# Utilizing Of The Quality Function Deployment (Qfd) To Analyze The Effects Of Using Autonomous Vessels On Maritime Shipping Factors

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## ABSTRACT

***Purpose:*** *The maritime sector has seen a significant digital shift and technical advances related to the design and development of unmanned ships. Autonomous cargo ships, also known as maritime autonomous surface ships (MASS), are crewless vessels that transport either containers or bulk cargo over navigable waters with little or no human interaction. Applying third and fourth generation of full autonomous vessels will be expected to improve maritime navigation in the future.*

***Design/ Approach/ Methodology:*** *This paper attempts to give a complete view of the development of autonomous vessels by exploring the long-term effects of using unmanned or fully autonomous vessels on regulations, technologies and shipping industries that reflect the new paradigm in the shipping industry. The effects of Maritime Autonomous Surface Ship (MASS) implementation of the maritime shipping factors were analyzed based on a Quality Function Deployment (QFD) Decision model that demonstrates global maritime shipping behavior through implantation of MASS.*

***Findings:*** *The research paper results indicated the most important factors and criteria, in order of importance, in the recent trends in the development of autonomous vessels. The safety requirements in operating ports, cyber security from hacking risks, legal approval and ethical issues, cost implications, and maritime recruitment are some of the most important factors to consider, adopting such technological development for maritime shipping.*

**Key-words:**
*QFD-Port selection criteria, Multicriteria decision making, Task oriented weighting, Intelligent decision support, Autonomous ships, Maritime Autonomous Surface Ships (MASS).*

## INTRODUCTION

Recently, technology is moving forward as a step related to cyber-physical systems and autonomy as part of the "fourth generation of shipping". Given the demands of the shipping industry and the needs of shipping lines, the previous research offers several reasons for the use of autonomous vessels such as: the need for better crews' working environment onboard for mitigating the risk of future shortage of seafarers, reducing transportation costs, the global effort of reducing emissions, improving the safety in shipping, saving shipping voyage time and, shipping line and ports reputation.

On the regulatory side, IMO (2017) decided to initiate a Regulatory Scope Exercise (RSE) to determine the safe and environmentally sound operation of MASS. RSE will be complex as it will affect all activities of the maritime industry, including security and safety, interactions with ports, pilot life in response to incidents and the marine environment.

In terms of technology, by using the recent Information and Communications Technology systems (ICT), ships will be structured with advanced automatic control, communication, capabilities, and interface systems, and they will be operated remotely as land-based or offshore service centers. Unmanned or autonomous ships are currently used for aerospace, military, and scientific activities.

On the industrial side, there are various classes of remote or unmanned systems in other transportation modes such as the train, automobile and aircraft industries, as autonomous vehicles were already under development. Turning back to the maritime industry, MASS is expected to change shipbuilding, instrumentation, equipment, and port infrastructures (Ghaderi, 2019).

In this paper, the maritime shipping factors that might be affected by application of autonomous ships in global maritime shipping routes are presented. In addition, all main and sub factors that may be affected from autonomous ships application in the maritime shipping are ranked to clarify the priority of these factors in their order of importance, since the previous research in this field is lacking in detail, in exploring the long-term effect of using autonomous ships on the maritime shipping market in a scientific computational manner.

The main goal of the paper is to investigate the application of full autonomous (unmanned) ships on the maritime shipping industry, to assess the feasibility of applying this technology soon, and the seriousness of being considered as a real competitor to conventional shipping.

### Effects of Utilizing Autonomous Surface Ship on Maritime Shipping Industry Factors

#### *Regulation Effects Reviews*

Although autonomous surface vessels are a relatively new technology, they are still subject to the same international laws and regulations as any other vessel. These laws and regulations are in place to ensure the safe operation of any kind of vessel, even in seabed regions beyond the purview of any national jurisdiction.

Although some regulations for staffed vessels may be compatible and appropriate for unmanned and autonomous ships, such as some clauses of the International Code of Safety Management (ISM), they are also mandatory standards and characteristics of unmanned vessels in international withdrawals and regulations (Lang, 2020). As the maritime industry develops more advanced vessels with intelligent capabilities, the International Maritime Organization (IMO) is reviewing regulations for autonomous vessels, defined as a Regulatory Scope Exercise (RES) on autonomous vessels (Komianos, 2018).

