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An Analysis for Determination of the Port Position of Samsun in Turkey and Port Air Emissions

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Abstract: In terms of maritime freight transport utilization rate in Turkey it is very low. Samsun city has strategic importance and great potential for maritime transportation. In this study, firstly, the position of Samsun port in the ranking in terms of freight transport in our country and the Black Sea Region was investigated. It ranks first in the Black Sea Region in terms of import and export amounts and the number of ships arriving in Turkish ports, and 9th in the ports in our country. This port has 4% import and 1.5% export volume among other Turkish ports. It is the most important however highly polluted port in the Black Sea region and the ratio of cargo ships is high. For this reason, in the continuation of the study, the annual amount of emissions generated by cargo ships is examined with two different approaches and the annual emission values determined according to these methods are compared. Then, the reductions and differences between applications that reduce energy consumption and emissions are discussed. Preferring higher quality fuels and reducing the time spent at the port are among the methods that can be applied to reduce emissions from ships coming to Samsun ports. The emissions generated by the generators at the port and the exhaust emissions during the cruise should be reduced. It is inevitable for us to make improvements in our ships and ports to minimize air pollution by international regulations and developments. In the numerical examination, it was observed that air pollution caused by the ship could be reduced by taking such measures.

Keywords: Samsun; Port; Freight Transport; Air Pollution; Precautions

Samsun'un Türkiye'deki Liman Konumunun ve Liman Hava Emisyonlarının Belirlenmesi Üzerine Bir Analiz

Öz: Yük taşımacılığı açısından Türkiye'de denizyollarından faydalanma oranı oldukça düşüktür. Samsun şehri denizyolu taşımacılığı için stratejik öneme ve büyük potansiyele sahiptir. Bu çalışmada, önce Samsun limanının Ülkemizde ve Karadeniz Bölgesinde denziyolu yük taşımacılığı açısından sıralamadaki yeri araştırılmıştır. İthalat ve ihracat miktarları ve Türk limanlarına gelen gemi sayısı bakımından Karadeniz Bölgesinde 1. sırada Ülkemizdeki limanlarda ise 9. sırada yer almaktadır. Bu limanın Türk limanları arasında %4 ithalat ve %1.5 ihracat hacmi payı bulunmaktadır. Karadeniz bölgesi içinde en önemli fakat fazla hava kirliliği oluşturan bir limandır ve yük gemilerinin oranı yüksektir. Bu nedenle çalışmanın devamında yük gemilerinin oluşturduğu emisyonların yıllık miktarı iki farklı yaklaşımla incelenerek, bu yöntemlere göre belirlenen yıllık emisyon değerleri karşılaştırılmıştır. Devamında enerji tüketimini ve emisyonları azaltan uygulamaların oluşturacağı azaltmalar ve aralarındaki fark irdelenmektedir. Samsun limanlarına gelen gemilerden oluşan emisyonların azaltılması için uygulanabilecek yöntemlerin başında daha kaliteli yakıtların tercih edilmesi ve limanda geçirilen sürelerin azaltıması yeralmaktadır. Limanda jeneratörlerin oluşturacağı emisyonların ve de seyirde egzoz emisyonlarının azaltması gerekir. Uluslararası mevzuatlara ve gelişmelere uygun olarak hava kirliliğini en aza indirmek için bizim gemi ve limanlarımızda da iyileştirmeler yapmamız kaçınılmazdır. Yapılan sayısal incelemede bu tür önlemlerin alınması ile gemi kaynaklı hava kirliliğinin son derece azalabileceği görülmüştür.

Anahtar Kelimeler: Samsun; Liman; Yük Taşımacılığı; Hava Kirliliği; Önlemler.

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1. Introduction

Maritime transportation is mostly used in international deliveries in the World. The top 10 container terminals are located in Asia, and the largest container terminal in the World is Shangai Port. Moreover, the port of Rotterdam is the largest in Europe. 14 ports in Asia are on the top 20 ports list. Others are Dubai Ports (United Arab Emirates), Rotterdam (Netherlands), Antwerp (Belgium), Hamburg (Germany), Los Angeles (USA) and Long Beach (USA) Ports [1].

Unlike container ports, bulk and liquid ports are not common user ports and tend to represent the interests of several cargo owners. This makes it difficult to obtain statistics on these sectors [2]. 14 of these top 20 ports are in China, three in Asia (Singapore, Port Klang, and Busan ports) and each in Australia (Port Hedland), Europe (Port of Rotterdam), and North America (South Louisiana harbor).

Turkey is surrounded by sea on three sides, international trade is carried out by mainly maritime mode of transportation Turkey. Turkey, which has 8333 km of coastline, has approximately 172 ports owned by the government, municipalities, or private companies [2].

Marmara Region is the busiest area for maritime trade. Black Sea, Aegean, and the Mediterranean are other developing regions today. In this context, Samsun Port, the largest port of the Black Sea Region, was investigated to examine the future potential of the Black Sea Region for sea trade. On the other hand, the Black Sea is connected to the Bosphorus and the Marmara Sea, and the Marmara Sea to the Dardanelles and the Aegean Sea [2-3].

Port of Samsun, which is located in the Black Sea region of Turkey, important port as a geographic location. It was opened in 1944 and started operations in 2010 by private owners. The port is the only international port in the Black Sea with a railway connection.

As in all sectors, air pollution occurs in the transportation sector. In particular, the role of ships in international freight transport and the share of emissions generated accordingly have gradually increased. Studies are underway in many countries to improve this situation. Samsun is located in the third rank with the highest incidence of overall air pollution among the cities in Turkey. In the study, after examining the number of cargo ships and the tonnage of cargo in Samsun port, which has an important position in the Black Sea region, the air pollutant emissions caused by the year were estimated and their suggestions to reduce them were emphasized.

2. Samsun Port And Its Importance In Cargo Transportation

Samsun port is multi-purpose with its general cargo, container, and Ro-Ro facilities. Samsun port is the biggest port of the Black Sea region and has a large hinterland and is the meeting point of goods coming from Anatolia. It covers the following cities with rail and road connections in the Samsun port hinterland; Sinop, Çorum, Amasya, Ordu, Sivas, Erzincan, Yozgat, Tokat, Kastamonu, Ankara, Kırşehir, Kayseri, Niğde, Konya, Malatya. Ports compete with each other not only by the sea but also on the land side. The expansion of the port hinterland is also important for modern ports.

