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RESEARCH ARTICLE

An overview on the readiness level of the Turkish maritime industry for decarbonization in shipping

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ABSTRACT

Decarbonization is under spotlights for shipping as with many other transportation units. However, the readiness and awareness of the Turkish maritime industry is a common uncertainty. To reveal and show the current progress of the industry, a survey has been carried out. Participants from different companies with different education levels and experiences have been joined and answered the questionnaire which aims to clarify the past, present, and future of the maritime industry. The results of the survey show that the Turkish maritime industry is not fully ready at the company level, however, they perform better at the individual level. Furthermore, the industry may require additional regulation and technical support from maritime stakeholders such as chambers, related government departments, and non-governmental organizations.

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Introduction

Maritime transportation has the major share of 90% of the worldwide trade (Anonymous, 2022a), 90% of the outer freight transportation, and 40% of the inner freight transportation (Fan et al., 2018). According to United Nations Conference on Trade and Development (UNCTAD) (2020), maritime transportation was done by 98.140 commercial ships of 100 gross and above in January 2020 which equals 2,06 billion deadweight tons. Maritime transportation constituted 12% of worldwide transportation energy need (USEIA, 2016) and consumed 300 million tons of fossil fuels which were 72% of residual fuels (heavy fuel oil), 26% distillate fuels (marine diesel oil, marine gas oil), and 2% of liquefied natural gas (LNG) in 2015 (IMO, 2015).

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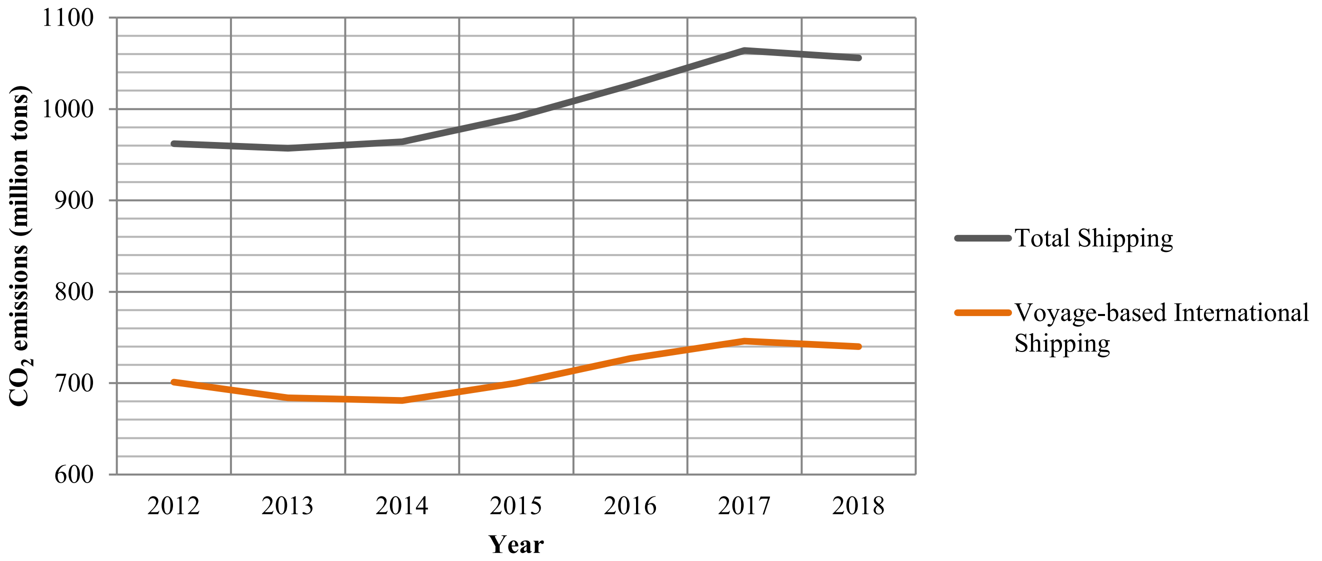

Figure 1. Maritime transportation CO_2 emissions between 2012 and 2018 (data retrieved from IMO, 2020)

Despite maritime transportation being the most efficient way of transportation and emitting less CO_2 per ton-km than other types of transport (Balcombe et al., 2019), it has a considerable contribution to worldwide environmental impact (Lister et al., 2015). A study states that the amount of greenhouse gas (GHG) emissions of international maritime transportation is comparable to the GHG emissions of Germany (Olmer et al., 2017). The maritime transportation GHG emissions, CO_2, methane (CH_4), and nitrous oxide (N_2O), rise from 977 million tons to 1,076 million tons and CO_2 emissions increased from 962 million tons to 1,056 million tons from 2012 to 2018 (IMO, 2020). It can be seen that CO_2 emissions are the major GHG emissions from maritime transportation. Figure 1 shows voyage-based international shipping and total shipping CO_2 emissions between 2012 and 2018.