### Effects of MASS on Shipping Industry Reviews

In the past century, the maritime industry has been dependent on the knowledge and experience of the ship's crew. Recently, artificial intelligence, automatic control, and autonomous technology to repair marine transportation have been replaced by unmanned ships. Furthermore, MASS will have effects on shipbuilding, port infrastructure, construction, and design, including services and interfaces. With the expected automation, the components of land freight will be transformed, port selection criteria, port infrastructure and cargo handling will be altered due to land logistics and the transport chain (DNV GL, 2018).

## Effects of MASS on Marine Technology Reviews

Autonomous ships feature technology like remote flying objects or autonomous vehicles that use an array of physical sensors to control autonomous operations (Lloyds Register & QinetiQ, 2020).

Ten years ago, providing internet access to crew members and travelers was difficult and expensive. In recent years, maritime has embraced different technologies for generic communications. Commercial cell phones with 3G or 4G networks can connect ships to shore up to 30 kilometers offshore. Instead of the secluded lifestyles that restrict them from accessing the maritime sector, crew members with access to the internet may have a competitive edge in developing their knowledge of ships (Burmeister et al., 2019).

The first challenge to develop technology for autonomous vessels is to demonstrate that remote and staffed systems meet the minimum safety requirements as a manned vessel system and ensure that the Shore Control Center (SCC) is provided with adequate situational awareness (Porathe et al., 2021). The implementation of MASS technology will have a range of beneficial and detrimental effects on safety. The goal is to increase the dependability of autonomous and unmanned ships' safety in comparison to conventional ships (Taufer, 2019).

## Main Factors Considered on MASS

### *Security*

As the operation of autonomous vessels becomes increasingly reliant on data technology and communication information systems both on board and on shore, the risk of cyber-attacks becomes a significant concern. Compared to conventional ships, autonomous vessels are at a greater risk of cyber-attacks due to the ability to control activities remotely. Hackers can target and compromise communication links to gain direct control of the vessel's processes.

Due to the increased reliance on software and communication systems for ship control, autonomous ships are more vulnerable to cyber threats. Additionally, new security issues will be confronted as malicious activity increases and new technologies, like the Internet of Things (ITO), are developed, making it more crucial than ever to safeguard networks, data, and systems (DNV GL, 2020).

MASS might alter how criminal, hacking, and terrorist actions are organized. The implementation of autonomous ships soon is supposed to reduce the number of casualties, including cases of hostages and kidnappings by pirates and armed robbery. On the other hand, unmanned vessel hijacking of any type of cargo is increasing along with the inherent risks that lead to criminalities such as illegal transportation of goods, containing both drugs and weapons.

### *Jobs and Training*

The maritime industry is growing rapidly, and it can be challenging to find suitable skilled seafarers to meet the demand. Additionally, the idea of autonomous ships has raised concerns about potential job loss, as artificial intelligence and autonomous systems are expected to replace some roles traditionally performed by humans.

However, this trend will be followed by the chance to start a new career and generate employment, which will require particularly highly qualified crews and operators with knowledge of technology and IT systems. The use of automation can help compensate for the anticipated worker shortage. Many offshore activities will become SCC onshore because of the remote activity and autonomous operations, allowing employees who find careers on land and offshore more appealing to join the transportation business. Additionally, because MASS is managed from land it could cause maritime accidents due to the difficulties of remaining on board for an extended period (Kim et al., 2020).

### *Safety*

Automation can improve environmental safety, as it can address human deficiencies such as fatigue, information overload, attention span, and a natural bias pertaining to the likelihood of incidents (Porathe et al., 2021). According to a United States Coast Guard (USCG) investigation, between 75 and 96 percent of maritime accidents were due to human error. Burnout, a lack of standards and maintenance, a lack of knowledge and information, and poor communication abilities were to blame for these incidents (Hinrichs et al, 2021).

Therefore, risk assessment is a useful tool for making pertinent design decisions and may be used to demonstrate the primary degree of risk. The complexity of the autonomous marine system leaves a gap in the availability of pertinent information, expertise, experience, and data. Given the multitude of uncertainties in episodic, probabilistic, and hazardous circumstances, it can be challenging to fully estimate the amount of risk to MASS as a result (Rodseth, 2021).

