prices per day are varying from USD 19.01 to USD 571.09 dependent on the time spent on the voyage. The tour packages based on the homeport, Galataport Istanbul.

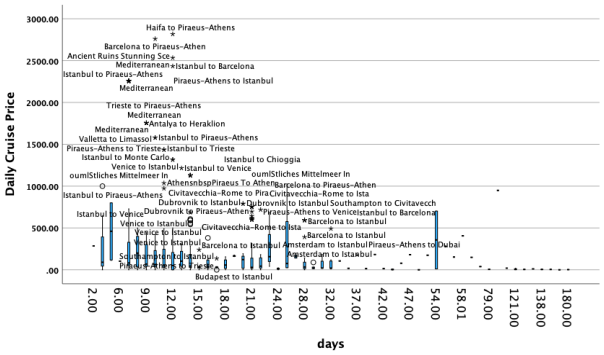

Figure 18. Cruise tour package price (daily)

In the examination, it was determined that the factors affecting the daily cruise fee are determined by the completion rate of the sale of space on the ship, the daily fee varies as the number of cabins open for sale on the ship decreases, and the prices are consistent in case the tour is purchased in advance.

On the other hand, it is observed that the purchase price of the ticket offered for sale when the tour starts does not increase much if there is space on the ship, but if there is less space available, the tour price goes up due by offering luxury cabin types for sale.

Another issue is that the pricing policy applied by shipowners is slightly higher than the prices offered by cruise lines. One reason for this is in tours offered for sale, when the rate of open seats is higher than the rate of sold tours, cruise lines organize temporary sales discount promotions to accelerate the sale of remaining empty capacity on hand.

A daily cruise fee graph is shown in Figure 18. Accordingly, it has been determined that the daily cruise tour price starts from 29.01 dollars and goes up to 571.29 dollars.

The total travel tour fee graph is shown in Figure 19. Accordingly, it has been determined that it starts from 332.75 dollars and is 15795.72 dollars.

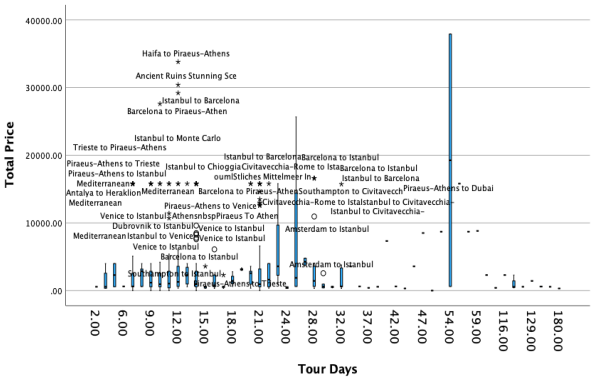

Figure 19. Cruise tour package price (total)

Total Package and Daily prices per ship are shown on Figures 20 and 21.

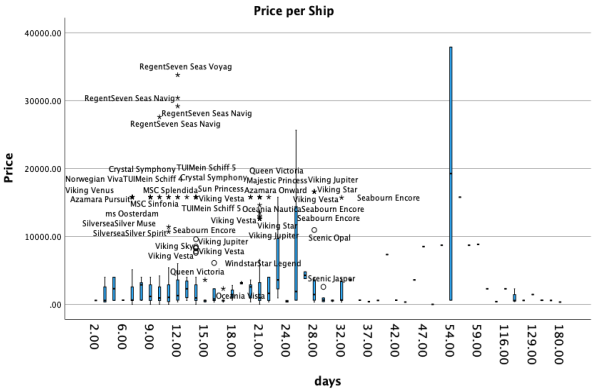

Figure 20. Price per ship

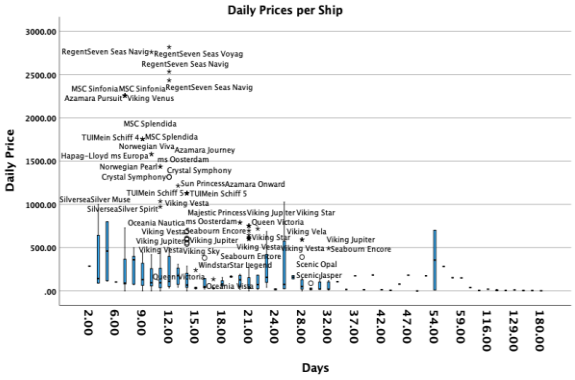

Figure 21. Daily price per ship

It has also been observed that the daily tour fee does not change much in case of long travel duration of tour packages.