Maritime transportation CO_2 emissions are in increasing even though the efforts of the International Maritime Organization (IMO), which is an agency of the United Nations that develops regulations for international maritime transportation. It is observed that the increase rate of voyage-based international shipping CO_2 emissions is lower than the total shipping CO_2 emissions increase rate. The reason is IMO's efforts to control and mitigate CO_2 emissions slows down the increase rate of the voyage-based international shipping, on the other hand, the global fleet number is increased and the total shipping CO_2 emission increase rate is higher. The total CO_2 emissions from maritime transportation are approximately 3.1% of the total worldwide CO_2 emissions, but IMO predicts that the amount of the CO2 emissions will grow between 50% to 250 by 2050 (IMO, 2015) if there will be no mitigation plan or strategy.

IMO started its effective intervention to mitigate CO_2 emissions with the Regulations on Energy Efficiency for Ships. This regulation entered into force on 1 January 2013 by an amendment to MARPOL Annex VI (IMO, 2011). The purpose of the regulation is to control and mitigate CO_2 emissions both from the new building and existing ships. The regulation came with terms, the Energy Efficiency Design Index (EEDI), the Ship Energy Efficiency Management Plan (SEEMP), and the Energy Efficiency Operational Indicator (EEOI). The EEDI is a mandatory design index for the new building ships. It determines the design index limits for specific ship types and directs the use of energy-efficient materials, technologies, or engines. The maximum allowable EEDI limit has been reduced every five years by 10% in general (Dere & Deniz, 2020), but it varies according to specific ship types. The SEEMP is another mandatory term that aims to increase shipboard operation efficiency of ships doing international maritime transportation. The SEEMP comprises operational measures such as ship speed optimization, speed reduction (slow steaming), trip optimization, weather routing, etc. Moreover, the EEOI is a voluntary operational indicator that shows voyage-based CO_2 emissions per transport work of ships (Zincir & Deniz, 2016).

The latest regulation of IMO on CO_2 emissions is IMO Data Collection System (DCS) which is an amendment again to MARPOL Annex VI and is entered into force on 1 March 2018 (Anonymous, 2022b). The regulation aims to record the annual CO_2 emissions from ships larger than 5000 gross tonnage and above. After the emission data is recorded by the shipping

Table 1. Candidate measures of IMO Initial GHG Strategy (IMO, 2018)

Short-term Measures	Mid-term Measures	Long-term Measures
Enhancement of EEDI and SEEMP	Implementation program for alternative low-carbon and zero-carbon fuels, including an update of national action plans	Development and provision of zero-carbon or fossil-free fuels
Development of technical and operational energy efficiency measures	Operational energy efficiency measures for both new and existing ships	Encourage and facilitate the general adoption of other possible new/innovative emission reduction mechanisms
Establishment of an existing fleet improvement program	Market-based measures for emission reduction	
Speed optimization, speed reduction	Further, continue and enhance technical cooperation and capacity-building activities	
Measures to reduce methane and volatile organic compounds	Development of a feedback mechanism	
Development and update of national action plans		
Continue and enhance technical cooperation and capacity-building activities		
Encourage port developments and activities		
Initiation of research and development activities on marine propulsion, alternative low-carbon, and zero-carbon fuels, and innovative technologies		
Incentives for initiators of new technology development		
Development of lifecycle GHG/carbon intensity guidelines for all types of fuels		
Undertake additional GHG emission studies		

companies, data have to be reported to the flag State after the end of each calendar year. Furthermore, IMO has an Initial Greenhouse Gas Strategy for maritime transportation that aims to diminish GHG emissions by 50% in 2050, compared to 2008 (ICCT, 2018). The Initial Strategy also aims to reduce CO_2 emissions per transport work at least 40% and 70% in 2030 and 2050, respectively, when it is compared to 2008. It is the first action of IMO to help the worldwide goals of the Paris Agreement on climate change (Serra & Fancello, 2020). IMO proposes candidate measures for short-term (2018-2023), mid-term (2023-2030), and long-term (2030-…) in the Initial Strategy (IMO, 2018). Table 1 shows candidate measures for short-, mid-, and long-term.

IMO announced its Initial GHG Strategy, but the route to achieving GHG, especially CO_2 emissions, reduction goal is left to maritime stakeholders and flag states. At the meeting, IMO MEPC 75 on 16-20 November 2020, new technical and operational measures, the Energy Efficiency Existing Ship Index (EEXI) and the Carbon Intensity Indicator (CII), respectively, were adopted (de Kat, 2020) to speed up the decarbonization action of global maritime transportation. The EEXI is a technical measure and is going to enter into force on

1 January 2023. It is similar to the EEDI and shows the energy efficiency level of the ship, but it is going to be applied to existing ships. An attained EEXI will be calculated for each existing ship, and this index has to meet the required maximum EEXI of this type of ship. On the other hand, the CII is a new operational indicator that will be applied after 2025. The annual operational CII will be collected from shipping companies as part of the IMO DCS, and an operational rating from A to E (five-point scale) will be given to each ship (Psaraftis & Kontovas, 2021). The CII does not have any strict enforcement, but well-known cargo shippers can prefer higher rated-ships to transport their cargoes.

