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ARTICLE

Autonomous shipping — an analysis of the maritime stakeholder perspectives

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Abstract
Several major initiatives have been undertaken worldwide towards the development and commercialisation of maritime autonomous surface ships (MASSs). This study aims at capturing the current understanding and perspectives of the maritime industry stakeholders pertinent to the challenges and requirements for the design and operation of MASSs. A methodological approach consisting of five steps is followed. A questionnaire is developed and employed to conduct two surveys among the identified maritime industry stakeholders. Subsequently, the acquired response results are analysed, whereas statistical metrics are calculated and comparatively assessed using the box plot method, to provide evidence for identifying the perspectives and gaps from the considered stakeholders' groups. Recommendations are provided for addressing these gaps, whereas further initiatives required in the maritime industry are also highlighted. This study contributes to the better understanding on the perspectives of the maritime industry stakeholders, whereas the results can support the prioritisation of future initiatives towards addressing existing barriers and overcome misconceptions for the next-generation autonomous shipping.

Keywords Autonomous shipping · Maritime industry stakeholders · Perspective analysis · Survey

1 Introduction

The autonomous shipping development is expected to contribute on enhancing the sustainability of the shipping industry (Li and Yuen 2022) as well as the resilience and efficiency of the serviced supply chains (Munin 2019). Additional benefits include the enhancement of the shipping operation safety (Kim et al. 2022), in terms of the reduction of the maritime accidents, the mitigation of the piracy threats, as well as the lifetime

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costs reduction (Hoeam et al. 2022). The Fourth Industrial Revolution and its associated technologies, which already greatly affected several sectors, have been also started penetrating in shipping (UNCTAD 2016). The wider use of emerging technologies, such as cloud computing, Big Data, the Internet of Things (IoT) and robotics, is anticipated to penetrate in the maritime industry, greatly influencing the design, building and operation of future ships. Using cloud computing and machine learning is expected to enable real-time decisions making by collecting and evaluating data from various sources, as required when planning a voyage and optimising the route (Ang et al. 2017). The Internet of Things will effectively allow for interconnecting the subsystems and components of the autonomous shipping ecosystems (Dombrowski and Wagner 2014). The basic idea for the fourth-generation shipping industry is to combine all these technologies and render them to function together (Lambrou and Ota 2017). By interconnecting ships, ports, cargoes, and shipping companies, the involved procedures and decisions making can be effectively controlled and organised in real time (EPICOR 2021).

Through its vision on electronic navigation, the IMO aimed to introduce regulations for improving shipboard navigation systems, manage information on ship traffic and improve communication infrastructure between ships and shore (Burmeister et al. 2014). While this vision was not referred to unmanned and autonomous ships, it laid the foundations on the digitisation of the ship bridge by employing smart technologies. In addition, the European Union (EC 2021) as well as the European Platform for Floating Technologies (WATERBORNE 2021) encourages and supports developments on autonomous shipping and maritime autonomous surface ships (MASSs), to maintain and strengthen a leading global position in the maritime sector. Competitiveness, innovation, safety, and environmental requirements are included among the areas that need to be addressed for the development and commercialisation of MASSs (Burmeister et al. 2014).

The rapid development of technologies in the maritime sector also supports the advances in autonomous ships (Kim et al. 2021). Among others, the Shore Control Centre is a key enabling technology that needs to be developed with its own functions, rights and responsibilities to remotely operate autonomous ships (Bolbot et al. 2020). In these operations, qualified personnel (operators/supervisors) is expected to deal with emergencies (Porathe et al. 2014). In addition, the ship will be fully equipped with modernised autonomous systems, which will allow its remote monitoring in real time (KONGSBERG 2021). Several projects have been investigating the autonomous shipping aiming to overcome the existing barriers and challenges and render autonomous shipping feasible. Early projects on autonomous shipping explored various aspects including technical, economic and legal (Burmeister et al. 2014) (MUNIN 2014). 'Yara Birkeland' (KONGSBERG 2021) is the first fully electric, autonomous transport container vessel, which is remotely controlled from three decision centres for ensuring safety at any operating conditions. ReVolt (DNV 2021) is another project aiming to develop an unmanned ship for short voyages, which considers batteries as a power source. The Autonomous Shipping Initiative for European Waters (AUTOSHIP project) aims to design, build and test in full-scale conditions two demonstrators (an Inland Water Ways (IWW) barge and a Short Sea Shipping (SSS) cargo vessel), developing the required key enabling technologies (AUTOSHIP 2021), thus accelerating the next generation of autonomous ships. Furthermore, the Automated Vessels and Supply Chain Optimisation for Sustainable Short Sea Shipping (MOSES project) aims at a significant enhancement of the SSS component of the European container supply chain by addressing the vulnerabilities and challenges pertaining to the operation of large containerships (MOSES 2020). The Advanced Efficient and Green Intermodal Systems (AEGIS project) scope is to develop a new waterborne transport system for Europe using innovations that leverage the benefits of ships and barges, while overcoming the challenges of dependence on terminals, high transhipment costs, low speed and frequency and low automation in information processing (AEGIS 2020).

Autonomous ships' technology has become an immense topic in the quest for enhancing efficiency, as well as developing environmentally friendly, more sustainable and safer maritime transport solutions (Munim 2019). Efforts to address the introduction of commercially feasible solutions for autonomous ships have been pursued globally (Wasilewski et al. 2021). Safety is a crucial aspect that must be effectively addressed to allow for the development and operation of autonomous ships (Porathe et al. 2018). The use of autonomous ship technology is associated to safety challenges; nonetheless, the human element will still be an important factor to be considered, even when fully unmanned ships are used (Zhu et al. 2019). Autonomous systems are expected to require extensive training to cover most of the potential real-life situations (Chang et al. 2021). The ship autonomous operation (from shore) imposes new safety challenges, whereas the interaction of manned and unmanned ships in the same traffic area is still unpredictable (Man et al. 2016; Rødseth et al. 2021). Therefore, the autonomous ship technologies should be considered for the training of future seafarers (Bachari-Lafteh and Harati Mokhtari 2021). Autonomous ships' navigation points out the importance of human element for developing the next-generation autonomous ships (Yan et al. 2009).

It is likely that only a few ship types (Shimizu 2021), or an additional new entrant, may be the most promising option for the first applications of ship autonomous functionality and operations. The developed autonomous ships' feasibility and safety are considered prerequisites to justify pertinent investments (Autonomous Ships 2022). The fundamental limitations for the development of autonomous ships are associated with the lack of consideration of the economic, ethical, legal and social aspects, as well as their links with security and their interactions. Additionally, technology-related issues deserve much closer and detailed attention (Zhou et al. 2020). In particular, inappropriate design of software or the remote control centre could lead to losing control of ships and, thus, causing accidents, urging shipping companies to pay much attention to human error related hazards (Chang et al. 2021). Similar findings pertaining to challenges and perspectives for the development of maritime autonomous surface ships (MASSs) were reported in Kim and Schröder-Hinrichs (2021). A survey conducted in the MUNIN project (MUNIN 2016) indicated contradictory perspectives from the involved stakeholders. An indicative example is that the respondents who did work onboard ships were less inclined to agree that shifting jobs from ship to shore would increase attractiveness, compared to those without shipboard experience. Another recent survey focused on the safety perceptions for different automation degrees concluding that men are more inclined to increased automation compared to women (Goerlandt and Pulsifer 2022). Generally, this survey identified the improved environmental performance as the most significant perceived benefit that could arise from autonomous shipping, whilst safety was highlighted as the most significant concern.

The preceding literature review points out the following important findings: (a) studies are required to understand the full impact of the autonomous shipping on the maritime sector; (b) research and innovation initiatives are required focusing on the design, building and operations; (c) the current understanding of the maritime industry stakeholders is not documented, whereas there is lack of studies on providing these stakeholders perspectives.

The aim of this study is to capture, interpret and analyse the positions, understanding and perspectives on autonomous shipping of the main categories of stakeholders involved in the shipping industry. Following several iterations, a questionnaire was developed, based on which two surveys were conducted targeting groups of the maritime stakeholders including stakeholders with activities on autonomous shipping. The survey's responses were analysed by employing descriptive statistical methods and using the "notched box plot" representation to allow for effectively comparing the response distributions for each group, as well as their central tendency and significance medians. The findings pertaining to several aspects of autonomous shipping are identified, whereas the perspectives of the involved stakeholders are comparatively assessed. Based on these findings, recommendations are provided for addressing the identified gaps, whereas further initiatives required in the maritime industry are also highlighted.

The novel elements of this study include (a) comprehensive analysis of the involved stakeholders' and public' perspectives regarding autonomous shipping; (b) comparative analysis/assessment of various stakeholders' and public' perspectives; (c) the identification of the areas in autonomous shipping that need special attention; and (d) the key areas that require further investigation.

The remaining of this study is structured as follows. Section 2 describes the methodological approach and employed method for designing and conducting the survey, as well as the survey result analysis. The description of the derived results is provided in Section 3, whereas the core findings along with their discussion are presented in Section 4. Section 5 provides recommendations for further investigations on identified critical areas. Finally, the main findings and conclusions are presented in Section 6.

2 Methodological approach

The methodology followed in this study consists of five steps, as depicted in Fig. 1, which are explained in the following sections.