It is also one of Turkey's major transit port and Central Europe, the Balkans, and the Middle East and has a central location for a combined sea-rail transport between Russia and the Central Asian countries. The following ports are within the Black Sea hinterland (region behind the port) of Samsun Port;

- Georgia; Batumi, Poti, and Sukhumi

- Russian Federation; Sochi, Tuapse, Novorossiysk, Azov, Taganrog, Yalta, Jdanov, Berdinsk, Genichesk,
- Ukraine; Mykolaiv, Odesa, Ilyichevsk, Crimean Mis. Kız-Ogul, Feodosiya, Todor, Sevastopol, Yevpatorskiy.
- Romania; Constanta
- Bulgaria; Varna.

Samsun is located between Kızılırmak and Yeşilırmak Rivers and is an important trade city between Black Sea countries and other potential developing countries for trade and maritime transportation. Samsun port serves export, import cargoes, and transit sea traffic.

On the other hand, Samsun port is ideally located for cargoes arriving from continental Europe to the Middle East countries despite the Rhine-Main-Danube river and the Black Sea. Ports are important for the world economy and the heart of trade for centuries. Valuable products or less valuable but high quantity of goods pass-through ports. Within the scope of the research, a statistical analysis was made for 2019, and the information about the ships arriving at Turkish ports is given in Table 2.1 considering the 10 most operating ports [4-5].

Table 1. a Number of ships operating in Turkish Ports [4]

	Port Department	Loading						
		Export				Cabotage Loading	Transit Loading	Total Loading
		Turkish Flag	Own Country Flag	Foreign Flag	Total			
1	Kocaeli	1,705,468	556,816	19,198,955	21,461,239	5,131,272	749,911	27,342,422
2	Botas	328,037	35,321	4,105,230	4,468,588	1,493,535	52,775,652	58,737,775
3	Aliaga	1,001,827	760,497	19,244,478	21,006,802	5,555,142	18,570	26,580,514
4	Iskenderun	437,270	569,902	15,538,761	16,545,933	5,165,239	445,829	22,157,001
5	Mersin	1,167,536	900,615	13,754,809	15,822,960	248,276	344,984	16,416,220
6	Ambarlı	1,864,013	215,547	8,979,728	11,059,288	1,009,006	5,056,243	17,124,537
7	Tekirdag	81,444	35,690	2,618,532	2,735,666	748,152	5,396,973	8,880,791
8	Gemlik	723,842	337,097	4,463,494	5,524,433	1,405,111	12,536	6,942,080
9	Karabiga	334,420	16,103	1,667,125	2,017,648	496,783	0	2,514,431
10	Samsun	73,205	3,019	1,650,105	1,726,329	979,111	0	2,705,440

Considering the loading values of ships with Turkish flags, with their flags and with foreign flags, there is a loading process of 2,705,440, accordingly, Samsun port ranks 9th in Turkey.

Table 2. Number of ships operating in Turkish Ports [4]

	Port Department	Unloading						
		Import				Cabotage Unloading	Transit Unloading	Total Unloading
		Turkish Flag	Own Country Flag	Foreign Flag	Total			
1	Kocaeli	2,794,796	2,584,555	33,736,767	39,116,118	5,488,419	249,456	44,853,993
2	Botas	340,199	55,359	5,484,871	5,880,429	2,298,967	27,873	8,207,269
3	Aliaga	2,373,882	1,757,453	33,650,098	37,781,433	1,416,726	20,389	39,218,548
4	Iskenderun	1,617,028	416,967	36,211,698	38,245,693	1,359,879	405,140	40,010,712
5	Mersin	1,076,313	519,226	17,410,021	19,005,560	785,780	166,143	19,957,483
6	Ambarlı	1,001,050	317,895	10,152,922	11,471,867	1,577,790	4,475,290	17,524,947
7	Tekirdag	458,611	2,805,559	10,229,443	13,493,613	2,913,874	4,645,699	21,053,186
8	Gemlik	637,306	289,360	4,790,126	5,716,792	1,238,166	11,314	6,966,272
9	Karabıga	60,048	20,912	9,742,099	9,823,059	632,498	0	10,455,557
10	Samsun	548,594	1,106,427	5,762,859	7,417,880	1,027,676	0	8,445,556

Considering the unloading values of the Turkish flagged, self-flagged, and foreign-flagged ships, there is an 8,445,556 unloading process, accordingly, Samsun port ranks 8th in Turkey.

Table 3. Number of ships handled in Turkish Ports [4]

	Port Department	Total						
		Total Import - Export				Total Cabotage	Total Transit	Total Handling
		Turkish Flag	Own Country Flag	Foreign Flag	Total			
1	Kocaeli	4,500,264	3,141,371	52,935,722	60,577,357	10,619,691	999,367	72,196,415
2	Botas	668,236	90,680	9,590,101	10,349,017	3,792,502	52,803,525	66,945,044
3	Aliaga	3,375,709	2,517,950	52,894,576	58,788,235	6,971,868	38,959	65,799,062
4	Iskenderun	2,054,298	986,869	51,750,459	54,791,626	6,525,118	850,969	62,167,713
5	Mersin	2,243,849	1,419,841	31,164,830	34,828,520	1,034,056	511,127	36,373,703
6	Ambarlı	2,865,063	533,442	19,132,650	22,531,155	2,586,796	9,531,533	34,649,484
7	Tekirdag	540,055	2,841,249	12,847,975	16,229,279	3,662,026	10,042,672	29,933,977
8	Gemlik	1 361,148	626,457	9,253,620	11,241,225	2,643,277	23,850	13,908,352
9	Karabiga	394,468	37,015	11,409,224	11,840,707	1,129,281	0	12,969,988
10	Samsun	621,799	1,109,446	7,412,964	9,144,209	2,006,787	0	11,150,996

Considering the handling values of ships with Turkish flags, with their flags, and with foreign flags, there are 11,150,996 handling operations, accordingly, Samsun port is ranked 10th in Turkey.

To see the alteration between 2004-2019, total export and import tonnages, cabotage and total loading, and unloading values of Samsun port are given in Table 4.