Various ways or combinations of different ways provide CO_2 emission reduction. Shipboard efficiency improvement actions on compressed air systems (Dere & Deniz, 2019a) or cooling water systems (Dere & Deniz, 2019b) can decrease CO_2 emissions to some extent. Balcombe et al. (2019) state that LNG is the main actor in alternative fuels. Biofuels, hydrogen, nuclear power, electric propulsion, and carbon capture and storage system are some of the routes for higher decarbonization. The study of Yalcin & Suner (2020) shows that using hydrogen reduces carbon emissions and related health risks (Suner & Yalcin, 2017; Yalcin & Suner, 2020). Using methanol as an alternative fuel with an advanced combustion concept (Zincir et al., 2019) and fuel cell application on a ship (Inal & Deniz, 2020; Inal & Deniz, 2021) can be other decarbonization methods in maritime transportation. To achieve effective decarbonization, multiple measures should be applied and stronger policy is required. A study was made on a systematic assessment of the technical feasibility of decarbonized maritime transport by 2035 (Halim et al., 2018). According to the study, the governments should involve in the decarbonization action and put some policies or regulations including zero-carbon operations, more stringent energy efficiency targets, a speed limit, and a low-carbon fuel standard. Moreover, ports' infrastructure should be improved by shore power facilities for cold ironing, battery charging stations, and alternative fuel bunkering facilities.

The IMO Initial GHG Strategy is a complicated process and there are various organizational, economic, technical, and political challenges and barriers (Serra & Fancello, 2020). The Strategy should be discussed more in detail from the perspective of both policymakers and ship owners/operators. The flag states which agreed on the Strategy should prepare their roadmap to remove the barriers for decarbonization of maritime transportation and contribute to the global decarbonization action by organizing shipowners and ship operators.

There are some studies in the literature that are based on interviews with the industry to see the progress of decarbonization in various sectors. Sovacool et al. (2018) have a study on national and regional transport challenges of Nordic countries about climate policy priorities. The study had 227 expert interviews from Denmark, Finland, Iceland, Norway, and Sweden. The experts are the stakeholders of transport technology, policy, and practice. The results of the study showed that fossil fuel intensity (42%) was the highest challenge, long travel distances (17%), public transport infrastructure (16%), congestion (15%), population density (10%), and electrification of transport (10%) follow it. A qualitative interview study was made with Greek shipowners about the decarbonization of maritime transportation (Koustoumpardis, 2019). The shipowners indicate that the LNG as an alternative fuel and electric propulsion are the main routes for the decarbonization of maritime transportation. Furthermore, an appropriate legislative framework must be established for successful decarbonization. Shell & Deloitte (2020) did a market survey study to understand the maritime industry trends. According to their study, more than 90% of maritime industry stakeholders count decarbonization as their business strategy. Another sector-based study was conducted in Italy (Sofia et al., 2020). The study focused on the decarbonization of various sectors including energy, transport, and household in 2030. According to the study, electrification is the road map for the decarbonization of maritime transportation in 2030. The world's largest container shipping company, Maersk, has declared their objective to be zero-carbon by 2050 (A.P. Moller-Maersk, 2018).

Turkey is one of the important flag states with its 1528 vessels (449 national flagged-vessel, 1079 foreign flagged-vessel) above 1000 gross tons and above (UNCTAD, 2020). Nevertheless, when the literature search is done, there are not many studies on the decarbonization of Turkish maritime transportation. The status of Turkish maritime transportation and opinions of Turkish shipowners and ship operators on the decarbonization of maritime transportation is unknown. This study aims to fill the literature gap by conducting a survey study. A questionnaire about the decarbonization of maritime transportation is formed and it is sent to Turkish shipowners and ship operators. The answers to the questionnaires are analyzed and the status and opinions of the Turkish maritime sector are discussed.