In this section, the ship classification obtained from the data set of 90 ships arriving at Galataport shown in Figure 16 has been analyzed. The characteristics of the 90 ships calling at Galata Port between 2024-2025 are summarized with the given graphs below.

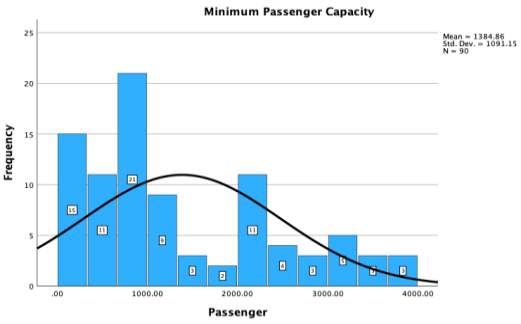

Figure 22. Minimum passenger capacity of ships arriving at Galataport

When the ship characteristics arriving at Galataport Port are examined, the average minimum passenger capacity is indicated in Figure 22 and is observed as 1384.86.

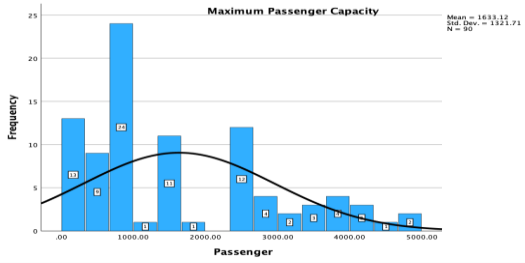

Figure 23. Maximum passenger capacity of ships arriving at Galataport

In Figure 23, the average maximum passenger capacity is given as 1633.12 by applying the same method.

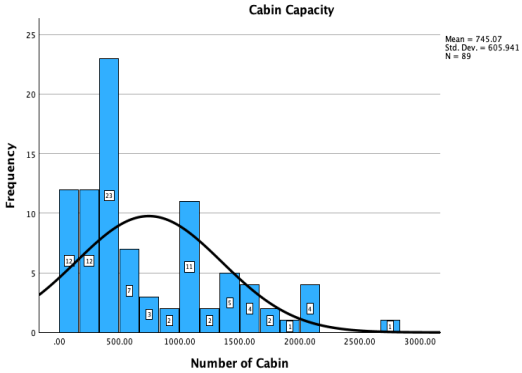

Figure 24. Number of cabin capacity

It has been determined that cruise ships arriving at Galataport have an average of 3 thousand to 4 thousand people, including the crew. Many ship and passenger needs, such as provisions, fresh water supply, and bunker supply, which are included in the agency services, are often supplied by the port cities on the route. In Figure 24, the average cabin number of the arriving ships is seen as 745.07.

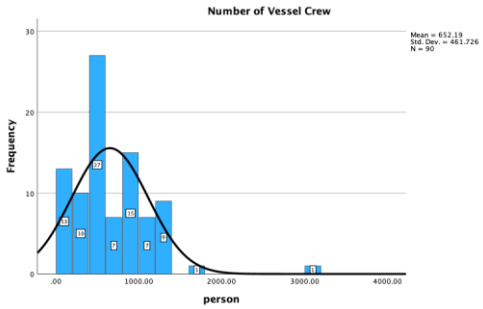

Figure 25. Number of crew

In Figure 25, the total number of personnel (crew) working on the ships is shown. Accordingly, the average number of crew on the ships arriving at Galataport is determined as 652.19.