Table 4. Samsun Port export-ımport values by years [6]

Years	Total Export (tonnes)	Cabotage Loading (tonnes)	Total Loading (tonnes)	Total Import (tonnes)	Cabotage Unloading (tonnes)	Total Unloading (tonnes)	Total Handling (tonnes)
2004	126,215	341,200	467,415	2,616,846	266,389	2,883,235	3,350,650
2005	99,485	304,091	403,576	2,442,485	335,525	2,778,010	3,181,586
2006	263,298	31,430	294,728	3,666,010	385,418	4,051,428	4,346,156
2007	420,102	66,900	487,002	4,769,947	492,265	5,262,212	5,749,214
2008	942,772	305,112	1,247,884	4,651,198	575,647	5,226,845	6,474,729
2009	1,112,313	141,635	1,253,948	4,933,202	501,786	5,437,658	6,691,606
2010	1,336,090	44,639	1,380,729	5,218,767	682,611	5,901,378	7,282,107
2011	1,270,572	283,990	1,560,763	5,764,789	944,765	6,709,554	8,270,317
2012	1,150,458	775,457	1,925,915	6,089,038	895,473	6,984,511	8,910,426
2013	966,440	898,894	1,865,334	6,298,324	1,388,555	7,686,879	9,552,213
2014	1,126,353	937,771	2,074,124	6,618,523	665,987	7,284,510	9,358,634
2015	1,144,986	949,317	2,094,303	6,896,842	785,417	7,682,259	9,776,562
2016	748,768	996,499	1,745,267	7,458,588	799,977	8,258,565	10,003,832
2017	1,388,880	1,049,747	2,438,627	8,911,006	975,450	9,886,456	12,325,083
2018	1,902,877	1,304,187	3,207,064	7,809,921	830,553	8,640,474	11,847,538
2019	1,726,329	979,111	2,705,440	7,417,880	1,027,676	8,445,556	11,150,996

It is observed that the total export and import, coastal and total loading and unloading tonnages of Samsun port have increased gradually over the 14-year period examined. An increase in these values is also expected in the future. Increasing the share of maritime transport in freight transport is very important and necessary. Transportation of these loads by road forces the road, which has a high share in transportation.

However, while the number of ships and the amount of cargo transported increases, it is increasingly important not to harm the environment and to operate in an environmentally sensitive manner. In this regard, our country should adapt to developments in the world.

3. Air Pollution From Sea Vehicles And IMO

The International Maritime Organization (IMO) provides cooperation between governments in terms of the legislation and practices of countries engaged in international trade, about to any technical issues affecting the shipping industry. IMO is responsible for the preparation of various maritime-related international conventions, arrangements comprising navigation, maritime rescue, and the structural and equipment necessity of ships [6].

More than 150 countries have become members of IMO. Among IMO's objectives are maintaining safety in maritime transport, improving suitability for the cruise, and conserving the ocean from pollution. The International Maritime Organization is an internationally enforceable organization that does serious work on world maritime trade and environmental impacts [7].

Although the International Maritime Organization has a separate international legal personality, it can also be described as a UN Specialist Institution due to its special cooperation relations with the United Nations. The 'Marine Environmental Pollution Committee' (MEPC), a subsidiary of IMO, is responsible for the preparation of relevant regulations to prevent ships from polluting the ocean and the atmosphere and was established by the General Assembly in November 1973.

To protect the ocean environment, the International Maritime Organization (IMO) has adopted the International Convention for the Prevention of Pollution from Ships [8]. With the rapid growth of international trade, the global number of ships has also increased significantly. Pollution from these ships is of great importance. The committee started to examine the air pollution of the ships in 1988. As a result, a new air pollution supplement called " Air Pollution Prevention from Ships " or MARPOL 73/78 Annex VI has been added to MARPOL 73/78, which came into force in May 2005.

IMO aims to reduce emissions by 20% by 2020 and 50% by 2050 by taking measures taken globally and by using alternative energy sources with low emissions [9].

Over the years, there has been an increase in maritime transportation that was utilized for transportation and cargo operations in various parts of the world. Emissions of sulfur dioxide, particulate matter, and greenhouse gases from global shipping have increased from 585 to 1096 million tons between 1990 and 2007. CO_2 emissions from global transport were approximately 1 billion tons for 2006, and currently, international shipping accounts for 3% of global CO_2 emissions [10-11].

In 2005, in the seas surrounding Europe (Baltic Sea, North Sea, North-East part of the Atlantic, Mediterranean and the Black Sea), sulfur dioxide (SO_2) emissions from international transportation were determined to be 1.7 million tons. In the 'Sulfur Emission Control Areas' in the northern Baltic Sea and the English Channel, since the 0.1% MARPOL limit was applied since early 2015, ship-induced sulfur emissions have decreased significantly in these regions. By applying the global sulfur limit, which limits sulfur to 0.5% in transport fuel in 2020, emissions will be further reduced in other EU seas [12-15].

By 2020, NO_X and SO_X emissions from international shipping across Europe are said to be equal or exceed total emissions from all land-based mobile, fixed, and other sources in the 25 European Union Member States. These figures include only ships in international trade, not the emissions from the transportation of countries on inland waterways. The given statistical values show air pollution occurring only in international waters [16-18].

The study will first focus on the determination of air pollutant emissions for this port, and then, effective methods and reduction rates to minimize them will be examined.

4. Emission Determination Methods And Implementation In Ships

In the study, Samsun province was chosen as the port to be examined since it is the most important port in the Black Sea Region and air pollution has reached important dimensions. As the share of freight transport is high, air pollution caused by cargo ships has been explored.

In order to determine the emissions that create air pollution from ships; methods such as the 'Trozzi-Vaccaro Method', 'Ship Resistance Approach Method', 'Emission Estimation Method', 'Ship Activity Method' can be used [19,26]. There are dissertations, master thesis, and articles using these methods in the literature.

In this study, the number of ships using the port of Samsun and benefiting from the tonnage of Samsun Port statistical analysis was conducted to determine the location in Turkey. Then emissions from these ships during the cruise, maneuvering, and waiting at the port; It is determined by using the 'Tier 3 Ship movement methodology' and 'Ship Activation Method'. Emission limit values are gradually lowered, some measures are required in fuel and onboard to ensure these values. If some of these are implemented, the energy and emission reductions that can be achieved are estimated approximately in the study.

The current number of ships using the port has been determined by making use of the ship statistics and thesis and article studies of the 2019 Turkish Republic Ministry of Transport and Infrastructure [4-5] In this port; Bulk carrier, dry cargo ship, container ship, tanker, ro-ro, passenger ship, fast ferry, tugboat, fishing ship are available, however, a review has been made for cargo ships [23-25]. Because the ratio of freight ships in total ships is higher and more statistical values can be found. In addition, their impact on air pollution is greater in terms of ship tonnage, fuel type, and the number of ships. When determining emission values on ships, factors such as fuel type used, engine types of ships, operating modes, engine power are important.

Although the types of fuel used in these ships are generally marine diesel oil, marine gas oil, heavy fuel oil, heavy fuel oil HFO is considered as the type of fuel used since it is the most widely used. Engine Types; It is high-speed diesel, medium-speed diesel, low-speed diesel, but has been studied based on the medium-speed diesel engine type for cargo ships.