Table 2. Participants' profile

	Qualification	*Percentage*
Education Level	Undergraduate	60,1
	Master	32,1
	Doctorate	7,8
Department	Management	5,3
	Operation	21,1
	Technical	47,9
	Personal	15,3
	Other	10,5
Company Experience	1-3 years	26,8
	4-6 years	31,6
	7-9 years	26,3
	10+ years	15,3
Onboard Ship Experience	1-3 years	37,4
	4-6 years	31,6
	7-9 years	15,3
	10+ years	15,8

Table 3. Question frames were used in the survey

Notation	*Topic Description*
T1	Assess the knowledge level about maritime decarbonization strategies.
T2	Assess the company culture about decarbonization.
T3	Assess the knowledge about EEDI, SEEMP, and EEOI.
T4	Assess the knowledge about EEXI, and CII.
T5	Assess the usage ability of DCS and MRV.
T6	Assess the seaman's knowledge about decarbonization.
T7	Assess the company procedures and improvements on the decarbonization.
T8	Assess the operational energy efficiency applications.
T9	Assess the point of view market-based measures approaches such as taxes, levies.
T10	Assess the point of view on renewable energy sources for decarbonization.
T11	Assess the point of view on hybrid and electrical propulsion.
T12	Assess the point of view on capital and operational expenditures of new technologies.
T13	Assess the point of view on the maritime education curriculum.
T14	Assess the point of view on the governmental approaches.
T15	Assess the point of view on the class societies.
T16	Assess the point of view on the professional chambers and NGOs.

Note: Abbreviations: DCS: Data Collection System; EEDI: Energy Efficiency Design Index; SEEMP: Ship Energy Efficiency Management Plan; EEOI: Energy Efficiency Operational Index; EEXI: Energy Efficiency Existing Ship Index; CII: Carbon Intensity Index; MRV: Monitoring, Reporting, and Verification; NGO: Non-governmental Organizations.

Methodology

To understand the point of view and current status of the maritime industry, a questionnaire which is formed by 29 questions has been prepared. The survey contains different questions types to match the research data. Four questions types; multiple-choice, numeric open-ended, Likert scale, and ranking scales have been used. The descriptive information of the participants and their percentages are given in Table 2. The questionnaire answers are entered into SPSS Statistics Version 25.0 to analyze the data. According to gathered data from the participants, four main categories have been formed; education level, department, company experience, and onboard ship experience. The categories will be used to elaborate and understand the bias among different responses for the same questions.

As can be seen in Table 2, the four main categories have different subtitles. The education level of the participants is divided into three undergraduate levels, a master level, and a doctorate level. The graduate-level participants are the majority but slightly in front of the master level. However, participants with a doctorate are the minority as expected. Secondly, participants are also categorized according to their departments. Companies may have different departments however, the major four -management, operation, technical, and personal- are the same for all. Therefore, besides these four departments, another is also added and 5 subtitles are formed for the department category. The majority of the participants are from the technical department of the companies. Thirdly and fourthly, company and onboard ship experiences are selected as categories. Both are divided into same-year scales; 1-3, 4-6, 7-9, and 10+ years. The majority of the participants are in 1-3 years.

The questionnaire has been formed by 29 questions from different perspectives. Therefore, they are clustered under 16 topics and given as question frames in Table 3.

Results and Discussion

The responses were given in five scales where 1 is very weak and 5 is very good. Table 4 gives the evaluation scales for each question, Table 5, Table 6, Table 7 and Table 8 give the mean of the responses respecting education level, department, company experiences, and onboard ship experiences of the participants, respectively.

Table 4. Evaluation scales for the questions

Evaluation Scale	Indication
1	Very Weak
2	Weak
3	Moderate
4	Good
5	Very Good

Table 5 shows the mean value of the answers according to the education level of the participants and the total average value of the answers. The values of T1 – knowledge level of maritime decarbonization strategies, T3 – knowledge about EEDI, SEEMP, and EEOI, and T14 – governmental approaches indicate no relation to the education level. Because the mean values under three education levels do not show a meaningful trend. When T2 results are checked, it is observed that the participants with a higher education level think that the company culture on decarbonization action does not adequate. The doctorate-level participants have a lower mean value of 2,33 than the total average value of 3,16. These participants see company culture on decarbonization as weak. T4 – knowledge of EEXI, CII results show that the participants with a higher education level think that the company that they work do not aware of new decarbonization regulations such as EEXI or CII. The participants with doctorate-level think that the company has a very weak awareness of new decarbonization regulations by the mean value of 1,67. T5 – usage ability of DCS and MRV

Table 5. Results of the topics according to the education level of participants

Topic No	Undergraduate	Master	Doctorate	Average
T1	3	4.13	3	3.47
T2	3.38	3.25	2.33	3.16
T3	4	4	4	4
T4	3.13	3.38	1.67	3
T5	3.63	3.13	3.34	3.37
T6	2.5	2.75	2	2.53
T7	3.38	3	2.67	3.1
T8	2.63	3.38	3.34	3.05
T9	4.5	4	3.67	4.16
T10	4.5	3.75	3.67	4.05
T11	4.5	4.13	4.67	4.37
T12	3.88	4.25	4.33	4.11
T13	1.88	1.5	2.67	1.84
T14	2	1.75	2	1.89
T15	2.5	2.37	2.67	2.47
T16	1.75	1.5	2	1.68