## Research Stages Implementation

The research is structured in the manner described as: **Step1:** Reading and analyzing literature; recent relevant literature must be reviewed in this stage. **Step 2:** Based on the results of Step 1, the three main axes to examine the effects of applying autonomous shipping should be conducted from the perspective of maritime transport stakeholders who are integrated into the global logistics chain. In this phase, questionnaires that will ask the target group a series of questions are carefully prepared. **Step 3:** Questionnaires will be received by the target group. After replies have been received, the findings of the surveys will be examined, and important information will be extracted and concluded using statistical procedures. **Step 4:** At this point, QFD will be applied to obtain results for this subject, i.e., building the QFD HOUSE and determining the relative relevance of criteria. **Step 5:** The focus at this point will be the house of quality (HOQ) of Quality Function Deployment (QFD). The model findings will be interpreted, and the research findings will be sought after. **Step 6:** Study findings will be summarized, any limitations will be discussed, and suggestions for more research will be made.

## Structured Communication Technique

The Delphi method has been used in the research paper as a popular tool in information systems research for identifying and prioritizing the critical maritime factors that will be affected by applying autonomous shipping technology for managerial and technical decision-making.

The research adopted a systematic approach to conduct a "Delphi survey method as structured communication technique, originally developed as a systematic, interactive forecasting method which relies on a panel of experts" for structuring a group communication and meeting with maritime experts and different shipping stakeholders, that was essential for collecting opinions and judgments analytically (experts' opinion depended on real data and the previous knowledge of future autonomous technology application) to estimate the correlation relation between the maritime shipping customer needs as voice of customers (VOC) and each maritime factors and port criteria that expected to be affected from full automation technology.

The research provides rigorous guidelines for the process of selecting appropriate experts for the study and gives detailed principles for questionnaire design that ensure a valid study. The research used questionnaires distributed to stakeholders in maritime shipping to obtain original data and then used some basic statistical methods (average, and quartile). To find out the sample size, the following steps were applied:

1- Designate margin of error **(E= 0.05)**

2- Determine how confident you can be; in case of E= 0.05 **(Z score = 1.96)**

3- Define population size (Maritime Shipping Stakeholders Estimation) **N = 260**

4- Define the standard of deviation (In case of uncertainty of population size) **P= 0.5**

5- Finalize sample size $n = \frac{P*(1-P)*(Z)^2/(E)^2}{1+P*(1-P)*(Z)^2/(E)^2 N}$

Given this result, the questionnaires were distributed to 225 dynamic shipping clients, yielding 155 functional answers, the survey participants involved cargo carriers, port management, freight forwarding, ship manufacturing companies and some other stakeholders, volume distribution of investigated customers shown in **Figure 1.**

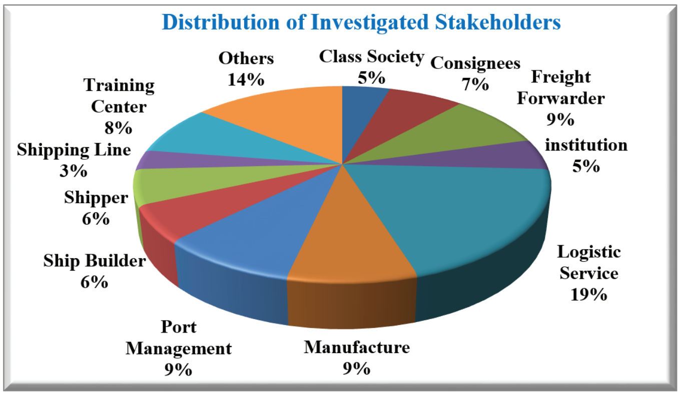


Figure 1. Volume distribution of investigated customers

## Quality Function Deployment (QFD) Concept

Quality function deployment (QFD) is a method to transform user demands into service design quality to deploy the functions forming quality, to deploy methods for achieving the design quality subsystems and component parts, and to specify elements of the manufacturing process according to the Quality Function Deployment website. QFD aids in translating the Voice of the Customer (VOC) into new goods and services that meet customer demands. In the current report, QFD will be examined to comprehend how it functions, to point out both the advantages and the disadvantages, and to talk about its potential applications (Shillito et al., 2013).