In this study, the 'Tier 3 Ship movement methodology' method developed by Carlo Trozzi, Riccardo De Lauretis is applied. Then, the results obtained by applying the "Ship Activation Method" applied in the studies conducted in our country are compared. The second method is actually the derivative of the first method. Since 2 versions are used in the study, both are explained respectively. When determining the methodology, the flow chart given in Figure 1 should be taken into consideration. The available data, the method suitable for examination in terms of scope and sensitivity can be determined from this scheme.

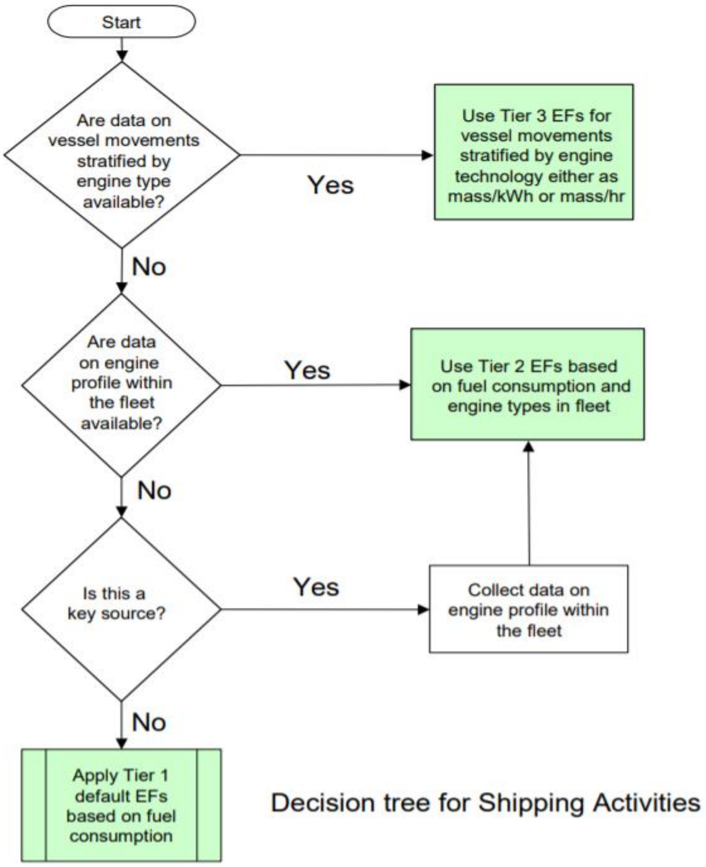


Figure 1. Methodological flow chart [22].

By examining the scheme, the most appropriate method for Samsun Port in terms of the mentioned factors is; It is determined that it is Tier 3 Ship movement methodology. The method is very practical and the annual emission amounts can be estimated as a result of the evaluation of the ship type and number, speed, operating mode, fuel type, engine type, emission factors together. Formulas used in the study (1, 2) are as follows [22];

$$E_{Trip} = E_{Hotelling} + E_{Manouvering} + E_{Cruising} \quad (1)$$

$$E_{Trip\ e,i,j,m} = \sum_{p} [T_P \sum_{e} (P_e \text{ x } LF_e \text{ x } EF_{e,i,j,m,p})] \quad (2)$$

Bağıntılardaki değişkenler aşağıda verilmektedir;

E_{Trip} = emission over a complete trip (tonnes),
EF = emission factor (kg/kw),
LF = engine load factor (%),
P = engine nominal power (kw),
T = time (hours),

e = engine catagory (main, auxilarry),
i = pollutant (CO_2, CO),
j = engine type,
m = fuel type,
p = different phase of trip.

To apply the Tier 3 Ship movement methodology, load factors must first be determined. Values from EMEP (European Monitoring and Evaluation Programme) / EEA (European Environment Agency) air pollutant emission inventory guidebook 2019 are given in Table 5, speeds and times depending on the ship type are given in Table 6.

Table 5. Operating phase and load factors [13].

Phase	% Load Of MCR Main Engine (LF_{ME})	% Time All Main Engine Operating	% Load Of MCR Auxiliary Engine (LF_{AE})
Cruise	80	100	30
Manoeuvring	20	100	50
Hotelling	20	5	40
Hotelling (tankers)	20	100	60

Table 6. Speed and times for ship types and modes [13].

Ship Type	Average Cruise Speed (km/h)	Manoueuvring Time (hours)	Hotelling Time (hours)
Bulk Carrier	28	1	52
General Cargo	26	1	39
Container	37	1	14
Tanker	26	1	28
Ro-Ro	33	1	15

For the main engine and generator powers of the studied cargo ships, Okay Ferhat Uçar's study titled 'Investigation and Environmental Effects of Exhaust Gas Emissions of Ships Arriving in Samsun Ports' in 2014 was used. Here, it is assumed that the main engine is working for a fifth of the time spent by the ships other than tanker at the port and accordingly, the power values are given in Table 7.

Table 7. Power values of cargo ships [24].

Ship Type	Main Engine Nominal Power (kw)	Auxiliary Engine Nominal Power (kw)
Bulk Carrier	8620	542.88
General Cargo	1614.92	115.88
Container	10161.89	626.91
Tanker	3342.66	348.92
Ro-Ro	3402.46	327.5

Emission factors used in the method and determined by EMEP / Corinair are given separately for cruise, maneuvering, and port activities of ships. The emission factors in cruise mode are given in Table 8 and were taken from the study of ENTEC (Euro NATO Training Center) for Europe in 2007.

Table 8: Emission factors for driving mode (kg / ton fuel) [25].

Ship Type	NO_x	SO_2	CO_2	HC	PM
Bulk Carrier	16.2	10.9	649	0.54	1.28
General Cargo	16.2	10.9	649	0.54	1.28
Container	17.3	10.8	635	0.57	1.56
Tanker	14.8	11.7	690	0.5	1.43
Ro-Ro	15.3	11.1	655	0.52	1.17

Ship emission factors for maneuver mode and port mode are similarly determined based on the work of ENTEC and are provided in Table 9 – Table 10.

Table 9. Emission factors for maneuvering mode (kg / ton fuel) [25].

Ship Type	NO_x	SO_2	CO_2	HC	PM
Bulk Carrier	13.2	12.1	715	1.03	1.59
General Cargo	13.2	12.1	715	1.03	1.59
Container	13.8	12	705	1.19	1.73
Tanker	12.5	12.7	745	1.1	1.82
Ro-Ro	12.8	12.2	719	1.06	1.68

Table 10. Emission factors for port mode (kg / ton fuel) [25].