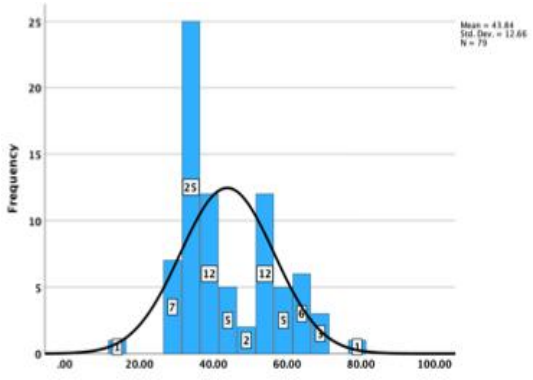

Figure 26. Passenger-Area ratio

In Figure 26, the passenger area ratio is shown, 79 data sets are used, and the passenger-area ratio is observed as 43.84.

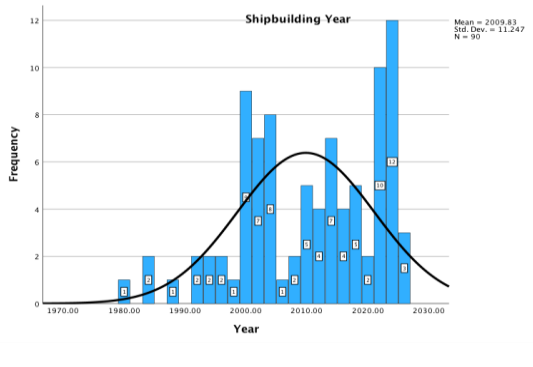

Figure 27. Overall length of vessel

In Figure 27, the overall of length of ships graph is illustrated. Accordingly, it is seen that the average length of the ships is 235.27 meters. After Galataport modernization, quay capacity has been increased as well.

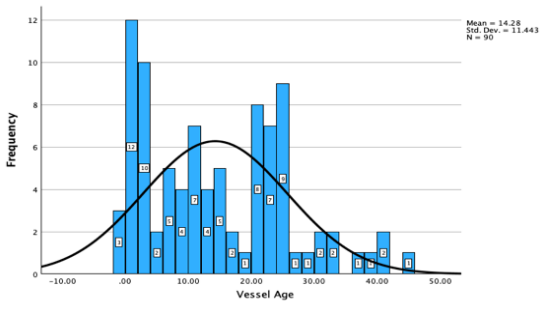

Figure 28. Vessel age

The average age of the ships is shown in Figure 28 and is seen as 14.28. It is generally observed that new ship are calling to Galataport.

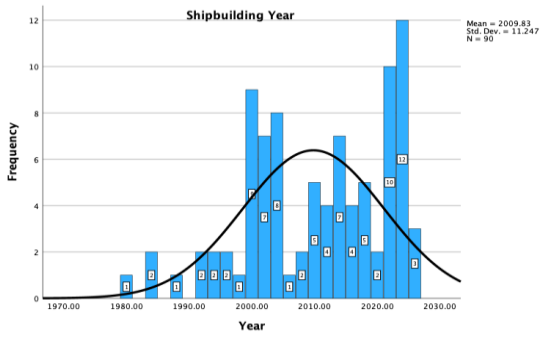

Figure 29. Shipbuilding year

The average shipbuilding year of the 90 ships arriving at Galataport in between 2024-2025 is shown in Figure 29 as 2009.

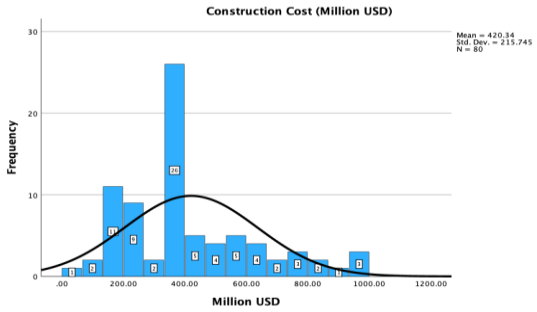

Figure 30. Construction cost

In Figure 30, it is understood that the approximate reconstruction cost of the ships is 420.34 million dollars according to the data obtained for the existing 80 ships.

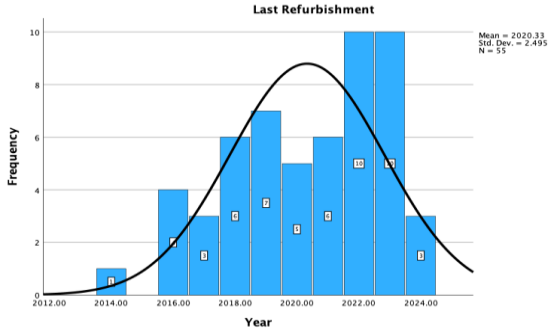

Figure 31. Last refurbishment

In Figure 31, it has been determined that 55 out

of 90 ships have refurbishment and the average maintenance and refurbishment year is observed as 2020.