2.1 Step 1: Mapping of the key stakeholders

The mapping of the maritime industry stakeholders was performed according to the process described in detail in Molica Colella et al. (2021). Several key performance indicators (KPIs) were employed to identify the innovation networks and champions, as well as their positioning pertinent to the autonomous shipping value chain and market. This process led to the following outcomes: (a) the technology trends' determination and the mapping of the top technology providers; (b) the

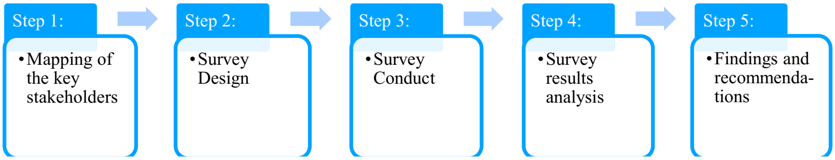


Fig. 1 Methodology flowchart

identification of the incumbent market leaders and their potential competitors; (c) the selection of the champions of research and development (R&D) activities and the networks of knowledge pertinent to autonomous shipping; (d) the mapping of patents and protected intellectual property (IP) rights; and (e) the identification of R&D start-ups focusing on technology transfer and open innovation. The selected groups of the key stakeholders include the owners, operators, builders, designers, technology providers, port authorities, regulators, flag states, technical advisors, legal advisors, environmentalists, international organisations, professional societies, academia, research institutions, seafarers and the public.

2.2 Step 2: Survey design

Predominantly, an effective questionnaire is key to a successful survey. There exist several methods to capture people's view (Groves et al. 2009), including the "one to one interview", "paper questionnaire" and "online surveys", each one with its advantages and disadvantages. The last method was the most suitable for the purpose of this study, due its greater accessibility, convenience for the participants, dissemination capabilities and response time. The questions were designed using Likert scales (Carifio and Perla 2007) with 5 or 7 qualitative, but scored, scales of agreement (i.e. agree or disagree), as their friendly approach is well suited to capturing participants' perspectives.

The Mentimeter (Mentimeter 2021) software was employed to carry out the online survey, due to its compatibility with smartphones, its user-friendly environment and the automatic statistics and visualisation of the results once the participant completes the survey.

To design the questionnaire in a neutral and complete format, the principles of privacy, simplicity and appropriateness were followed. Through several workshops with the AUTOSHIP partners and the strategic advisory group (SAG), the areas of interest for autonomous shipping developments were captured. Through several iterations, which included AUTOSHIP partners as well as externals (from the SAG), the questions were developed to explore the wide range of benefits, impact, challenges, barriers in terms of the economic, financial, legal, social, technological, operational, environmental, safety and security perspective. Additionally, several questions were set, pertinent to the expectations of the various government roles and the ship types considered as the most viable. A sample audience was employed to test the questions' credibility and the survey filling process. The latter was also employed to fine-tune the questions and finalise the questionnaire, which was employed to conduct the two surveys (surveys 1 and 2) allowed for testing the adequacy and comprehension of the developed questions. A more detailed description of the followed process and reference materials is provided in Rentifi et al. (2021).

The developed questionnaire consists of 10 questions; each one includes various sub-questions. The first two questions were pertinent to the participants' professional background, as well as the need towards the transition to autonomous shipping. The remaining eight questions included sub-questions pertinent to the benefits, the impact on shipping, the viability in specific ship types, the improvement expectations in various sectors, the barriers, the technical limitations, the significant challenges and the governments' role.

Except for questions 1 and 2, all other questions were not mandatory, i.e. the participants did not have to answer questions that they did not feel comfortable with. Considering both surveys, about 3% of the questions were left unanswered. The questions of this survey as well as the provided ranges and their characterisation are listed in Appendix 1.

2.3 Step 3: Survey conduct

The questionnaire was disseminated to two different audiences. In the first one (hereafter called survey no. 1), the spectrum of the participants ranged from the public to maritime professionals, both involved in conventional and autonomous shipping. In the second one (hereafter called survey no. 2), the participants were engaged within autonomous shipping. Thus, the two surveys led to a comparative study, with the main differentiation being the participants' involvement with activities in autonomous shipping.

To effectively disseminate the questionnaire to the selected audiences, a range of communication channels was employed, including e-mails, social networking websites (Facebook and LinkedIn), the AUTOSHIP project website and instant messenger combined with phone calls to request participation in the surveys, with the latter to be the most effective method of acquiring responses.

Survey no. 1 was set available online at Mentimeter (Mentimeter 2021) for 2 months, in the period September and October 2020, until the data sample reached the number of 170 responses. Following the initial elaborations, 138 responses were considered complete and were further analysed. The respondents were grouped into categories, as presented in the next section.

In January 2021, the survey no. 2 was released to an audience exclusively involved in various sectors of autonomous shipping, collecting 36 responses. The respondents were also categorised in the same groups as the survey 1.

2.4 Step 4: Survey result analysis

The survey responses were analysed using descriptive statistical methods considering (i) the distribution for each stakeholders group (category) to identify the overall dispersion in the received responses; (ii) the similarities between the response distributions of each group, whilst indicating the different groups' expertise in autonomous shipping; and (iii) comparing the responses between both surveys to demonstrate differences in perceptions for groups with expertise in autonomous shipping.

The statistical analysis was carried out using the "notched box plot", which provides an effective visual representation of the data distribution' principal statistics, thus allowing for comparatively assessing between them (Langford 2006). The traditional box plot represents the data distribution (Fig. 2a) as a box with the bottom (lower quartile) and top (upper quartile) sides representing the 25% and 75% ranges of the cumulative probability distribution, a line inside the box that represents the data median (50%), and whiskers that show the range of nonoutlier data (0% and 100%). An outlier was defined as the data value that is more than 1.5 times the box size, which is known as the interquartile range (IQR) from the upper and lower quartile boundaries, i.e. the IQR is defined between the 25 and 75% of the data distribution.

The notched version provides evidence of a statistically significant difference between the medians of groups, represented as a notch around the median line, i.e. in cases where the notch areas of different groups overlap their medians that show statistical similarity. The notch region, considering 5% significance level, is calculated by the following equation:

$$\text{Notch} = m \pm \frac{(1.57\text{IQR})}{\sqrt{n}} \tag{1}$$

where m is the median and n is the data number. An example of a standard well-behaved discrete distribution and its notched box plot representation is presented in Fig. 2a.

However, due to the characteristics of the developed survey, i.e. discrete, few options and not bounded to normal distributions, the survey responses can result in either a concentrated distribution or a distribution with high dispersion (both leading to different box plot representations as illustrated in Fig. 2b, c). For the case where most responses are the same (concentrated distribution), the box plot is represented as a horizontal line (Fig. 2b), indicating that all IQR are concentred in a value and the other responses are treated as outliers. Distributions of high dispersion (Fig. 2c) indicate a low respondents' agreement and high uncertainty. The resultant box plot includes a long notch region that can surpass the IQR, which is represented as a "folded box", indicating a confidence interval for the median higher than the 25% and/or 75% of the distribution range. Considering the definition of the notch region, Eq. 1, the notch region will be amplified with fewer responses, which appears for some stakeholders' groups.

2.5 Step 5: Findings and recommendations

From the survey result analysis, the corresponding distributions and their main statistics were calculated for each question/sub-question. Subsequently, based on these metrics' thorough analysis, the most significant findings are identified, whereas recommendations for future research are provided.

3 Survey result analysis

This section presents the results derived from the conducted surveys. The results from each question are analysed and discussed leading to the understanding of the maritime stakeholders' perspectives, whilst providing proposals for future initiatives pertinent to the development of autonomous shipping.

Figure 3 presents the summarised representation of the responses for questions Q3 to Q10, considering the responses from all participants. The complete box plot representations for these questions are shown in Appendix 2 where bold boxes are employed to denote stakeholder groups with more experience in the question subject. It should be noted that no weight correction was used for deriving the sum of each stakeholder group to infer it to the entire population. Hence, the comparison between the two surveys only reflects the survey sample and does not have an inferential statistical representation.

3.1 Q1 — Which of the following categories most closely matches your job title? Range 1–9

The first question was introductory to depict the categories and proportion of the respondents. The stakeholder group sizes for each survey are presented in Table 1. Survey 1 had a fair number of participants in each group, with a minimum of 6 participants in the category 6 (research institution/academia), which allows for performing an effective statistical analysis. Almost half of the participants of survey 2 belongs to the category 6 (20 participants, i.e. 56%) whereas few participants belong to the other groups. This reduces the significance of the statistical analysis, i.e. increases the uncertainty, as the low participant number reduces the statistical representation of the distribution and compromises the data statistics (consequently, the box plot representation).

3.2 Q2 — Is there a need for the transition from the conventional to the autonomous shipping? Range 1–7

Figure 4 shows the statistical analysis for question 2 responses using the box plot representation illustrating the categories (stakeholder's groups) for each survey (blue colour refers to survey 1, orange colour denotes survey 2). The category numbers 1–9 are defined in Table 1.

In Fig. 4, the responses from categories 6 and 7 are examples of the respondents' low agreement, i.e. distributions with high dispersion (similar to Fig. 2c) in the considered scale (1–7). These distributions are represented by a large boundary box (distance between the lower and upper quartile), encompassing major part of the response's distributions, with a large confidence interval (high uncertainty) for the median (notch region). In contrast, the results from categories 1 and 2 show typical distributions denoting the respondents' good agreement (similar to Fig. 2a). The box plots for the categories 3 and 8, which resemble "fold boxes" (similar to Fig. 2c), are examples of confidence intervals that surpass the boundary box, representing an overall agreement with some distant responses due the increased median uncertainty. Lastly, the responses from categories 1 and 4 from survey 2 are examples of concentrated distributions (similar to Fig. 2b), in which the participants voted in the same option.

Considering the above, most participants agreed (median of 5) that there exists a need for the transition to autonomous shipping. Owners/operators (group 1) were the most optimistic for this transition, whereas the research institutions/academia (group 6) and seafarers (group 7) were more sceptical; however the observed perspective is still neutral to slightly positive towards autonomous shipping transitions (median of 4.5).