Ship Type	NO_x	SO_2	CO_2	HC	PM
Bulk Carrier	13.4	12.2	721	0.5	0.9
General Cargo	13.4	12.2	721	0.5	0.9
Container	13.5	12.3	720	0.5	0.9
Tanker	12.5	12.6	743	1.1	1.7
Ro-Ro	13.3	12.3	722	0.5	0.9

Air pollutant emissions occurring in each mode were calculated separately for each type of ship in accordance with the previous correlations for Method 1. Considering the location and coastal shape of Samsun ports in cruise mode, previous studies have been examined and a 60 km cruise distance has been evaluated [23-25]. The same distance is valid for the ships leaving the port. Annual emissions in the 3 modes examined are given in Table 4.7 in tonnes.

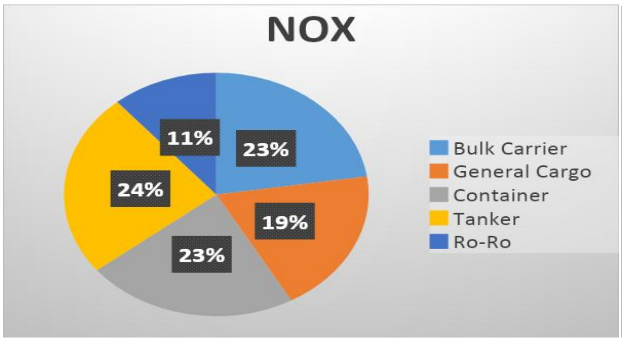
Table 11. Annual emission values of the cargo ships arriving and going to the port (tons/year)

Ship Type	NO_X	SO_2	CO_2	HC	PM
Bulk Carrier	137.9697	104.6254	6209.526	5.196626	10.84124
General Cargo	117.1249	87.43627	5191.429	4.393834	9.279459
Container	137.446	93.88586	5515.898	5.388397	12.55862
Tanker	149.4517	170.0999	8190.772	16.21294	18.96029
Ro-Ro	68.85627	53.24987	3139.074	2.677151	5.522104
Total	610.8486	509.2973	28246.7	33.86895	57.16171

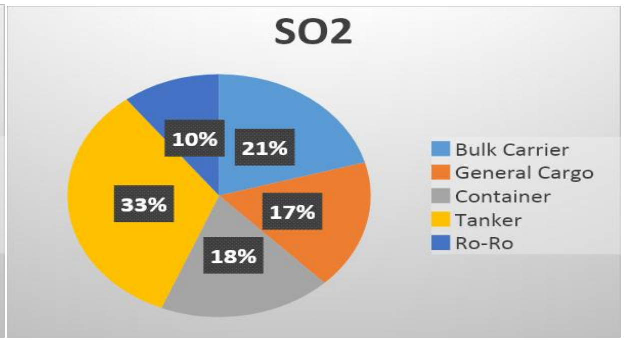
The ratios of the pollutant emission amounts calculated according to the type of the cargo vessel are given in the figures below (Fig. 2 a, b, c, d, e), respectively. The rates of NO_X, SO_2, CO_2, HC, PM emissions vary considerably according to the cargo ship types.

4.2 Examination According to Ship Activation Method

In this method, cruise time, maneuvering time, port length, and installed power value are taken into consideration. In fact, although the methods are significantly similar, there are differences in parametric details and some assumptions. While determining the annual emission amount per ship based on the main engine and generator power, the correlations used (8-10) and terms are given in the order below [24].



(a)



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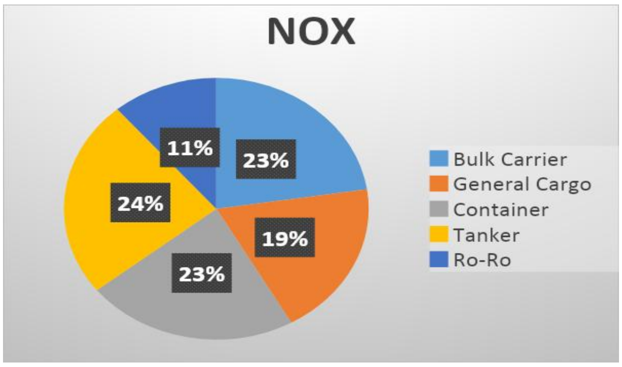

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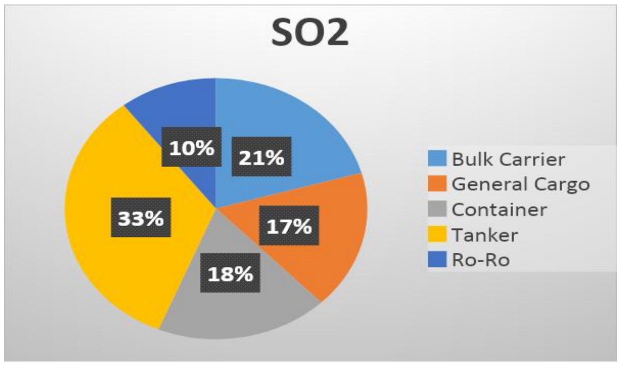
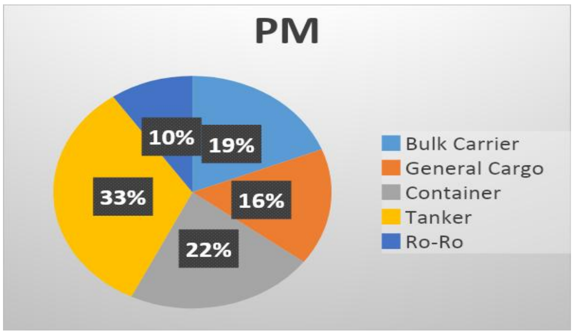


(d)



(e)

Figure 2. a) NOX Emission percentages by type of cargo ship; b) SO_2 Emission percentages by type of cargo ship; c) CO_2 Emission percentages by type of cargo ship; d) HC Emission percentages by type of cargo ship; e) PM Emission percentages by type of cargo ship

$$E_{Trip} = E_{Hotelling} + E_{Manouvering} + E_{Cruising} \tag{3}$$

$$E_{Cruising} = D/V\ [ME\ .\ LFME\ .\ EF1 + AE.LFAE\ .EF1] \tag{4}$$

$$E_{Manouvering} = T_1\ (ME.LFME..EF2 + AE.LFAE.EF2\ ) \tag{5}$$

$$E_{Hotelling} = T_2\ (\ AE.\ LFAE.\ EF3\ ) \tag{6}$$

Kullanılan parametreler;
D = Distance cruised (km)
V = Average cruising speed (km/hr)
ME = Main engine nominal power (kw)
LFME = Main engine load factor (%)
AE = Auxiliary engine nominal power (kw)
LFAE = Auxiliary engine load factor (%)
T = Time (hr)
EF = Emission factor (kg/kw)

Indices from 1 to 3 were used for the emission factor (EF) for each model. EF1 represents emission factors for cruise mode, EF2 for maneuvering mode, EF3 for port mode. Load factors [25]. were taken for the main engine and generator. In this method, it is assumed that the main engine does not work in the port and the generator operates at the same loading factor for all three phases. Table 12.