QFD is founded on gathering and translating customer requests into specifications and individual features, and then process plans, production and service necessities are developed. Figure 2 demonstrates each of the sections contained in "the House of Quality (HOQ)". Each segment contains crucial information that is unique to that section of the QFD analysis. In fact, the procedure is flexible and the order in which the HOQ is completed depends on the research team. Typically, the matrix is completed by a specifically created team who follows the logical sequence provided by the letters A to F. HOQ is a qualitative and subjective tool for translating the client's requirements into technical features (Terninko, 2017).

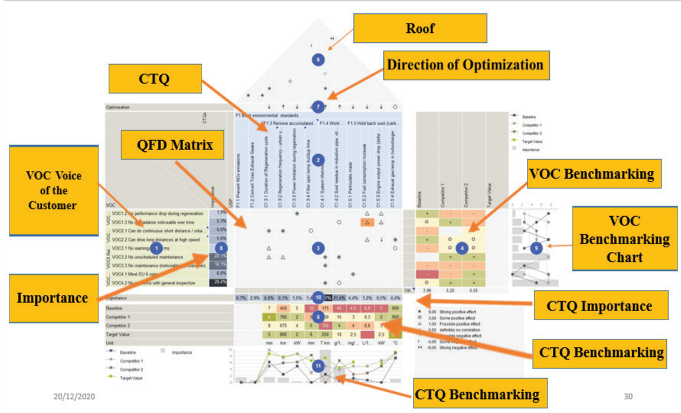


Figure 2. The House of Quality (HOQ) overview

## Results and Discussion

### Voice of Customer Importance Evaluation

The VOC defines the direction that should be taking. Collecting the VOC should occur throughout the autonomous technologies service development cycle. It should take place before the final concept is defined, while the service is in development and after the service has been launched. One of the most effective ways to gather VOC is through a customer focus group.

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Table 1: VOC Importance Evaluation

| Customer needs | | importance evaluation |
|---|---|---|
| The need for better crews | VOC 1 | 7.73 |
| Reduce transportation costs | VOC 2 | 8.15 |
| The global effort of reducing emissions | VOC 3 | 1.98 |
| Improving the safety in shipping | VOC 4 | 6.34 |
| Saving shipping voyage time | VOC 5 | 4.61 |
| Shipping line and ports reputation | VOC 6 | 4.38 |
| Improving the cyber security | VOC 7 | 7.26 |
| Delivery of cargo undamaged condition | VOC 8 | 4.52 |

Table 1 (importance evaluation) and Figure 3 show in detail the average of the voice of customers in order, it was clear that the largest average (VOC2) (8.15) and the lowest average (VOC3) (1.98).

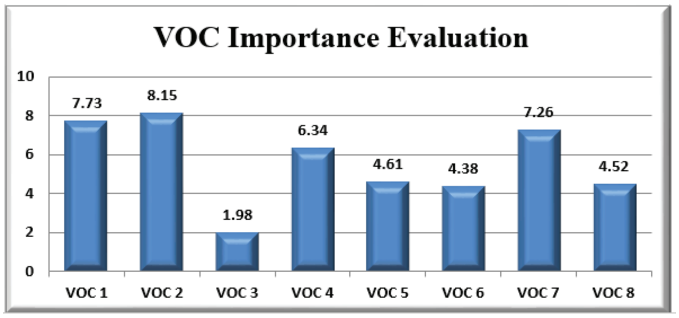


Figure 3. VOC Importance valuation

## Maritime Shipping Initial Criteria

Global and local laws and practices, as well as a distillation of prior experience, regulate the maritime transportation industries, technology, and regulations. These might lose significance with time, particularly when innovative technologies are involved. Autonomous surface shipping is one example of such innovation in the marine sector. The enormous range of design solutions clearly outstrips the capacity of prescriptive restrictions. Furthermore, prescriptive laws may become out of date if best practice is changing, such as with developing technologies or shifting paradigms surrounding ship operations. These regulations reflect the best engineering practice at the time they were enacted. To characterize the issues, make solution suggestions, and outline future research paths in risk assessment of autonomous, QFD applied to explore the effects of deploying autonomous shipping technology on marine shipping major factors.