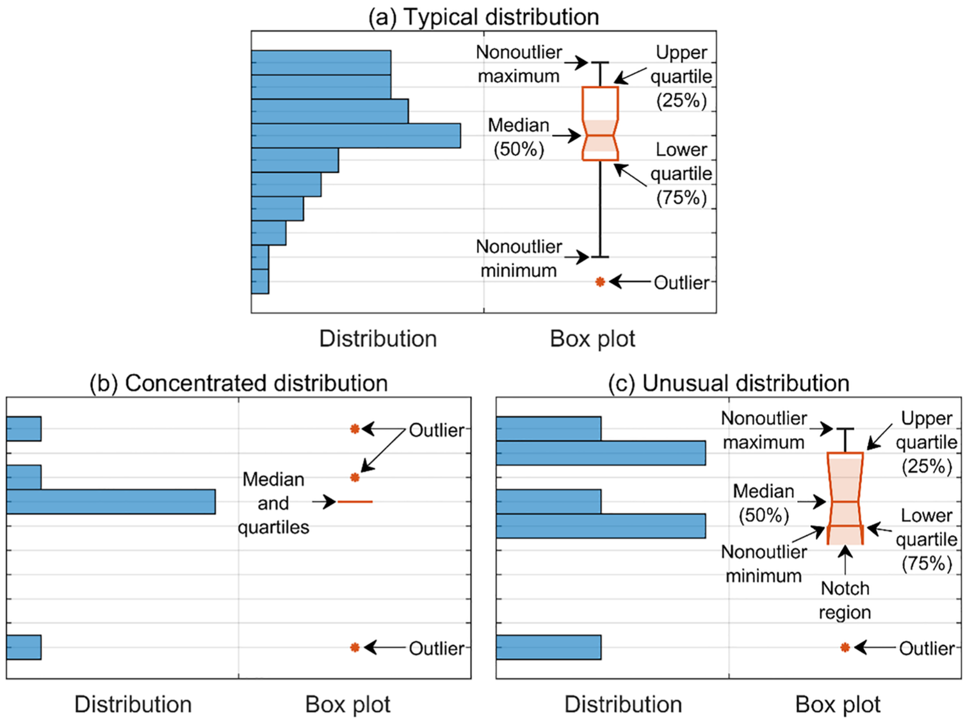


Fig. 2 Examples of the box plot graphs: **a** typical distribution, **b** concentrated distribution, and **c** distribution with high dispersion

In both cases, the scepticism is associated with high dispersity in the results, indicating a need to effectively disseminate information pertinent to autonomous shipping. This assumption is reinforced when comparing the two surveys, as stakeholders already involved in autonomous shipping (survey 2) are more positive towards this transition.

3.3 Q3 — Which would be the benefits from the transition to autonomous shipping? Range 1 – 5

In general, the participants agreed (median of 4) that the transition will bring benefits for the aspects covered in the survey in each sub-question, i.e. financial (3.1), environmental (3.2), social (3.3), safety (3.4) and resilience (3.5). It is deduced that a disagreement exists between the participants from regulatory/state/port authorities (group 3) for each survey for question 3.2, from the two participants of survey 2 expressing pessimism for the autonomous shipping environmental benefits. Considerable dispersion was exhibited in the responses from research institutions/academia (group 6),

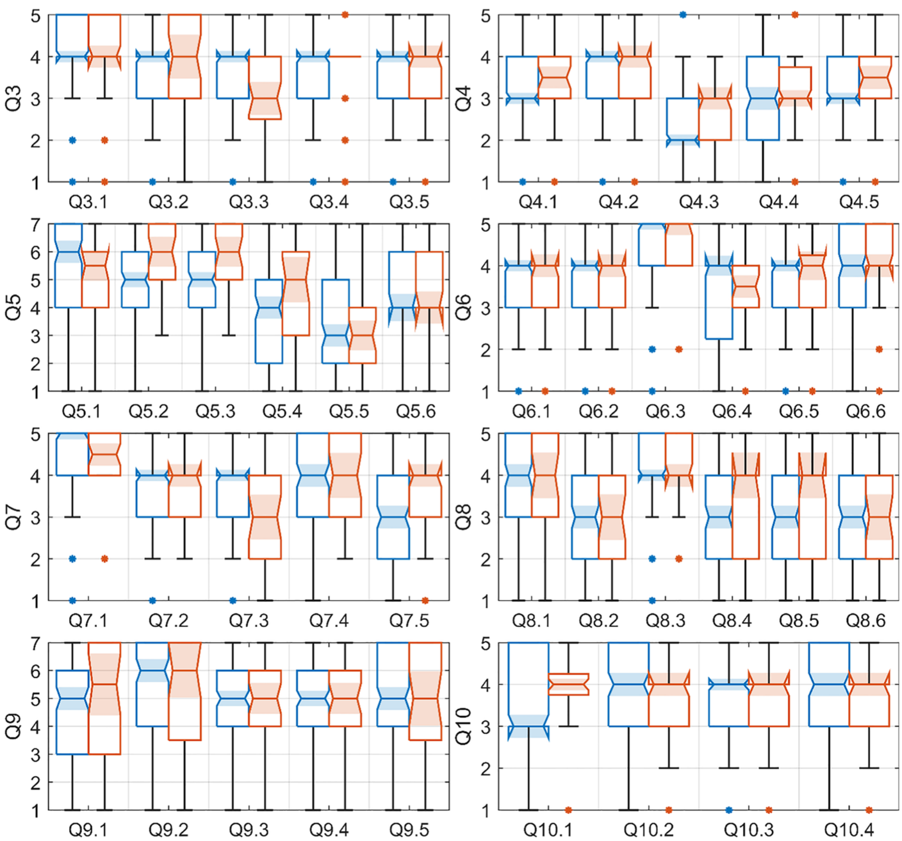


Fig. 3 Responses for all questions separating by survey and grouping the categories (groups of stakeholders)

seafarers (group 7) and public (group 8) about the social benefits of autonomous shipping (Q3.3). This is attributed to the fact that social benefits were not explicitly be defined, and thus, they are perceived in a different way from the respondents.

3.4 Q4 — How would the transition to autonomous shipping impact the shipping industry? Range 1–5

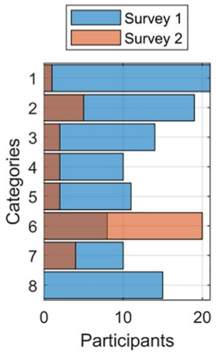
The respondents expressed different perspectives/expectations for each sub-question; the autonomous shipping profitability (Q4.2) was considered positive (median of 4), the autonomous shipping impact on income (Q4.1) and resilience (Q4.5) were evaluated as neutral-to-positive (medians in the range from 3 to 4), the autonomous shipping effect on financing was considered neutral (median 3), whereas the autonomous impact on the number of employees was estimated as negative (median of 2). In general, the views of participants of survey 2 were slightly more positive compared to the participants of survey 1.

3.5 Q5 — The autonomous shipping will be a viable option for the following shipping sectors: range 1–7

For ocean-going vessels (Q5.1), a major part of participants agreed that they will be a viable option for autonomous shipping (median of 6). However, considerable dispersions were exhibited for owners/operators (group 1) and seafarers (group 7), denoting greater variety in the perspectives of these respondents. The participants agreed that the Short-sea shipping (Q5.2) and inland shipping (Q5.3) are considered viable options for autonomous shipping (median of 5 and better agreement in the stakeholders' responses). The participants considered neutral the autonomy applications in working ships (Q5.4) and other ships types (Q5.6). This can be attributed to the more demanding/diverse operations of working ships (tugs, dredgers). Other ships were not clearly defined, and therefore, the responses were affected by the participants interpretation on their meaning. Cruise ships (Q5.5)

Table 1 Survey no. 1 and no. 2 participants' groups

#	Categories	Participants [counts / %] Survey 1	Survey 2
1	Owners / Operators	21 / 15%	1 / 3%
2	Designers / Builders / Technology providers	19 / 14%	5 / 14%
3	Regulators / Flag States / Port Authorities	14 / 10%	2 / 6%
4	Legal Advisors / Technical Advisors	10 / 7%	2 / 6%
5	Environmentalists / Professional Societies / International Organizations	11 / 8%	2 / 6%
6	Research Institutions / Academia	8 / 6%	20 / 56%
7	Seafarers	10 / 7%	4 / 11%
8	Public	15 / 11%	/ 0%
9	Other / Not responded	30 / 22%	/ 0%
	Total	138 / 100%	36 / 100%



*One hundred thirty-eight participants for survey no. 1; 36 participants for survey no. 2

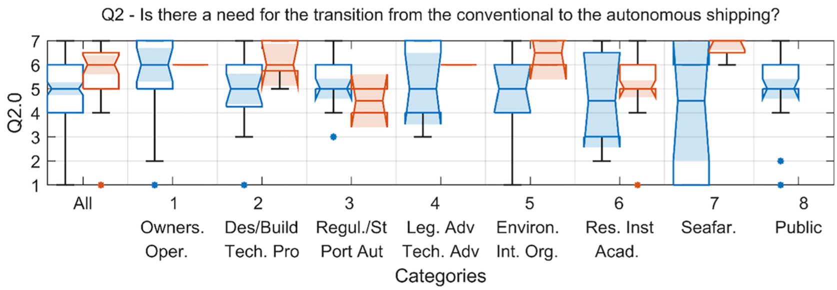


Fig. 4 Question 2 responses, using box plot, separated by categories (groups of stakeholders) for surveys 1 (blue-left) and 2 (orange-right)

were the only ship type that the participants indicated as non-viable option (median of 3), despite some positive responses. This can be attributed to the fact that these ships carry large numbers of passengers and crew, therefore, autonomy cannot offer demonstrable benefits.