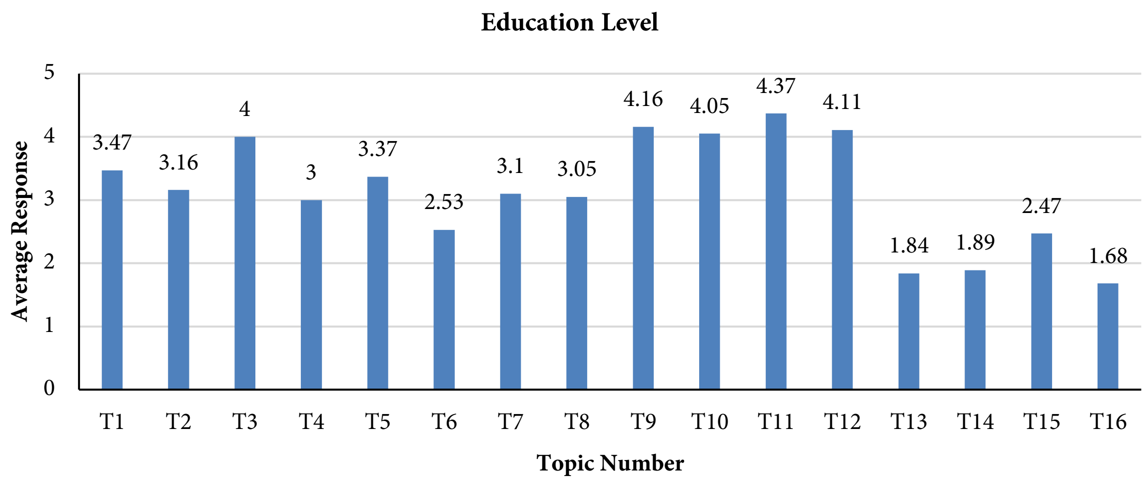

Figure 2. Average response results of the topics according to the education level of the participants

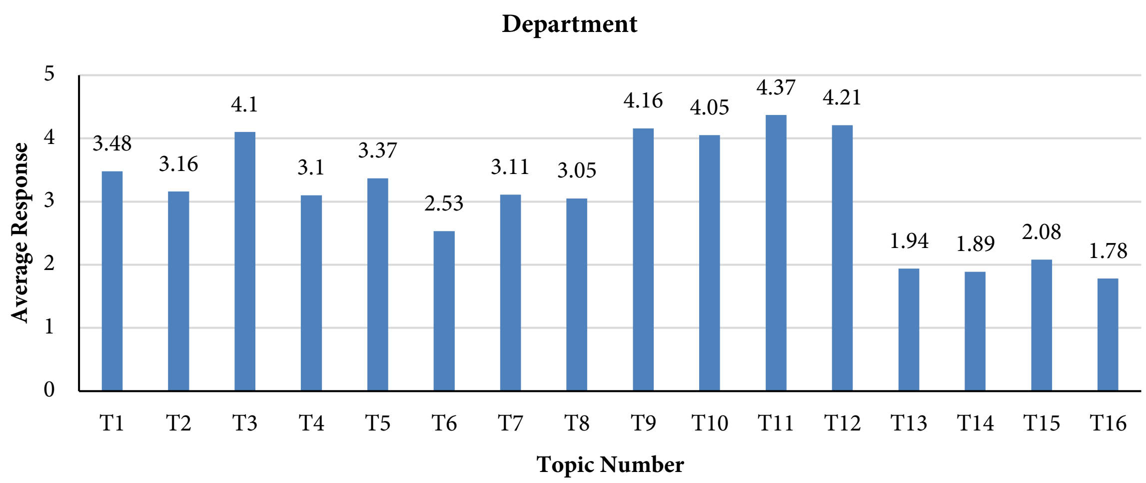

Figure 3. Average response results of the topics according to the department of the participants