Table 2 shows in detail the empirical finding of applying QFD on Marine shipping factors relative to the customer needs. As shown QFD table illustrates the need for better crews VOC1, improving the cyber security VOC7 and reducing transportation costs VOC2, and ranking the highest percentage; that means mentioned requirement in order have the highest important relative to the Marine shipping factors, in the time that global effort of reducing emissions VOC3 rank the lowest percentage; which means that VOC3 is the least important relative to the Marine shipping factors.

Also, Table 2 illustrates that individual criteria monitor and control system (SCC) C14, the International Regulations for Preventing Collisions at Sea C6 and Automation Safety System C16 in order rank the highest percentage, which means the mentioned criteria have the highest importance relative to customer needs. At the same time, the table reflects that individual criteria international convention of Bills of lading C8 rank the lowest percentage, which means C8 is the least important relative to customer needs.

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Table 2: Maritime Shipping Initial Criteria

| Customer Needs | Importance | Marine Shipping Factors | | | | | | | | | | | | | | | | | | | | | | QFD | % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 | C9 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | C19 | C20 | C21 | C22 | | |
| VOC 1 | 7.73 | 7.90 | 8.31 | 8.72 | 8.52 | 4.52 | 8.66 | 3.28 | 2.66 | 4.45 | 4.03 | 5.00 | 6.45 | 7.48 | 8.66 | 7.41 | 8.24 | 4.17 | 4.17 | 7.28 | 5.21 | 5.90 | 5.21 | 1053.33 | 17.53 |
| VOC 2 | 8.15 | 4.59 | 3.28 | 4.03 | 7.21 | 5.71 | 6.55 | 6.83 | 6.07 | 3.62 | 3.62 | 3.55 | 5.76 | 6.66 | 7.21 | 7.83 | 7.48 | 4.10 | 4.10 | 6.45 | 6.52 | 6.24 | 6.66 | 1010.78 | 16.82 |
| VOC 3 | 1.98 | 3.76 | 3.41 | 2.86 | 1.76 | 8.66 | 2.59 | 2.38 | 2.10 | 1.41 | 1.34 | 1.34 | 1.62 | 4.52 | 4.45 | 1.55 | 4.31 | 1.62 | 1.90 | 5.07 | 8.03 | 5.76 | 7.83 | 155.27 | 2.58 |
| VOC 4 | 6.34 | 7.76 | 8.17 | 7.97 | 8.45 | 4.24 | 8.52 | 3.97 | 3.14 | 7.07 | 6.93 | 7.00 | 7.90 | 8.24 | 8.24 | 7.41 | 8.45 | 5.69 | 5.34 | 7.83 | 7.69 | 6.93 | 7.83 | 981.83 | 16.34 |
| VOC 5 | 4.61 | 6.24 | 4.38 | 3.90 | 2.24 | 1.48 | 8.59 | 5.76 | 5.00 | 6.31 | 5.83 | 5.62 | 7.62 | 7.83 | 8.03 | 5.41 | 7.48 | 3.83 | 4.17 | 7.14 | 5.21 | 5.76 | 4.93 | 565.49 | 9.41 |
| VOC 6 | 4.38 | 5.62 | 4.66 | 6.24 | 7.00 | 7.48 | 8.59 | 5.34 | 4.72 | 3.48 | 3.83 | 3.90 | 5.28 | 6.72 | 7.41 | 7.76 | 7.76 | 3.90 | 3.97 | 7.28 | 5.76 | 5.69 | 5.90 | 561.47 | 9.34 |
| VOC 7 | 7.26 | 6.79 | 5.41 | 4.93 | 1.97 | 1.41 | 8.10 | 2.17 | 1.69 | 8.45 | 8.66 | 8.59 | 8.52 | 8.72 | 8.86 | 9.00 | 8.66 | 7.97 | 7.90 | 8.38 | 5.21 | 7.14 | 5.14 | 1043.27 | 17.36 |
| VOC 8 | 4.52 | 6.71 | 6.14 | 6.14 | 5.86 | 2.07 | 9.00 | 7.57 | 6.43 | 5.36 | 5.21 | 5.50 | 7.00 | 7.79 | 8.00 | 6.43 | 7.36 | 4.14 | 4.00 | 7.50 | 7.93 | 6.71 | 8.07 | 637.64 | 10.61 |
| QFD | | 288.2 | 257.2 | 265.4 | 263.4 | 184.8 | 356.2 | 210.8 | 179.1 | 241.5 | 237.4 | 244.9 | 301.8 | 337.4 | 356.8 | 324.6 | 351.4 | 216.3 | 215.4 | 328.0 | 281.0 | 285.5 | 282.0 | 6009.08 | 100.00 |
| % | | 4.80 | 4.28 | 4.42 | 4.38 | 3.08 | 5.93 | 3.51 | 2.98 | 4.02 | 3.95 | 4.08 | 5.02 | 5.62 | 5.94 | 5.40 | 5.85 | 3.60 | 3.58 | 5.46 | 4.68 | 4.75 | 4.69 | | |