3.6 Q6 — The transition to autonomous shipping will: range 1–5

Seafarers (group 7) disagreed (median of 2.5) that the autonomous shipping will solve the deficit of seafarers (Q6.1). In contrast, the participants from same group that are involved in autonomous shipping initiatives (survey 2) agreed with this statement (median of 4), showing that dissemination of knowledge in this area can improve the acceptance of autonomous shipping. It is noteworthy that the responses of groups 4, 5, 6 and 7 exhibited considerable dispersions in this sub-question, denoting different perspectives within these groups. Seafarers (group 7) do not agree that the autonomous shipping will improve the quality of life for the employees in the shipping sector (Q6.2), although their responses exhibited considerable dispersion). Considerable dispersions (although smaller) are observed in the responses from groups 2, 6 and 8. All groups agreed that the current training framework modification is needed (Q6.3); however, it is noteworthy that Seafarers responses exhibited considerable dispersion. Regarding to the effect of autonomous shipping on the loss of the existing knowledge from seafarers (Q6.4), the overall responses indicate an agreement (median of 4); however, deviations in each group responses are noted. This can be attributed to the lack of this sub-question comprehension as agreement (high score) indicates negative effect of autonomy, on the contrary to the other sub-questions. The participants agreed with the autonomous shipping contribution to modal shift (Q6.5), however, the responses of groups 5 (environmental/professional/societal/international organisations) and group 7 (seafarers) exhibited large dispersions. In regard to Q6.6 pertaining to the attractiveness of small autonomous ships, an overall agreement is observed (median of 4) from all the groups, apart from the seafarers (group 7) that expressed a neutral response (median of 3).

3.7 Q7 — Please assess the impact of the following barriers to the transition to autonomous shipping: range 1–5

There exists a very good agreement among all the participants that the regulatory barriers (Q7.1) will have a major impact (median of 5) for the transition to autonomous ships, apart from seafarers (group 7), whose responses exhibited a median of 4 and considerable dispersion. This may be attributed to the individuals' understanding on autonomous shipping as well as the extend of the existing regulatory framework. Despite the overall agreement that the technological limitations (Q7.2) will have a moderate impact (median of 4) for the transition to autonomous shipping, group 2 (designers/builders/technology providers) and group 4 (legal/technical advisors) expect a more moderate impact (median of 3). An overall agreement that the social limitations (Q7.3) will have a moderate impact in the transition to autonomous shipping was expressed (median of 4). However, the groups responses exhibit considerable dispersions, which is attributed to the fact that the "social impacts/limitations" were not explicitly defined. Similar behaviour is exhibited in the results for Q7.4 pertaining to the safety and security issues and associated challenges for the transition to autonomous shipping. Regarding the economic barriers impact (Q7.6), the responses exhibited a median of 3, expressing a neutral view. However, the groups, 6, 7 and 8 expect a moderate impact (median of 4).

3.8 Q8 — Which are the biggest challenges for the development of autonomous shipping? Range 1–5

The participants agreed (median of 4) that the investment cost (Q8.1) will be a challenge for the development of autonomous shipping, with group 1 (owners/operators) expressing the strongest agreement (median of 4.5). Group 6 (research institutions/academia) disagreed (median of 2) on this statement, whereas group 4 (legal/technical advisors) were neutral (median of 3). The participants were neutral (median of 3) in considering the operation costs (Q8.2) challenging. Groups 5 and 7 slightly agreed (median of 3.5), whereas groups 4 and 6 disagreed (median of 2) with this statement. The lack of regulations (Q8.3) were also indicates as a challenge (median of 4) by all groups, with a strong agreement (median of 5). The participants were neutral (median of 3) on the challenges related to political issues (Q8.4). However, it is noted that groups 2 and 6 agreed that it can be a challenge (median of 4 and 4.5, respectively). The participants expressed neutrality (median of 3) on the technology maturity related challenges (Q8.5). However, groups 2, 3 and 8 responses exhibited considerable dispersions, whereas group 6 agreed that it can be a challenge (median of 4 with low dispersion). The lack of qualified workforce (Q8.6) was also considered neutral (median of 3), although groups 2, 3 and 6 agree that it can be a challenge.

3.9 Q9 — Which technical limitations do you consider to be the biggest challenge when designing and operating autonomous ships? Range 1–7

The participants expressed slightly positive responses (median of 5) on the technical limitations for the autonomous navigation (Q9.1). It is noteworthy that the designers/builders/

technology providers (group 2) of survey 2 provided neutral responses (median of 3), indicating that the autonomous navigation is not the biggest challenge. Groups 5, 6 and 8 responses exhibited a more positive agreement (median of 6) on this statement. Additionally, the participants agreed (median of 6) that communications in autonomous shipping poses a big challenge (Q9.2). Groups 4, 5, 7 and 8 responses exhibited a median of 5, indicating a somewhat agreement. Considering Q9.3 pertaining to the challenge of remote control centres, the participants somewhat agreed on this (median of 5). The autonomous shipping involved participants (survey 2) from group 2 expressed a slight disagreement (median of 3.5), which is attributed to their expertise on developing this key enabling technology. The participants somewhat agreed (median of 5) that the lack of procedures for testing (Q9.4) can be a limitation for autonomous shipping. It is noteworthy that the survey 1 participants from groups 2 and 3 provided a more solid agreement to this statement (median of 6). The survey 2 participants (involved to autonomous shipping initiatives) responses exhibited a median of 5. This is attributed to the knowledge/understanding on the in autonomous shipping developments of the latter participants. The participants responses were neutral to positive (median of 5) that the ship reliability (Q9.5) can be a limitation for autonomous shipping. The responses from groups 3, 4, 6 and 7 exhibited a median of 6, demonstrating agreement in this statement.

3.10 Q10 — The role of governments: range 1–5

In general, the participants were neutral (median of 3) on the role of governments in providing financial incentives (Q10.1). Owners/operators (group 1) strongly agreed that the governments should provide financial incentives for the transition to autonomous shipping (median of 4.5), along with groups 5 and 8 (median 5). The participants also agreed that the governments must assure the autonomous ships safety (Q10.2; median of 4). However, it is noted that the group of regulatory/state/port authorities (group 3) are neutral about this sub-question (median of 3). The participants agree (median of 4) that the governments should cover the infrastructure costs related to port adaptation. However, it is noticeable that owners/operators (group 1) and public (group 8) responses exhibited a median of 4, whereas the other groups responses exhibited a median of 3 (denoting neutrality on this statement). Similar outcomes were provided for the responses on the government role in the inland waterway infrastructures costs (Q10.4), with an overall agreement towards this question (median of 4), which was also confirmed for groups 1, 4 and 8, whereas the other groups responses were neutral.

4 Survey result discussion

In the previous sections, the most critical points of the respondents' feedback for each question were presented. These results are further discussed herein, to delineate the root causes underneath the received responses as well as to provide recommendations for future investigation.

In all the examined aspects, there exists a general view of the various respondents' groups that the transition to autonomous shipping will be partially beneficial

(Q3—median of 4). Those who provided the highest marks were the owners/operators (group 1) and the designers/builders/technology providers (group 2). On the contrary, the research institutions/academia (group 6) and seafarers (group 7) provided the lowest ranking, but still presenting an overall agreement that autonomous shipping will bring benefits (median between 3 and 4). The owners/operators (group 1) and seafarers (group 7) were the most sceptical on safety (median of 3). In general, the stakeholders involved in autonomous shipping (survey 2) present a similar trend to general participants, but some groups are more pessimistic (groups 3 and 7), whereas other more optimistic (groups 1 and 2).

Regarding environmental benefits (Q3.2), most groups believe that the transition to autonomous ships will be environmentally friendly, except for the two participants from group 3 in survey 2 (one neutral (3) response and one negative (1) response). It was noticed that group 6 and Public (group 8) presented a great dispersion in their responses, indicating that a communication plan seems beneficial to disseminate the outcomes and findings of ongoing projects pertinent to the autonomous shipping, and in specific, environmental assessments and comparison to the conventional shipping environmental performance.

Group 2 expect that autonomous ships will improve safety (median of 4 in Q3.4). The other groups also showed a similar agreement, except for the seafarers (group 7) who expressed a more neutral view (median of 3). This view should be further investigated, so that the advantages of the developed shore jobs are analysed in more depth and effectively communicated. Cost–benefit analyses will facilitate operators/owners to comprehend the factors to enhance the autonomous shipping sustainability.

All the respondents presented a scatter view in terms of the increase in the employees' numbers (Q4.3). The stakeholders' general perspective regarding the impact of the transition to autonomous shipping seems to be neutral to negative. However, new job openings, such as sensor experts, IT specialists, technology providers, and designers are expected to effectively develop technologies and systems required in autonomous shipping. Therefore, the various groups might not have considered a value-chain perspective of the autonomous shipping. Instead, they misjudged the seafarers' removal from the ships and their transfer/transformation of their jobs to the remote-control centres, where only a limited number of operating personnel is required and expected to handle several ships.

Several respondents' groups expressed the view that the transition to autonomous ships would slightly improve the crisis resilience (Q4.5) and the financial metrics (Q4.1, Q4.2 and Q4.4). It was noticed that the owners/operators (group 1) seem to have a more positive view of the profitability rather than income increase. Regarding the crisis resilience improvement, it would be beneficial to investigate the rationale behind these views that would delay the potential implementation of the autonomous shipping.

In terms of the viability of autonomous ship types, there exists a general agreement (median of 5 and 6) that inland waterways (Q5.3), shortsea (Q5.2) and ocean-going vessels (Q5.3) could adopt autonomous technology. The cruise ships are considered the least appropriate for autonomous shipping due to the large number of passengers and crew onboard, as well as the media attention that the cruise ships have received in the last years because of some fatal accidents. However, the safety of autonomous shipping is a prerequisite, so the shipping industry is required to move forward towards autonomy.