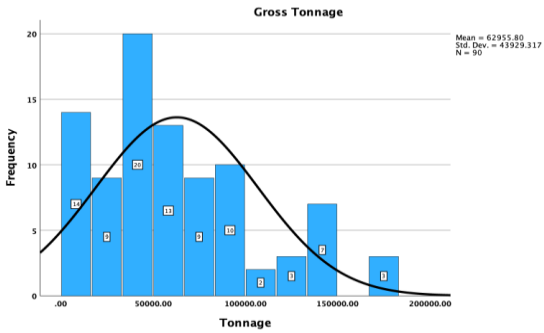

Figure 32. Gross tonnage of ships

The average Gross Tonnage of ships arriving at Galataport port is observed as 62995.80. Passenger ships have the capacity to serve 3 large ships at the same time with the modernization of Galataport in 2021.

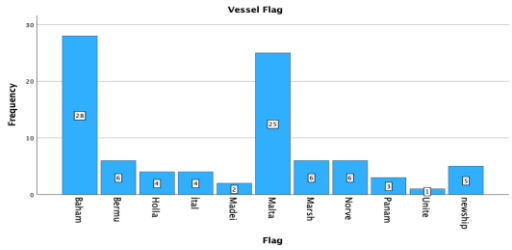

Figure 33. Convenience flag of vessels

The flag countries of the ships are shown in Figure 33. Accordingly, it is observed that 28 ships have the Bahamian flag, 25 ships have the Maltese flag, and six ships each have the Bermuda, Marshal Island and Norwegian flags. With the fiscal legislations applicable by Ministry of Treasury in Türkiye, Flag State of the ships calling at any Turkish port does not have any impact on income made by the country as "0" tax and duty applied by Türkiye to the cruise ships transiting/calling a homeport in Türkiye.

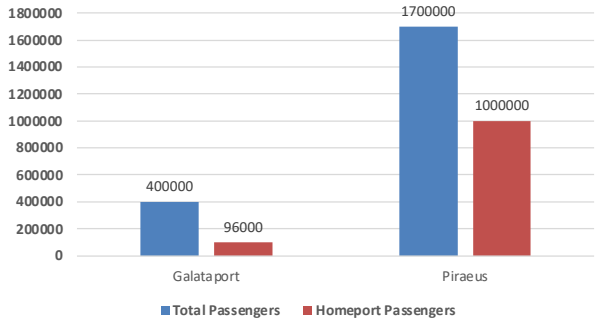

Figure 34. Comparison of Piraeus Ports against Galataport

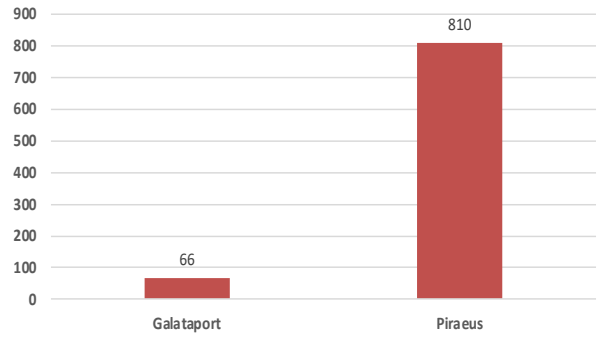

Figure 35. Comparison of Piraeus versus Galataport in terms of calls made by cruise ships and number of passengers handled

The aim of this study to have Türkiye get more share from Cruise tourism, if possible, by increasing the number of vessels from 0 to 3 till 2030 or adding more Cruise terminals to Istanbul city in order to get Istanbul as a key-gate for all Cruise Tours. In this regard, we compared Galataport to Piraeus port, statistics clearly demonstrates that Piraeus is taking the lead and Istanbul has a long way to go just to get to same level with Piraeus.