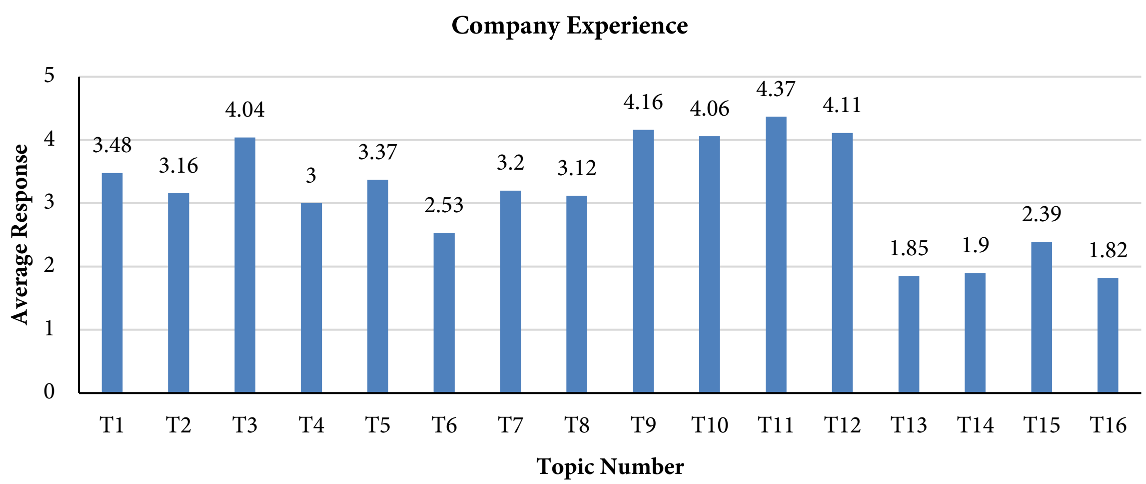

Figure 4. Average response results of the topics according to the company experience of the participants

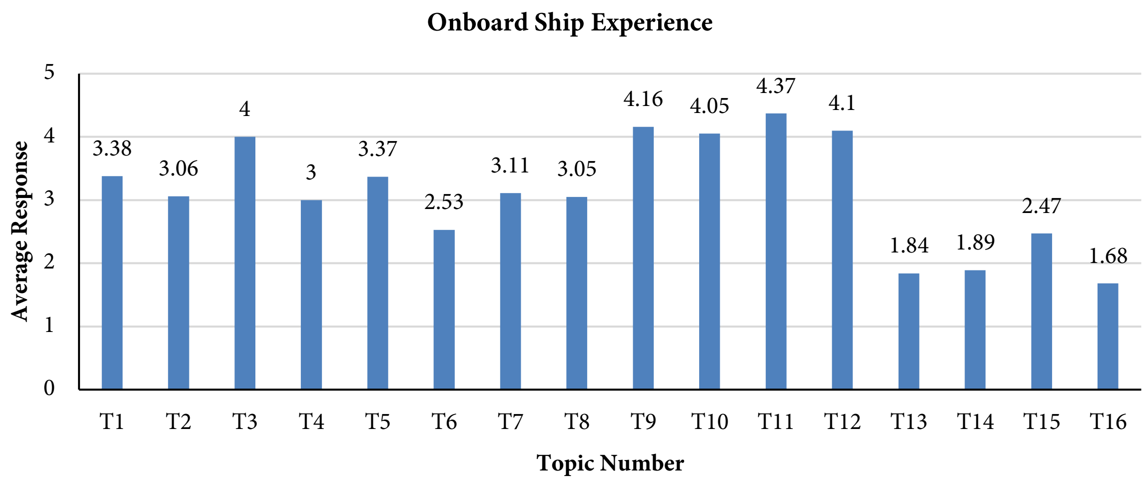

Figure 5. Average response results of the topics according to the onboard ship experience of the participants

results slightly change with the education level of participants. The participants with doctorate-level think that the company has a very weak awareness of new decarbonization regulations by the mean value of 1,67. T5 – usage ability of DCS and MRV results slightly change with the education level of participants. The participants with a higher education level think that the DCS and MRV are moderately applied, but with a lower mean value. With a higher education level, the participants think that the crew knowledge on decarbonization (T6) action is lower. The higher educated participants also answer with lower values at company procedures and improvements on decarbonization (T7) topic, which means the higher educated participants do not think that the procedures and improvements are enough for the decarbonization action. T8 – operational energy efficiency applications results show that higher educated participants are more satisfied with the applications on ships. On the other hand, when the education level increases the mean value of the answer reduces. Since these participants do not think that market-based measures (MBMs) are an effective solution for the decarbonization of shipping (T9). It is a surprise that the participants with a higher education level give lower value at T10 – renewable energy sources. The master level (3,75) and doctorate level (3,67) participants think renewable energy sources are a moderately effective solution for decarbonization. This can be because these participants have higher knowledge of renewable energy systems, and do not think that they are easy to apply on ships in the Turkish fleet. On the other hand, master and doctorate-level participants think that hybrid and electric propulsion can be a good option for decarbonization (T11). But they also answer that capital and operational expenditures are important factors for the new technologies (T12). The higher mean value with the higher education level can be related to higher knowledge and awareness of the participants on the new technologies with the increasing education level. One of the important topics, T13 – the maritime education curriculum, the result shows that in general nobody thinks maritime education is adequate for the decarbonization action in Turkey. They give points between 1,5 and 2,67 which corresponds to very weak and between weak and moderate, respectively. The participants with doctorate-level give the highest points with 2,67. It can be because they got education from undergraduate to doctorate level and they think that they have more enough knowledge on decarbonization. The higher educated participants think that class societies (T15) and chambers and NGOs (T16) in Turkey have knowledge and awareness on decarbonization action from weak to moderate (2.67) and weak (2), respectively.