Another barrier for the autonomous shipping development is the seamless and reliable communications (Q9.2) and data exchange between the various parties at the sufficient data transfer speeds. The short-sea and inland ships, due to their small size, can have redundancy of communication systems. In contrast, the ocean-going ships should be further investigated regarding this issue and its cost-effectiveness. Another considerable barrier was the regulatory framework (Q8.3), indicating that there are concerns among the participants on the effective adaptation of the international regulations for the ocean-going ships, and the national authorities regulations for the short-sea and inland ships.

Most of the feedback received referring to the autonomous shipping transition (Q2) were positive (median of 5); some groups expressed neutral to positive responses. In general, the responses from autonomous shipping related participants (survey 2) were more positive than the general ones. The seafarers (group 7) who are not familiar with the autonomous ships might have been concerned of losing their jobs due to this transition. Therefore, there is of utmost importance to comprehend the reasons behind this negative attitude and establish a dialogue with them about the transformation of jobs, safety, and any other fundamental points of the transition.

The perspectives from all the groups converge towards the need to modify the training framework (Q6.3) for the operation of the next generation of autonomous ships. Several national authorities have a more positive perception towards the development of autonomous shipping. The issue for the development of new or adapted regulations, including COLREGS, addressing the autonomous ships operations was expressed as of utmost importance and one of the biggest challenges by not only the regulatory/states/port authorities (group 3) but also among many individuals from all the other groups that participated in this survey.

As for the social limitations (Q7.3) that might arise from the shipping transition to autonomy, such as the lack of expert skills, the legal/technical advisors (group 4) and environmental/professional/societal/international organisations (group 5) expressed neutral views (median of 3). Autonomous safety and security (Q7.4) are some of the most critical challenges for the viability of autonomous ships, therefore a more detailed analysis of group 2 views and future expectations is recommended, so that the expected benefits of the new systems are analysed and achieved.

The economic benefits are strongly associated with low operational expenditure (OPEX), although the autonomous ships are expected to have a higher investment cost (CAPEX). The responded expressed consensus on the cost-effectiveness of autonomous ships considering the lifetime cost. The owners/operators (group 1) and designers/builders/technology providers (group 2) responses expressed neutrality (median of 3) in terms of the operational costs (Q8.2), but agreement was exhibited that the investment cost will be a barrier (Q8.1) (median above 4). However, groups 4 and 6 visions indicate that both CAPEX and OPEX will not be the most important barriers (median of 2).

Finally, with respect to the role of the governments, the AUTOSHIP respondents agreed that the transition should be supported by the governments in all aspects covered in the surveys. Significantly, the owners/operators (group 1) considered as essential subsidising the infrastructure costs either in the inland waterways or ports, as well as the assurance of the autonomous ship's safety.

The MUNIN survey (MUNIN 2016), which was conducted in 2015, seems to assimilate the general conclusions of the surveys presented in this study. The responses of the present surveys are more conservative compared to the MUNIN survey (MUNIN 2016). In the MUNIN survey, it is noteworthy that 50% of the participants with an onboard experience expressed a positive opinion regarding autonomous shipping. In the present study, the seafarers group provided neutral opinions for the autonomous shipping viability (Q5), being more positive for the short-sea shipping (Q5.2) and more negative for cruisers (Q5.5). The received responses also illustrate that the lack of qualified professionals (Q8.6) is not considered a significant challenge (neutral median) for the workforce and safety (MUNIN 2016), which requires further investigation. It is worth mentioning that both the current surveys and MUNIN survey participants expressed their considerations regarding the new threats, which must be mitigated. In MUNIN (2016) survey, the participants considered that the ship OPEX will be reduced, and thus, the shipping companies' profitability will be improved. The development of new or adapted regulations (Q7.1), addressing the autonomous ships operations was also pointed out in the MUNIN survey (MUNIN 2016).

5 Limitations and recommendations for further investigations

It should be noted that this study includes several limitations, which are related to the following areas. Limitations pertinent to the sufficient representation of the stakeholders of the maritime industry and new entrants for the case of autonomous shipping. Issues related to the different perspectives of the stakeholders in several geographical locations must also be investigated in future studies. The lack of knowledge and experience on autonomous shipping is an area that must be addressed, as the autonomous shipping projects/initiatives advance. The effective dissemination of future surveys is another area that needs to be considered. To address limitations of the employed analysis method, it is recommended to use in future studies inferential statistical methods, which can lead to systematic extrapolation of the survey results in larger populations whist enhancing the results confidence. This requires the questionnaire redesign and an effective dissemination process to ensure sufficient representation of each stakeholder group whilst employing appropriate metrics for allowing comparative assessment with the total population.

Based on Sections 3 and 4 discussion, several areas that require future investigation were identified. The different views between the stakeholders' groups pertaining to the economic benefits from autonomous shipping worth further elucidation. In addition, the software and their functions as well as their safety assurance and approval are an area that required more comprehensive investigation. It is required to comprehend what the designers, builders and technology providers need to technically confront the overall establishment of the autonomous navigation and communication between vessels and the shore. Further investigation is needed to identify and quantify whether the seafarers will be socially benefited from the ship to shore transition of their jobs.

Further studies must shed light on the stakeholders' expectations for governmental support and clarify whether the root cause of the neutrality they initially expressed is due to a lack of knowledge of what the governments could offer as well as their roles. It is recommended that both infrastructure and technology developments are further examined. It is essential to mention that the shipowners may need to understand the autonomous shipping incentives, especially the political incentives, to drive the transition in autonomous shipping.

6 Conclusions

This study focused on the delineation of the understanding, perspectives and positioning of the maritime industry stakeholders pertinent to the autonomous shipping. A five-step approach was followed to select the audience/participants, design a questionnaire, conduct surveys, analyse the collected responses and derive recommendations. The main findings of this study are summarised as follows.

- The transition to autonomous shipping (Q2) is considered beneficial by most of the survey participants.
- The participants were inclined towards the effect of autonomous shipping on the jobs number reduction (Q4.3), but it seems that the complete supply chain as well as the transitional period to develop autonomous shipping was overlooked.
- The Seafarers' group seemed to oppose on the concept of the autonomous shipping, whilst the designers/builders/technology providers exhibited neutrality (Q2 and Q3).
- The owners/operators group mostly agrees that the transition to autonomous shipping will assist in the deficit of the seafarers (Q8.6).
- There is an overall consensus that the modification of the training framework (Q6.3) is essential for the operation of autonomous ships.
- The viability of autonomous shipping (Q5) is considered positive for the short-sea, inland and ocean-going ships; neutral for the work ships/boats, whereas it is considered negative for the cruise ships.

This study limitations include among others, the survey design, participants knowledge/expertise in autonomous shipping, participants geographic location, dissemination issues. However, the present study findings can be used to identify the strong and weak points in the autonomous ships' context, investigating the key areas to focus on and directing future research and other initiatives. The study is expected to be beneficial to comprehend the maritime stakeholders' perspective on autonomous shipping, and as such, to administrate future strategies and policies from various groups of the involved stakeholders and decision makers.

Appendix 1

The questionnaire employed in this survey is illustrated in Table 2.

Table 2 Questionnaire

Surveys questions **No**		**Questions**		
		Which of the following categories most closely matches your job title?		
Q1	Resp.	1 - Owners/Operators 2 - Designers/Builders/ Technology Providers 3 - Regulatory/State/Port Authorities	4 - Legal Advisors/Technical Advisors 5 - Environmental/Professional Societal/International Organisations 6 - Research Institutions/Academia	7 - Seafarers 8 - Public 9 - Not responded
		Is there a need for the transition from the conventional to the autonomous shipping?		
Q2	Resp.	1 - Strongly disagree 2 - Disagree 3 - Somewhat disagree	4 - Neither agree nor disagree 5 - Somewhat agree	6 - Agree 7 - Strongly agree
		Which would be the benefits from the transition to autonomous shipping?		
Q3	1	Financial benefits (reduced fuel consumption, optimized routing, reduced manning cost and etc.)		
	2	Environmental benefits (reduced environmental footprint)		
	3	Social benefits (increased job opportunities onshore - especially for women, better working conditions for seafarers)		
	4	Increased safety (due to system automation)		
	5	Added resilience in case of major worldwide disruptions (diseases, wars, piracy)		
	Resp.	1 - Extremely Unlikely 2 - Unlikely	3 - Neutral 4 - Likely	5 - Extremely likely
		How would the transition to autonomous shipping impact the shipping industry?		
Q4	1	Increase the income		
	2	Increase the profitability		
	3	Increase the number of employees		
	4	Improve the access to financing (easier access to loans)		
	5	Improve crisis resilience (reduce the risk of company exposure to disturbance in the market)		
	Resp.	1 - Strongly disagree 2 - Disagree	3 - Neither agree nor disagree 4 - Agree	5 - Strongly agree
		I expect the autonomous shipping will be a viable option for the following shipping sectors:		
Q5	1	Ocean-going vessels		
	2	Short-sea shipping		
	3	Inland shipping		
	4	Working ships (tugs, dredgers)		
	5	Cruisers		
	6	Other		
	Resp.	1 - Strongly disagree 2 - Disagree 3 - Somewhat disagree	4 - Neither agree nor disagree 5 - Somewhat agree	6 - Agree 7 - Strongly agree
		The transition to autonomous shipping will:		
Q6	1	Solve the deficit of seafarers		

Table 2 (continued)