C1 Regulatory scoping exercises on autonomous ships (RES)
C2 International Safety Management (ISM) Code
C3 Standards of Training, Certification and Watch keeping for Seafarers (STCW)
C4 International Conventions for the Safety of Life at Sea (SOLAS)
C5 International Conventions for the Prevention of Pollution from Ships (MARPOL)
C6 the International Regulations for Preventing Collisions at Sea
C7 Ship Stability Strength and Loading Principles
C8 International Convention of Bills of Lading
C9 Automatic control communications
C10 Interface systems
C11 Information connection technique
C12 Decision support system
C13 Operation system on board
C14 Monitor and control system **(SCC)**
C15 Cyber security system
C16 Automation safety system
C17 Enterprise grates connectivity
C18 Big data capability
C19 Automation operations
C20 Ship builder and manufactures
C21 Equipment and devices required
C22 Ship building structure

QFD of Marine Shipping Factors Main Indicator with Respect to Initial Criteria and Voice of Customer (VOC)

The relative relation between Marine shipping factors and the maritime stakeholder's voice as customer needs is represented graphically; Figure 4 illustrates the impact of applying autonomous shipping and technologies on this sector by applying QFD.

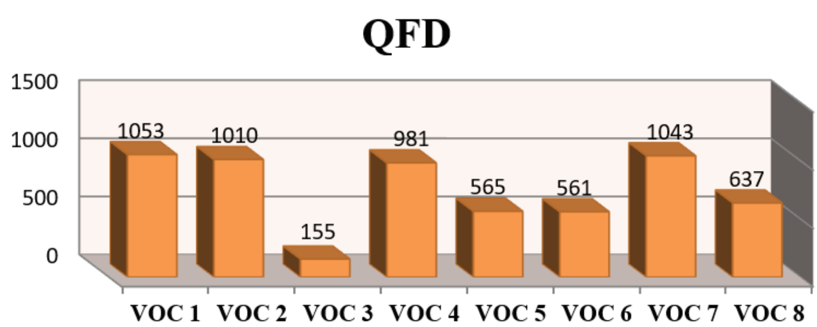


Figure 4. (A3) Marine shipping factors (QFD)

Table 2 on Marine shipping factors indicator and Figure 4 show in detail (A3) Marine shipping factors (QFD) (VOC1)(1053.33), (VOC2) (1010.78), (VOC3) (155.27), (VOC4)(981.83), (VOC5)(565.49),

(VOC6)(561.47), (VOC7)(1043.2), (VOC8)(637.64). The largest value is the need for better crews (VOC1)(1053.33) and the lowest value global effort of reducing emissions (VOC3)(155.27 ).

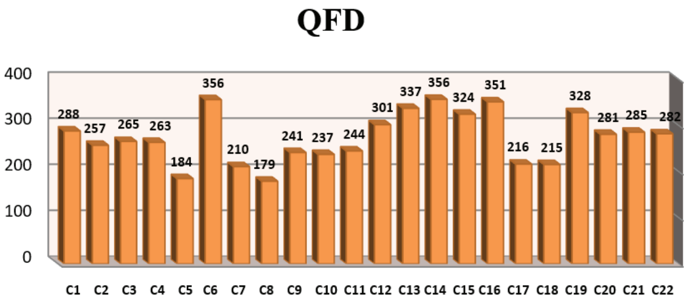


Figure 5. (A3) Marine shipping factors (QFD)

Table 2 on Marine shipping factors indicator and Figure 5 show in detail A3 Marine shipping factors (QFD) that values of variables ranged from (C1) to (C22). It is obvious that the largest value is Monitor and control system (C14) (356.8) and the lowest value is Convention of Bills of Lading (C8) (179.1).