Table 6 shows the mean value of the answers according to the department of each participant and the total average value of the answers. The values of T1 – knowledge level of maritime decarbonization strategies, and T3 – knowledge about EEDI, SEEMP, and EEOI are directly showing that the participants from the management and technical departments of the companies are much more aware of the way of decarbonization in the global maritime industry. T4 – knowledge of EEXI, CII, and T5 – DCS and MRV usage results show that the participants from management and technical departments of the company consider that their knowledge is fairly well and relatively enough for the industry. When T2 results are checked, it is observed that the participants from operational and personal departments think that the company culture on decarbonization action does not adequate. As expected, the participants from the management and personal department think that the crew knowledge on decarbonization (T6) action

Table 6. Results of the topics according to the department of participants

Topic No	Management	Operational	Technical	Personal	Other	Average
T1	4.7	2.5	4.21	3.6	2.5	3.48
T2	4.78	2.25	3.46	2	3	3.16
T3	4.8	3.5	4.45	2.1	3.2	4.1
T4	3.55	2.2	4.1	2	2.1	3.1
T5	3.66	3.25	4.8	2.2	2.8	3.37
T6	4.1	2.25	2.36	4.07	2.5	2.53
T7	4.9	2.25	3.37	2.1	2.9	3.11
T8	4.68	2.75	3.1	2.9	3	3.05
T9	4.9	3.76	4.27	2.1	1.85	4.16
T10	4.8	3.75	4.18	4	4	4.05
T11	4.9	3.75	4.64	3.2	4.1	4.37
T12	4.9	4.2	4.1	2.3	4.7	4.21
T13	3.1	2.5	1.46	4.1	1.2	1.94
T14	2	1.5	1.97	3.6	1.5	1.89
T15	2.8	2.78	2.45	2.2	1.1	2.08
T16	2	1.25	1.91	1.4	1.6	1.78

Table 7. Results of the topics according to the company experience of participants

Topic No	1-3 years	4-6 years	7-9 years	10+ years	Average
T1	3	3.43	3.8	4.9	3.48
T2	3.42	2.83	2.8	4.7	3.16
T3	3	4.17	4.6	4.82	4.04
T4	3.29	2.33	3.2	4	3
T5	3.29	3.67	2.89	5	3.37
T6	2.29	2.33	2.81	4	2.53
T7	3.57	2.5	2.64	4.9	3.2
T8	3.14	2.53	3.21	4.8	3.12
T9	4.14	4	4.2	5	4.16
T10	3.72	4.17	4.4	4	4.06
T11	4.43	4.33	4.2	4.7	4.37
T12	4.43	4	3.6	5	4.11
T13	1.57	2.04	1.84	3.08	1.85
T14	1.43	2	2.41	2.13	1.9
T15	2.57	2.67	1.65	4.23	2.39
T16	2.17	1.72	1.68	2.31	1.82

is high. However, results from other departments are in contrast. The participants from management also answer with higher values at company procedures and improvements on decarbonization (T7) topic and operational energy efficiency applications (T8), which means the management team thinks that the procedures and improvements are enough for the decarbonization action. Almost all participants think that market-based measures (MBMs) are an effective solution for the decarbonization of shipping (T9) since the average is one of the highest. The participants from whole departments think renewable energy sources (T10) and hybrid and electric propulsion (T11) can be good options and effective solutions for decarbonization. Hybrid systems show slightly better performance compared to renewable energy, this can be as same as table 5, because these participants have higher knowledge of renewable energy systems, and do not think that they are easy to apply on ships in the Turkish fleet. When T13 – the maritime education curriculum, T14 – governmental approaches, T15 – class societies, and lastly T16 – NGOs and chambers are under the scope, the participants give the lowest points in general. The result shows that nobody thinks neither maritime education is adequate for the decarbonization action nor chambers and NGOs (T16) in Turkey have knowledge and awareness on decarbonization.