	2	Improve the quality of life for the employees in the shipping sector		
	3	Require the modification of the current training framework for seafarers		
	4	Result in the loss of the existing knowledge, skills and experience of seafarers		
	5	Contribute to the transportation modal shift (from land or air to sea and inland waterways)		
	6	Render the use of smaller ships more attractive		
	Resp.	1 - Strongly disagree 2 - Disagree	3 - Neither agree nor disagree 4 - Agree	5 - Strongly agree
Q7		**Please assess the impact of the following barriers to the transition to autonomous shipping:**		
	1	Regulatory barriers (ships will not be allowed to sail until new regulations have been implemented)		
	2	Technological limitations (technology not mature)		
	3	Social limitations (lack of expert skills)		
	4	Safety and security issues		
	5	Economical barriers (question of profitability)		
	Resp.	1 - No effect 2 - Minor Effect	3 - Neutral 4 - Moderate Effect	5 - Major Effect
Q8		**What do you think which are the biggest challenges for the development of autonomous shipping?**		
	1	Investment cost		
	2	Operational costs		
	3	Lack of regulations		
	4	Political issues		
	5	Technology maturity		
	6	Lack of qualified workforce		
	Resp.	1 - Strongly disagree 2 - Disagree	3 - Neither agree nor disagree 4 - Agree	5 - Strongly agree
Q9		**Which technical limitations do you consider to be the biggest challenge when designing and operating autonomous ships?**		
	1	Autonomous navigation (e. g. collision avoidance)		
	2	Communication with the ship (including cyber-security issues and piracy)		
	3	Remote control centres (lack of operational experience)		
	4	There are no procedures for testing, verification and validation		
	5	Ship reliability and maintenance/repair requirements, especially during long voyages		
	Resp.	1 - Strongly disagree 2 - Disagree 3 - Somewhat disagree	4 - Neither agree nor disagree 5 - Somewhat agree	6 - Agree 7 - Strongly agree
Q10		**The role of governments:**		
	1	Provide financial incentives to support the transition process to autonomous shipping		
	2	Guarantee the safety of autonomous ships		
	3	Cover the infrastructure costs in port adaptation for autonomous ships		
	4	Cover the infrastructure costs in inland waterway infrastructure adaptation for autonomous ships		
	Resp.	1 - Strongly disagree 2 - Disagree	3 - Neither agree nor disagree 4 - Agree	5 - Strongly agree
Q11		**Please provide us with any additional comments or suggestions about autonomous shipping (Optional):**		

Appendix 2

Figures 5, 6, 7, 8, 9, 10, 11 and 12 show the box plot representation of the response's distributions for the questions and sub questions listed in the Appendix 1, separated by stakeholder group and survey type (1: general; 2: from autonomous shipping), using the categories presented in Table 1. The box drawn in bold denote stakeholder groups with more experience in the sub-question subject.

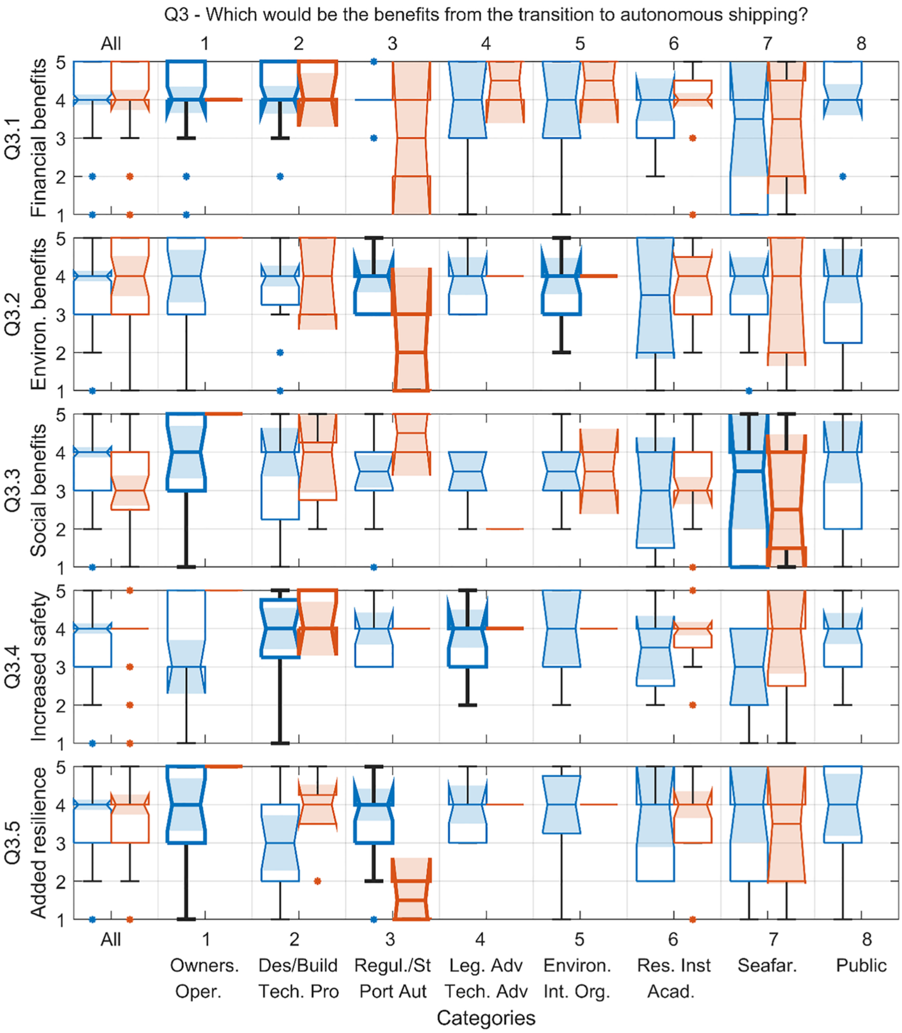


Fig. 5 Question 3 responses, using box plot, separated by categories (groups of stakeholders) and survey

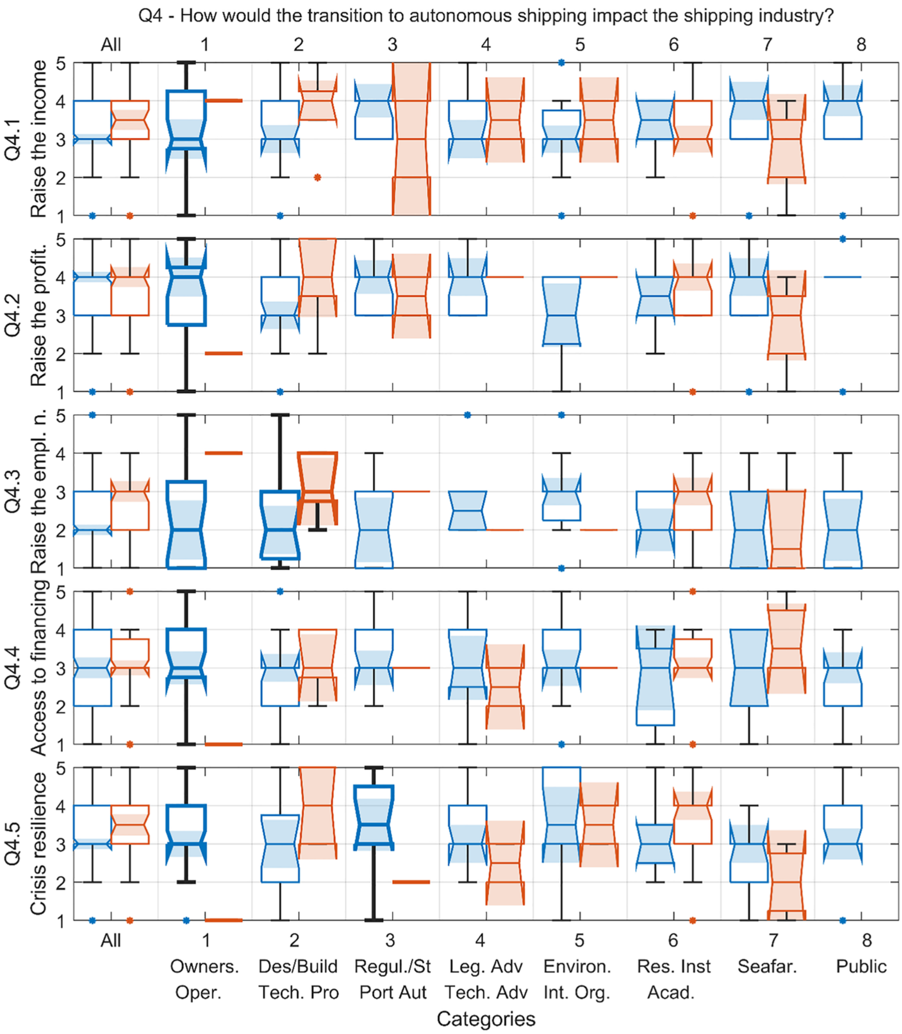


Fig. 6 Question 4 responses, using box plot, separated by categories (groups of stakeholders) and survey