When the number of passengers came to Piraeus port and Galataport are compared to each other for year 2024, it is obvious that Piraeus had 1700000 passengers in total whereas Galataport had only 400000. In addition, Piraeus was used a homeport by 1000000 passengers buying cruise tour packages while Galataport was only preferred by 96000 passengers (GTP, 2024). These numbers are clearly indicating that Türkiye is not having sufficient revenue from tourism although Galataport with its location which is very close to Piraeus port, with much better historical, touristic, culinary and health

tourism places that passengers can enjoy more than Piraeus, is not having necessary number of passengers, which in return can contribute to Türkiye's economy.

4. DISCUSSION

According to the statistical data published by the Ministry of Culture and Tourism: 1195 ships called at Turkish cruise ports in 2024, and the number of incoming cruise passengers is 153663 (Cruise Statistics, 2024; UAB,2024).

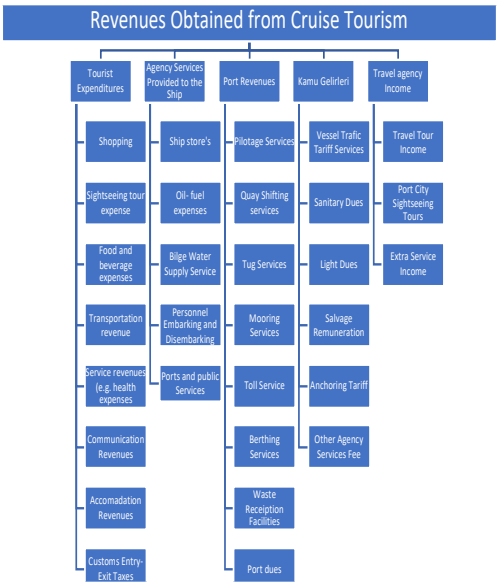

Figure 36. Revenues obtained from cruise tourism (edited by the author)

This item marks the potential income that can be made in proportion with the time and expenses that cruise passengers do at homeport with both sightseeing tours and shopping, if there is more than 1 day spent at the port. In such cases, it both increases the amount of expenditure per person and allows the ship's needs to be supplied at the port of call. It has been determined that the cruise ships arriving at Galataport have an average of 3000 to 4000 people, including the crew. Many ships and passengers need such as provisions, fresh water supply, and bunker supply, which are included in agency services, are often supplied by port cities on the route. In Figure 34 Revenues obtained from cruise tourism are briefly summarized.

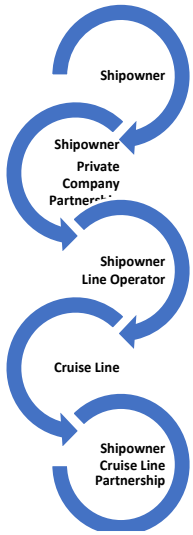

Figure 37. Relation analysis of shipowners, cruise lines of ships arriving at Galataport in between 2024 and 2025.

It has been determined that the relationship between Shipowner and Cruise Lines. The relation is shipowner, shipowner-private company partnership, shipowner's line, cruise line and cruise lines and shipowners' partnership, and this relationship is shown in Figure 37.
After the Galataport cruise lines and ship analysis, when the relations between the shipowner and cruise lines were examined, the result was that the shipowner either operated its own ships or operated them by a private company partnership or by the cruise company and the cruise company operated them by the shipowner partnership. This relationship is illustrated in Figure 30. It should be noted that cruise lines operate as an owner in the cruise market and sometimes act as a monopoly in holding the market. They can easily rise up or lower down the prices according to the available cabin space. In this context, it is seen that the 2M (Alliances) partnership seen in container market is also the same within cruise market as well. Royal Caribbean Group is a good example of this case.

5. CONCLUSION AND SUGGESTION

Although cruise tourism seems to be preferred by those over the age of 46, the trend now shows that the 18-25 age group also prefers this type of tourism. The most important differentiating

feature of cruise tourism from other tourism types that it offers the opportunity to visit the city centers of many countries with just 1 suitcase without carrying any luggage. This makes travel easier and more enjoyable.