Table 8. Results of the topics according to onboard ship experience of participants

Topic No	1-3 years	4-6 years	7-9 years	10+ years	Average
T1	3.67	2.67	4.61	4	3.38
T2	2.89	3	4.69	3.67	3.06
T3	3.67	3.83	5	5	4
T4	2.78	2.33	4.9	4.33	3
T5	2.56	3.83	5	4.33	3.37
T6	2.33	2.33	4.5	2.67	2.53
T7	2.89	2.83	5	3.67	3.11
T8	3	2.67	4.6	3.33	3.05
T9	3.89	4.17	5	4.67	4.16
T10	3.89	4.33	2.3	4.67	4.05
T11	4.22	4.33	4.8	4.67	4.37
T12	4.2	4.33	4.1	4	4.1
T13	1.89	1.67	2	2	1.84
T14	2	1.8	2	1.67	1.89
T15	2.67	2.17	2	2.67	2.47
T16	1.89	1.5	1	1.66	1.68

Table 7 shows the mean value of the answers according to the company experience for each participant and the total average value of the answers. In general scope, it can be said that the more experienced participants are more aware of the decarbonization in shipping. The values of T1 are drawing a meaningful trend line in coherence with experience. The same point of view is valid also for other topics. From T1 to T12, the knowledge of decarbonization, usage of alternative energy systems, crew awareness, and related regulations and equipment ability is increasing with company experience. This can be clearly observed from the answers of the 10 years plus experienced participants. The mean value of the experienced participants is higher than 4/5, therefore they believe that the knowledge, awareness, technological maturity, and base are enough at the personal and company level. However, the last four topics, T13, T14, T15, and T16 show the worse performance according to participants. Education curriculum, alternative supports, and informative letters from chambers, NGOs, or governmental branches seem like the weakest points in front of the Turkish maritime industry on the decarbonization roadmap.

Table 8 shows the mean value of the answers according to the onboard ship experience of each participant and the total average value of the answers. In general, while the sea experience increases, the general knowledge on the requirements of the decarbonization for the industry increases. T3, T9, T10, T11, and T12 have received greater points and showed better performance according to almost from all the participants from every scale of experience. This means, the participants believe that although capital and operational expenditures are high, renewable energy and hybrid propulsion systems are important on the way of the decarbonization. Moreover, the results are showing that the participants have more information on the current documentation rather than the incoming ones. This is the perfect reflection of difference between T3 and T4. On the other hand, T13, T14, T15, and T16 are rated as the weakest points for the industry in front of the decarbonization. All participants consider that the maritime education and also governmental, societies and NGOs contribution to the industry are not enough for this new era.

Conclusion

In this paper, a survey study has been carried out to show the current status of the Turkish maritime industry on decarbonization action. The questionnaire with 29 questions was prepared and sent to the participants from different companies with different departments, education levels, and experiences. By this questionnaire, the readiness and awareness level of the Turkish maritime industry were evaluated. The main findings of the study are:

- According to the analysis of the participant answers by the education level, higher educated participants think that company culture on decarbonization, knowledge on upcoming decarbonization regulations, application of DCS and MRV, crew knowledge on decarbonization action, company procedures on decarbonization, and MBMs to achieve decarbonization are not adequate. Moreover, they think that the knowledge of the class societies, NGOs, and chambers in Turkey do not have sufficient knowledge to assist companies. All participants, regardless of their education, think that the maritime curriculum is weak.

- Depending on the departments, the analysis shows that management and technical departments are much more aware of the decarbonization action. The knowledge of DCS and MRV usage and upcoming regulations of EEXI and CII is fairly well for these departments. On the other hand, operational and personal departments think that the company culture on decarbonization does not adequate. The crew knowledge on decarbonization is high according to the management and personal departments. All departments think that renewable energy sources and hybrid and electric propulsion can be good options for decarbonization. On the contrary, maritime education curriculum, governmental approaches, knowledge of the class societies, NGOs, and chambers get the lowest points in general.
- It is observed that the participants with more company experience are more aware of the decarbonization in shipping. The knowledge of decarbonization, usage of alternative energy systems and options, crew awareness, and related regulations increase with the company experience. The weakest points are the maritime education curriculum, informative letters from chambers, NGOs, or governmental branches.
- Another observation is while the sea experience increases the knowledge on the decarbonization action increases. The participants believe that renewable energy and hybrid and electric propulsion systems are important for decarbonization, despite their capital and operational expenditures. Generally, the participants have more information on the current regulations rather than the incoming ones. Another common point is all participants think that maritime education and the contributions of the class societies, NGOs, chambers, and governmental branches are not sufficient for decarbonization at Turkish maritime industry.

The main conclusions of this survey study are the maritime education curriculum has to be updated by considering decarbonization actions and maritime stakeholders such as class societies, NGOs, chambers, governmental branches have to give adequate informative letters, bulletins, seminars, etc. to improve the knowledge and awareness of the Turkish maritime industry on the decarbonization of shipping. In the future studies, periodical surveys can be performed to see the improvement of the industry and to determine the readiness level of the new technologies. This study shows a preliminary analysis as an overview of the industry.

Compliance With Ethical Standards

Authors' Contributions

Author BZ designed and wrote the study, OBI performed and managed statistical analyses and wrote the study, ÇD prepared the questionnaire and did the survey study, CD did supervision on the study. All authors read and approved the final manuscript.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

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