Table 12. Loading factors [25].

Phase	Load of MCR Main Engine	Load of MCR Auxiliary Engine
Cruise	80%	75%
Manoeuvring	40%	75%
Hotelling	0%	75%

The values accepted by the "European Union Environmental Commission" used for the average cruising speeds of the examined vessels are included in Table 6. The previously given values were used for the time spent at the port. The above correlations (4-6) were used, and the total annual emission values given in Table 13 were obtained by calculating the expected emissions of the 3 modes examined for each type of ship.

Table 13. Total annual emission values (tons/year)

Ship Type	NO_X	SO_2	CO_2	HC	PM
Bulk Carrier	166.9037	129.5459	7684.08	6.625296	13.3476
General Cargo	141.8437	108.5436	6440.6	5.61163	11.43022
Container	160.9011	113.4269	6663.062	6.925899	15.04387
Tanker	96.973	85.10829	5015.332	5.358864	7.314855
Ro-Ro	73.25315	58.63465	3455.104	3.116719	6.124552
Total	639.8747	495.2594	29258.18	27.63841	53.2611

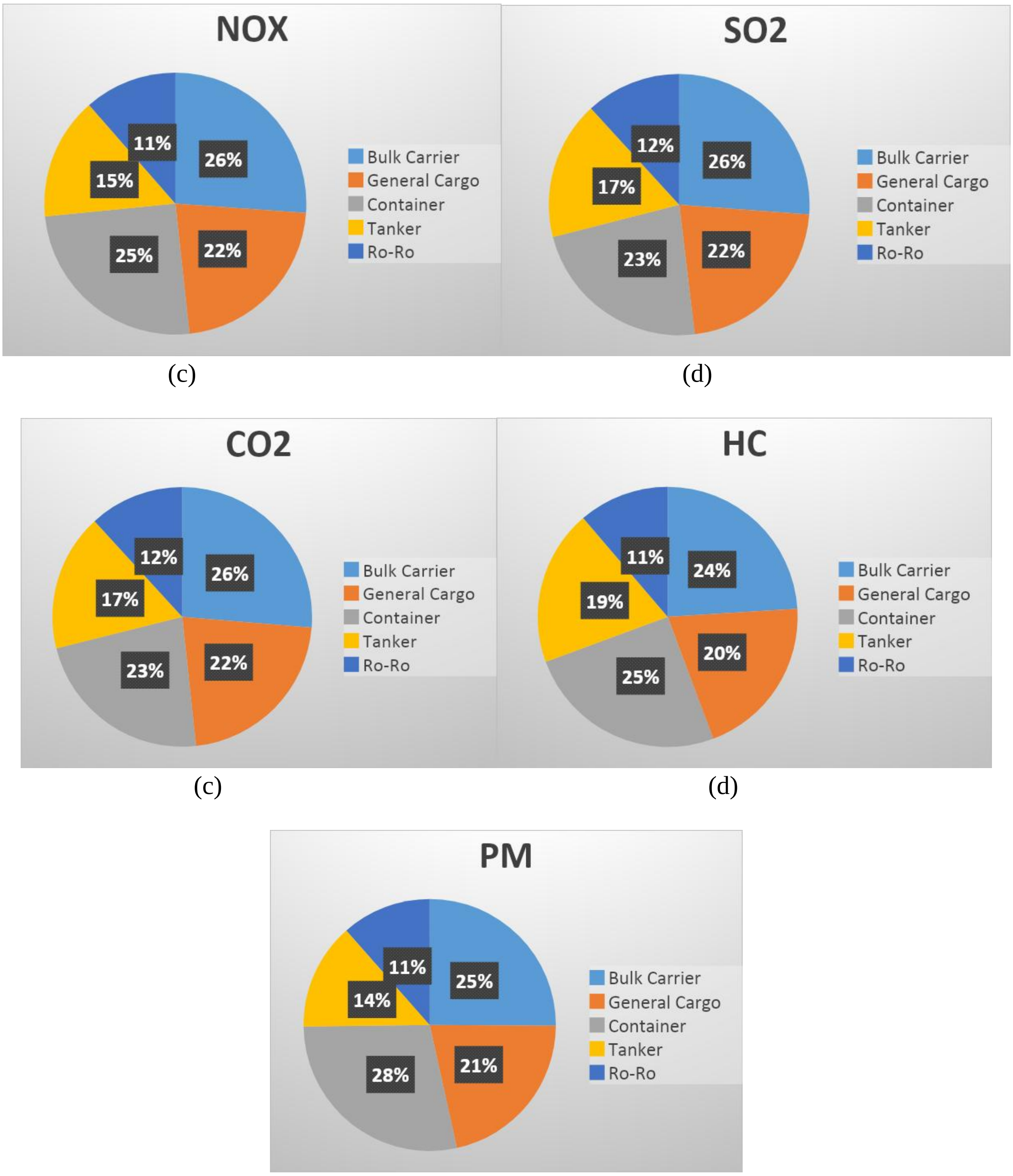
In Figure 3 a, b, c, d and e, the rates of emissions generated by cargo ships according to the Ship Activation Method are shown.

4.3 Comparison of the Two Approaches

When the emissions determined according to the two approaches are examined, it is seen that they give results. The annual emission values obtained are very close to each other. Both methods generally contain parallel solutions, and the difference (%) between the estimated annual emission values for both methods is determined. Table 15 was created with the (%) values obtained by dividing the difference by emission amount.