Galataport has the capacity to serve 3 ships per day since it was opened in 2021. The most frequent Galataport call tour routes are Istanbul 401, Piraeus-Athens 240, Mediterranean 218, Barcelona 102, Civitaveccihia 97, Venice 51, Trieste 44, Greek Islands 39, Eastern Mediterranean 30 and Budapest 29. The duration of the tours is between 2 and 180 days and the tours are grouped as one-way trip and round-way trip. It is understood that Galataport has an advantageous position in the market by many routes, including the world tour. It is seen that a total of 25 shipowners and 34 cruise lines preferred Galataport in their route lists. Türkiye should have a position that attracts more tourists by combining the modern structure of Galataport with the attractiveness of Istanbul.

Istanbul is an invaluable jewel in terms of tourism in every way. In addition, it is clearly observed that the cruise industry has become the center of attention with the Galataport entering service as of 2021. In the analysis, it is understood that the preferred route of tourists who prefer tours ranging from 2 to 180 is Istanbul. It is seen that tour packages are Mediterranean, Aegean, Adriatic, Eastern Europe, America etc. routes and they are preferred by tourists.

When we analyzed the relationship between the Shipowner and Cruise Lines, it is understood that cruise lines operate as an owner in the cruise market and sometimes act as a monopoly in holding the market.

There are still many actions to be taken for the tourism potential of Türkiye and Istanbul. If we briefly mention these, first, Turkish shipowners are taking place in the market as quickly as possible.

It will be a very important step for Türkiye to enter the market with at least 3 ships of average size and 2000-3000 passenger capacity by the next 2030 and to increase this number to 10 in the coming ten years. Although the cost for building a new ship is over 400 million dollars, such cruise ships can amortize themselves in a short period of time when we consider the revenue to be coming into account as per the current daily tour packages in place. Turkish shipowners should quickly include cruise ships in their fleet, and this will enable Türkiye have a position in the cruise market. In this context, we can say that we are present in the current as Türkiye market and we can take a small but very effective step to become effective in the system. We can also progress by increasing the number of ships in our fleet with our long-term policies for the coming years. In addition, we should start selling our own fleet and our own travel tour packages not through our own offices, not via foreign Cruise lines. On the other hand, it is very important to ensure that Istanbul is a Homeport and that the ship stays for 1 day and more than one day. The increase in the ship's berthing-as free time will directly end up on increases on tourist expenditures and vessel expenditures. Thus, the income obtained from cruise tourism will increase.

The way to achieve this is to diversify the services we can offer in the city. It is necessary to create a wide range of alternative city tour packages that define historical places, entertainment venues, gastronomy areas from A to Z for tourists and to bring them together under a standard, to attract the attention of tourists and make Türkiye’s places and services preferable. This can be possible especially with fast and enjoyable tours takes in 4-5 hours. Thus, as soon as the vessel berths at the port, the tourist will be able to spend their time in the most effective way and will convince the passenger who does not want to get off the ship and avoid the join the city tours.

A wide variety of tour packages can be made for the entire day, ranging from food and beverage to entertainment venues. Moreover, health and cruise tour packages can be organized in these days when Istanbul stands as one of the leading cities in health tourism. In this instance, the person first goes on a cruise ship. He gets off the ship, has an aesthetic treatment and combines his travel with another tour if he or she wishes. Additionally, plane plus cruise packages can be offered much more through tour agencies.

Moreover, it is still not fully known how much income is obtained from cruise tourism in the

world. It is very important to follow the revenues obtained from the cruise economy for future. This cannot be followed completely in the world and in Türkiye. For this reason, it will be line analyzing method is used to analyze other cruise ports in Türkiye as well with the method used in this paper. For further studies, Kuşadası, İzmir and Antalya cruise ports be examined.

AUTHORSHIP CONTRIBUTION STATEMENT

Gülsüm KORALTÜRK: Conceptualization, Methodology, Validation, Formal Analysis, Resources, Writing - Original Draft, Writing-Review and Editing, Data Curation, Software, Visualization, Supervision, Project administration, Funding acquisition.

CONFLICT OF INTERESTS

The author(s) declare that for this article they have no actual, potential or perceived conflict of interests.

ETHICS COMMITTEE PERMISSION

No ethics committee permissions is required for this study.

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