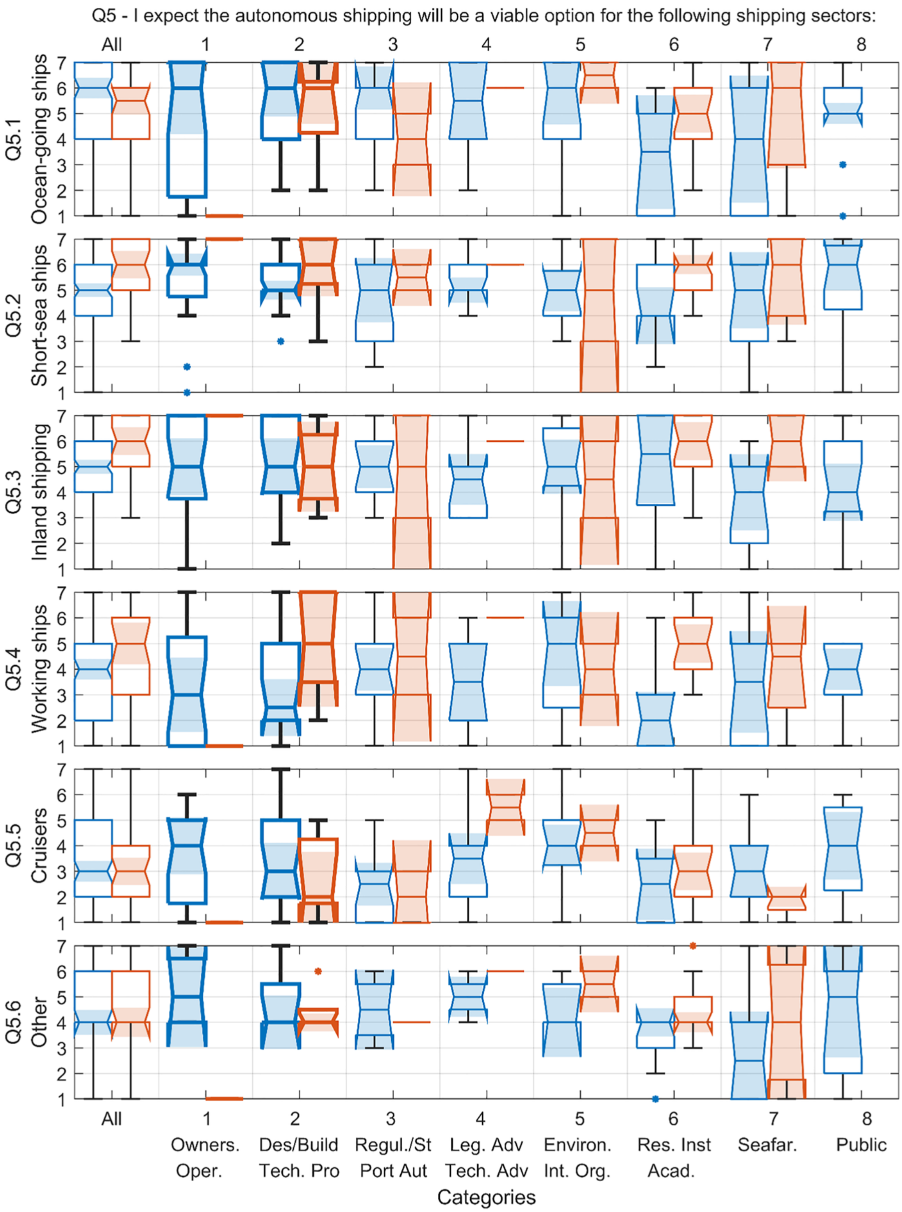


Fig. 7 Question 5 responses, using box plot, separated by categories (groups of stakeholders) and survey

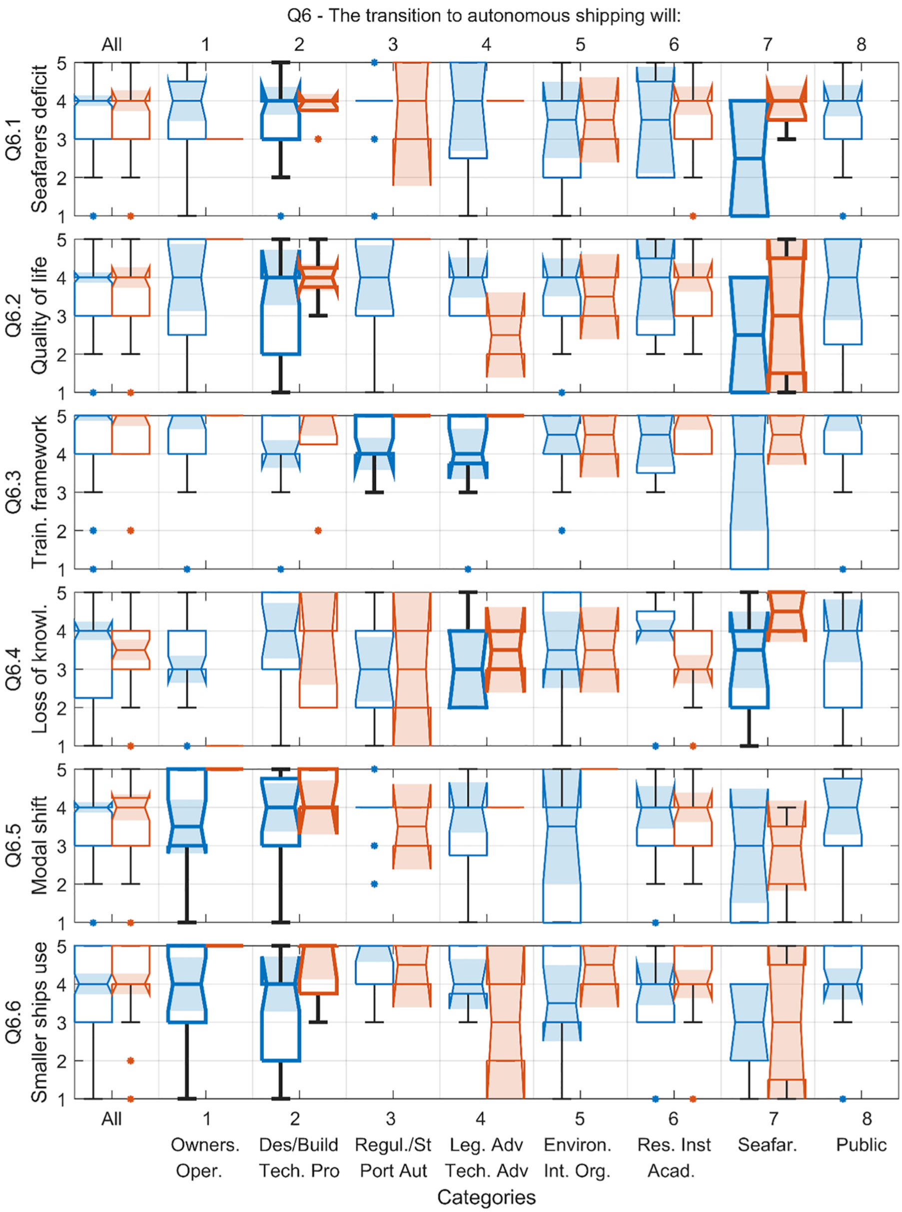


Fig. 8 Question 6 responses, using box plot, separated by categories (groups of stakeholders) and survey

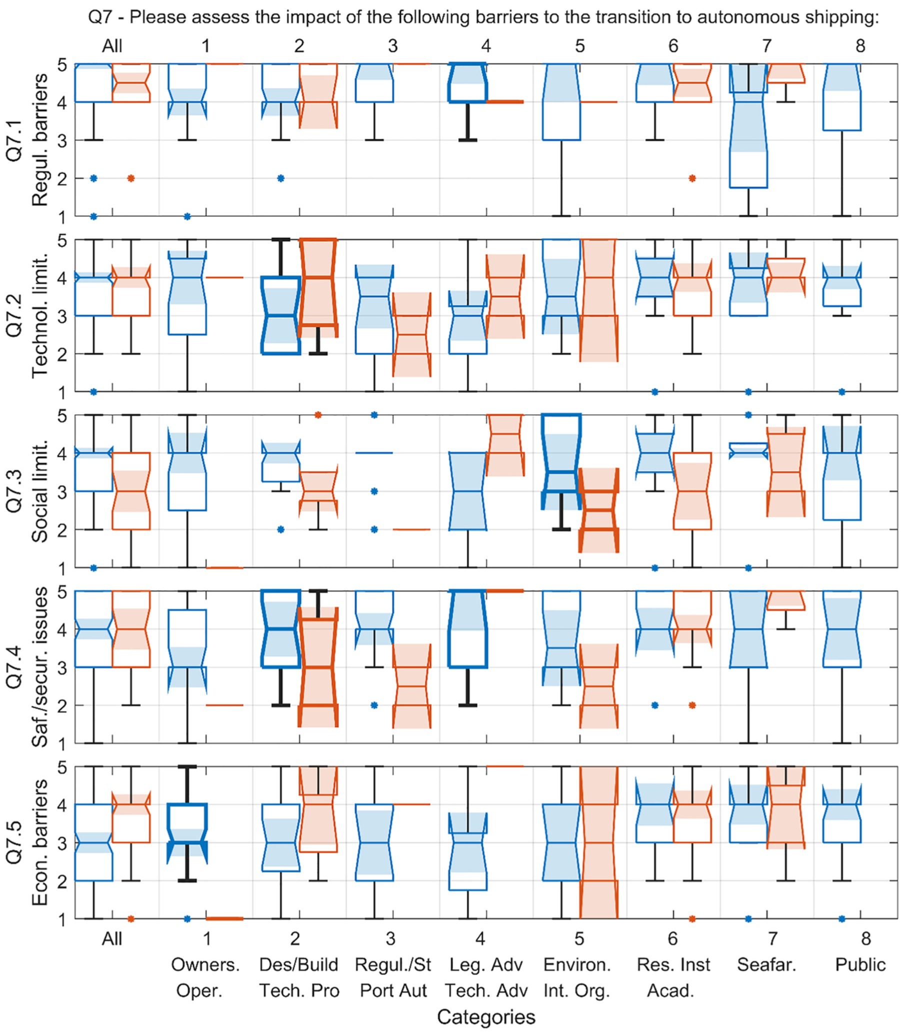


Fig. 9 Question 7 responses, using box plot, separated by categories (groups of stakeholders) and survey