Table 14. The difference between the annual emissions in terms of two methods (%)

Ship Type	NO_X	SO_2	CO_2	HC	PM
Bulk Carrier	0.17335754	0.192368164	0.191897335	0.215638576	0.1877765
General Cargo	0.17273485	0.192963718	0.19245569	0.215558896	0.186657083
Container	0.14577292	0.172278966	0.172167683	0.221993078	0.165200148
Tanker	0.54116784	0.998628817	0.633146692	2.025443265	1.592024795
Ro-Ro	0.06002304	0.091836194	0.091467654	0.14103531	0.098366052
Total	0.04520577	0.028338603	0.03447308	0.22503174	0.073140024



(e)

Figure 3. a) NO_X Emission percentages by type of cargo ship; b) SO_2 Emission percentages by type of cargo ship; c) CO_2 Emission percentages by type of cargo ship; d) HC Emission percentages by type of cargo ship; e) PM Emission percentages by type of cargo ship

To determine the values in the table, the difference between the two results in terms of percentage is revealed and the larger value is shown in the color in the related Tables (11 and 14). Accordingly, in total emissions, NO_X and CO_2 are larger in Method 2, while SO_2, HC, and PM are large in Method 1. The reason why the results of the two methods are partially different can be explained briefly as follows. In the analyzes, there are differences in the acceptance of load factors for the main machines and generators in different phases. In the first method, it is assumed that the main machines of the tankers worked during the time they spent in the port, while the ships other than the tankers worked for twenty-one of the time spent in the port. In the second method, while the main load factors are zero, large load coefficients are used for the generator. Since the loading factors of the first method and the assumptions made in the host operating times are more specific, the results of this method are considered to be more realistic.

As in all types of transportation, it is inevitable to try to minimize environmental impacts in maritime transportation. The decisions and targets of IMO about this have been announced before. In our country, it is necessary to take measures in parallel with these decisions and to work to reduce air pollution. The tables were rearranged, taking into account the vehicle technology, fuels, and operation-oriented measures and the reduction rates they can provide. Thus, by making possible improvements, it was tried to draw attention to the amount of reduction in air pollution [6].

4.4 Recommendations for Reducing Emissions and Contributions to Reduction

First of all, local and global emissions can be reduced by replacing older or less efficient or more polluting engines with more efficient and less polluting propulsion systems with technological advances [7].

With operational alterations, local emissions can be reduced by planning the way ships work when entering and approaching the harbor.

The insufficient engine technology and fuel quality used in ships caused high air pollutant emissions in maritime transportation. These emissions can be reduced with applications such as increasing engine performance and obtaining clean fuel. Generally, it is aimed at reducing NO_X, SO_X, and PM emissions. While the ships dock at the port, heating, cooling, electricity supply, loading and unloading operations are performed. For this, main and auxiliary engines are needed. Emissions occurring in the port are added to the existing emissions in that environment, increasing the risk of human health deterioration [7].

Fuels with low sulfur content can provide significant reductions in SOx and PM amounts compared to heavy fuel oil. Operational improvements are more useful when ships are in port, while technological improvements are useful during cruise and or hotelling. The reduction of air pollution emissions provided by the improvements in operation is very effective in reducing regional pollution.

Operational changes in emission reductions generally focus on measures taken while ships are in port, while technological improvements provide emission reductions in cruise and or hotelling conditions. Potential emission reductions due to operational changes; It is crucial as it can contribute significantly to improving local air quality and reducing the exposure of the nearby population to harmful pollutants.

Port operators; When ships are opated under port authority, they require cold ironing (landing) or use of low sulfur fuels and other emission control technologies. A wide range of studies is carried out with quite different methods to reduce air pollution from ships. Since the cargo ships are examined here, the reduction methods suitable for the cargo ships are examined. CO_2 reduction measures, the reduction rates it provides, and reduced CO_2 emissions are given in Table 15.

Also, depending on the reduction method for NO_X, SO_X, PM, and CO_2, the reduction values that can be achieved annually are investigated based on the number of cargo ships in 2019 and the rate of emission reduction methods. Applications and values found accordingly are given in Figure 4, Table 16,17,18 and 19 [28-30].

In existing ships, combinations of emission reduction methods are used to simultaneously reduce different types of emissions. Examples of these combinations are the use of marine gas oil as fuel with 15 years of selective catalytic reduction, the use of marine water scrubber with 5 years selective catalytic reduction, the use of 5% diesel oil and 95% natural gas.

Table 15. CO_2 emissions (tonnes) released annually and CO_2 quantities obtained by reduction methods applied [18].

	Applicable Method	Decrease Rate%	Bulk Carrier	General Cargo	Container	Tanker	Ro-Ro
1	Current state	-	7,936.24	6,629.06	7,044.11	10,434.82	4,003.14
2	Trim prevention wings	4	7,618.79	6,363.89	6,762.35	10,017.43	3,843.01
3	Adjusting the shaft line	2	7,777.51	6,496.47	6,903.23	10,226.12	3,923.08
4	Skeg shape and ship stern	2	7,777.51	6,496.47	6,903.23	10,226.12	3,923.08
5	Reducing the resistance from propeller cavities	5	7,539.43	6,297.60	6,691.91	9,913.08	3,802.98
6	Covering the underbody with air bubbles	3,5-15	7,202.14	6,015.87	6,392.53	9,469.60	3,632.85
7	CRP system	10.0-15	6,944.21	5,800.42	6,163.60	9,130.47	3,502.75
8	Propeller-body interaction	4	7,618.79	6,363.89	6,762.35	10,017.43	3,843.01
9	Improved propeller blades	2	7,777.51	6,496.47	6,903.23	10,226.12	3,923.08
10	Propeller-rudder combinations	4	7,618.79	6,363.89	6,762.35	10,017.43	3,843.01
11	Fixed and variable speed operation	5	7,539.43	6,297.60	6,691.91	9,913.08	3,802.98
12	Fixed and variable speed operation	8,5-21	6,745.80	5,634.70	5,987.50	8,869.60	3,402.67
13	Wind power and fletner	30	5,555.37	4,640.34	4,930.88	7,304.37	2,802.20
14	Propeller efficiency	2.1,4	7,698.15	6,430.18	6,832.79	10,121.77	3,883.05
15	Electric diesel engine	20-30	5,952.18	4,971.79	5,283.08	7,826.11	3,002.35
16	CODED engine	4	7,618.79	6,363.89	6,762.35	10,017.43	3,843.01
17	Electric circuits loss reduction	2	7,777.51	6,496.47	6,903.23	10,226.12	3,923.08
18	Waste heat recovery	10.0-20	6,745.80	5,634.70	5,987.50	8,869.60	3,402.67
19	Common rail	1	7,856.88	6,562.77	6,973.67	10,330.47	3,963.11
20	Solar energy	4	7,618.79	6,363.89	6,762.35	10,017.43	3,843.01
21	Coolant pumps and speed	1	7,856.88	6,562.77	6,973.67	10,330.47	3,963.11
22	Automation systems	5.0-10	7,341.02	6,131.88	6,515.80	9,652.21	3,702.90
23	Fuel and additives	2	7,777.51	6,496.47	6,903.23	10,226.12	3,923.08
24	Reduction of operation time at the port	10	7,142.62	5,966.15	6,339.70	9,391.34	3,602.83
25	Propeller surface cleaning-polishing	10	7,142.62	5,966.15	6,339.70	9,391.34	3,602.83
26	Ship surface coating	3	7,698.15	6,430.18	6,832.79	10,121.77	3,883.05
27	Load reduction in engine operations	4	7,618.79	6,363.89	6,762.35	10,017.43	3,843.01
28	Speed reduction (3.0 knot)	23	6,110.90	5,104.37	5,423.97	8,034.81	3,082.42
29	Cruise planning	10	7,142.62	5,966.15	6,339.70	9,391.34	3,602.83
30	Ship trim	5	7,539.43	6,297.60	6,691.91	9,913.08	3,802.98
31	Auto pilot settings	4	7,618.79	6,363.89	6,762.35	10,017.43	3,843.01
32	Energy efficiency awareness	10	7,142.62	5,966.15	6,339.70	9,391.34	3,602.83
33	Condition-based care-attitude	5	7,539.43	6,297.60	6,691.91	9,913.08	3,802.98
34	Underhull cleaning	2	7,777.51	6,496.47	6,903.23	10,226.12	3923.08

As in the whole world, air pollution originating from transportation is important in our country. It is inevitable to take measures to minimize air pollution in the transportation sector, among other sectors. In line with the regulations prepared by IMO on this subject and measures that are suitable for the realities of the country should be implemented. Otherwise, air pollution will increase gradually in our cities and an increase will occur in parallel with the health problems related to air pollution [31].

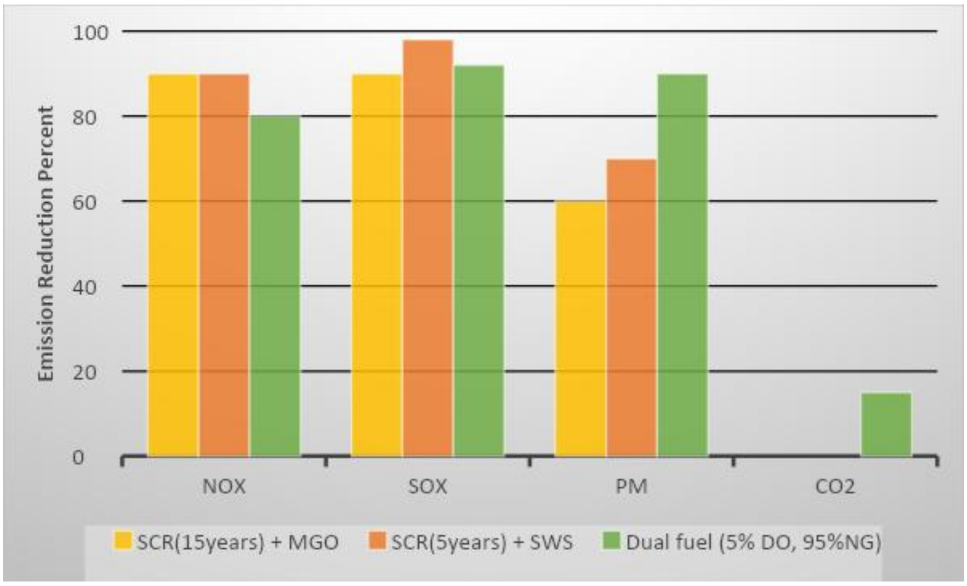


Figure 4. Emission reduction percentages of combined measures used to reduce exhaust emissions from ships [27].

Table 16. Emission amounts of ships arriving at Samsun Ports that can be achieved by using selective catalytic reduction (15 years) + marine gas oil [27].

Ship Type	NO_X		SO_2		PM	
Bulk Carrier	137.9697	13.79697	104.6254	10.46254	10.84124	4.336494
General Cargo	117.1249	11.71249	87.43627	8.743627	9.279459	3.711783
Container	137.446	13.7446	93.88586	9.388586	12.55862	5.023449
Tanker	149.4517	14.94517	170.0999	17.00999	18.96029	7.584114
Ro-Ro	68.85627	6.885627	53.24987	5.324987	5.522104	2.208842

Table 17. Emission amounts of ships arriving at Samsun Ports that can be achieved by using of selective catalytic reduction (5 years)+seawater scrubber [27].

Ship Type	NO_X		SO_2		PM	
Bulk Carrier	137.9697	17.63356	104.6254	2.092509	10.84124	3.252371
General Cargo	117.1249	14.95595	87.43627	1.748725	9.279459	2.783838
Container	137.446	17.55263	93.88586	1.877717	12.55862	3.767587
Tanker	149.4517	19.03973	170.0999	3.401998	18.96029	5.688086
Ro-Ro	68.85627	8.780974	53.24987	1.064997	5.522104	1.656631

Table 18. Emission amounts of ships arriving at Samsun Ports that can be achieved by using dual fuel (with 95% natural gas and 5% diesel oil) [27].

Ship Type	NO_X		SO_2		PM		CO_2	
Bulk Carrier	137.9697	27.59394	104.6254	10.46254	10.84124	1.084124	6209.525901	5278.097
Gen. Cargo	117.1249	23.42497	87.43627	8.743627	9.279459	0.927946	5191.429407	4412.715
Container	137.446	27.48921	93.88586	9.388586	12.55862	1.255862	5515.898214	4688.513
Tanker	149.4517	29.89033	170.0999	17.00999	18.96029	1.896029	8190.772325	6962.156
Ro-Ro	68.85627	13.77125	53.24987	5.324987	5.522104	0.55221	3139.073627	2668.213

5. Conclusions

The study examines the ports of Samsun, the most important port city in the Black Sea Region, and the air pollution caused by the number and tonnage of cargo ships using these ports. In the review, it was observed that the number of ships using the ports and the share of ports in imports and exports increased regularly. This increased rate over the years has been higher than the increase rate in all Turkish ports. Most of the cargoes are generally related to international trade and the port's import rate is higher than the export rate. The passenger transport rate is quite low compared to freight transport. In the study, the difference between the annual air pollutant emission values caused by the cargo ships using the port and the results obtained from the methods was tried to be determined with two different approaches. Then, the measures to reduce emissions in cargo ships and the emission values that will occur as a result of the implementation of some of these have been examined.

Preferring higher quality fuels and reducing the time spent at the port are among the methods that can be applied to reduce emissions from ships coming to Samsun ports. It is important that the time spent in the port is shortened by taking advantage of the technological developments and the planned time is not exceeded. The emissions generated by the generators at the port and the exhaust emissions during the cruise should be reduced. It is also economically important to achieve emission reduction without decreasing the shipping speed too much. It is inevitable for us to make improvements in our ships and ports to minimize air pollution by international regulations and developments. In the numerical examination, it was observed that air pollution caused by the ship could be reduced by taking such measures.

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