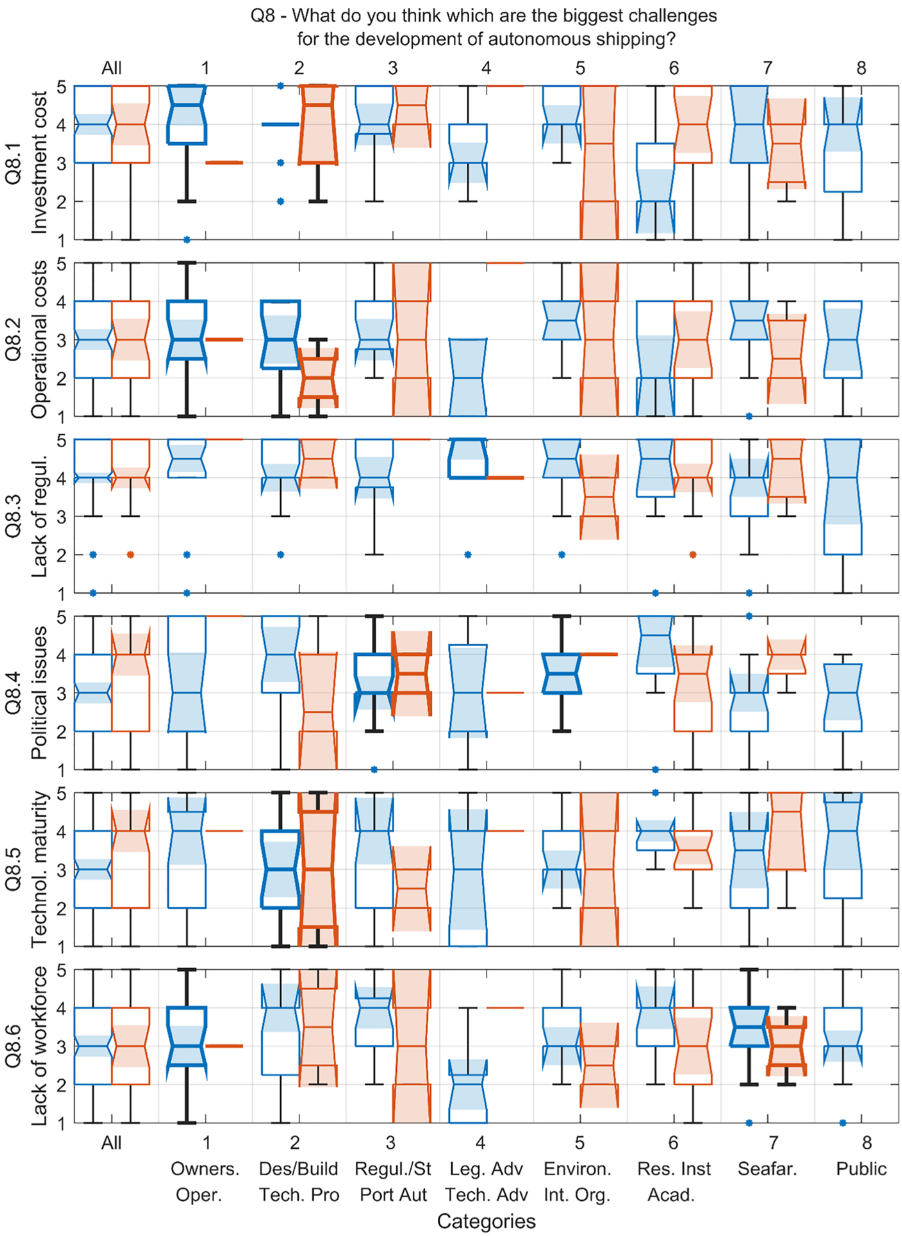


Fig. 10 Question 8 responses, using box plot, separated by categories (groups of stakeholders) and survey

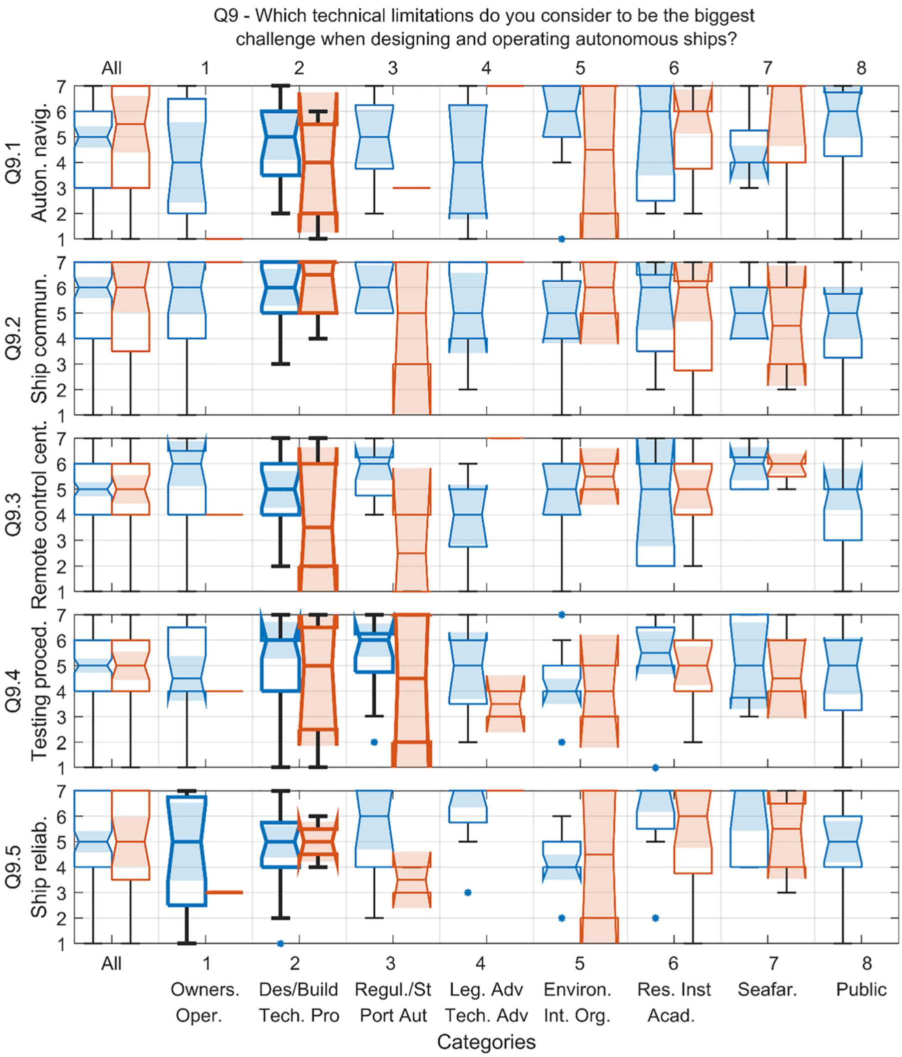


Fig. 11 Question 9 responses, using box plot, separated by categories (groups of stakeholders) and survey

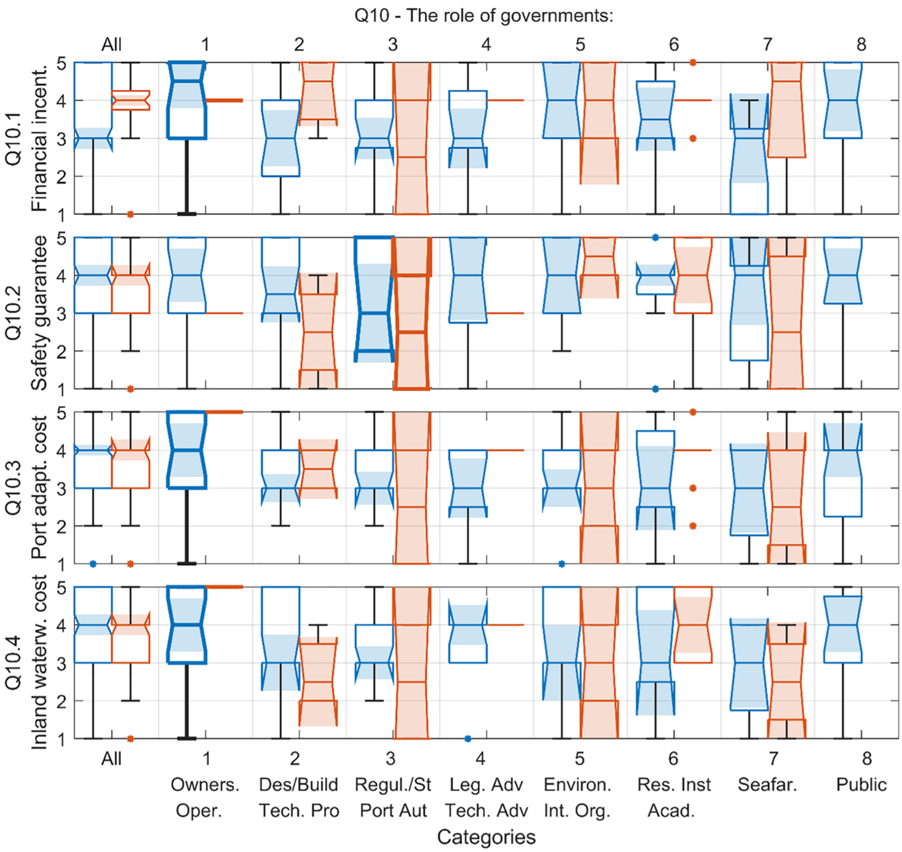


Fig. 12 Question 10 responses, using box plot, separated by categories (groups of stakeholders) and survey

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Declarations

Conflict of interest The authors declare no competing interests.

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