## Marine Shipping Factors Sub Indicators

In this section, the individual marine shipping factors of autonomous shipping were divided to sub indicators (B's) groups by finding the mean averages of the individual criteria (C's) for each group, to facilitate the analysis and comparison process with the same sub indicators of regular shipping.

Table 3: Marine Shipping Factors Sub Indicators

| Customer Needs | Marine Shipping Factors | | |
|---|---|---|---|
| | B1 (C1- C8) Marine regulation | B2 (C9- C16) Marine technology | B3 (C17- C22) Marine industry |
| VOC 1 | 6.57 | 6.47 | 5.32 |
| VOC 2 | 5.53 | 5.72 | 5.68 |
| VOC 3 | 3.44 | 2.57 | 5.03 |
| VOC 4 | 6.53 | 7.66 | 6.89 |
| VOC 5 | 4.70 | 6.77 | 5.17 |
| VOC 6 | 6.21 | 5.77 | 5.41 |
| VOC 7 | 4.06 | 8.68 | 6.95 |
| VOC 8 | 6.24 | 6.58 | 6.39 |

## CONCLUSION

a- The research findings contend that global effort of reducing emissions rank the lowest percentage, which means it is the least important relative to maritime shipping factors. Consequently, the main effects of applying full autonomous shipping third and fourth generation appear obviously on some critical marine shipping factors criteria (highest average from applying QFD on the statistical result) that is illustrated in Table 2 as follows:

**(1) Monitor and control system C14**

**(2) International Regulations for Preventing Collisions at Sea C6**

b- The Effects on Marine Shipping Factors are as follows:

(1) In terms of international regulations, the weight **Regulatory scoping exercises on autonomous ships (RES) C1** in (HOQ) result reflect that RSE has been accepted into the Maritime Safety Committee (MSC) work program to determine how to address the safe and environmentally sound operation of MASS in IMO instruments. Amending all relevant conventions will take a lot of work and a long time.

(2) In terms of technology, the weight of **Monitor and control system (SCC) C14** in (HOQ) result, explained that MASS must be monitored and controlled remotely by SCC operators by an intelligent alarm system that receives necessary and critical information via satellite. The systems and sensors required for MASS and SCC must be identified and developed, and their synergistic effects must be closely reviewed.

(3) In terms of maritime shipping industry, the weight of **Shipbuilder and manufactures C20 and Shipbuilding structure C22 in result** reflects that the manufacturers and other shipping stakeholders realized that they should have a high degree of redundancy and durability to avoid failures. The MASS will have an impact on ship design, shipbuilding, port infrastructure including services and interfaces.

## Recommendations for Future Research

a- To enhance the capabilities of applying QFD as decision tools in future maritime research, the integration of other quality engineering techniques into QFD should be considered to increase its efficacy.

b- Further research needs to prove that the technology will improve competency, reduce physical exertion, and create more shore-side jobs, to prove that the application of this technology will be a real contributor to the future shipping industry.

c- The amount of autonomy should be defined in any further research as early as possible to cut costs and guarantee that business demands and safety hazards are identified and handled.

d- Further studies should demonstrate that the purpose of applying this advanced technology is to enhance the lives of people in the maritime domain and not just reduce operational fees and to reduce the expected resistance to this autonomous technology and any AI innovation.

## Recommendations for Autonomous Ships Application

a- Updating the International Maritime Organization (IMO) Convention on the International Regulations for Preventing Collisions at Sea (COLREGs) must be mentioned in the future research of applying autonomous shipping that is based on decision making tools.

b- Due to the "uncharted areas" of "unknown and unexpected risks, the future effects of maritime shipping elements and implementation barriers" that the current research has been exploring, as well as the highest level of consideration shown for all pertinent stakeholders, improved information dissemination, and information flow, the short periods should be continuously considered on the technology's viability along with the level of risk presented by the proposed system compared to the conventional shipping system and any legal restrictions.

c- As for maritime employment, the potential proliferation of unmanned ships is sparking further discussions about the future of offshore business opportunities. According to an autonomous shipping customer survey, technical innovations would provide several opportunities for seafarers to work nearer to their homes and "engage in more complex and high-level tasks" where "routine and more risky activities" are automatic. On the other hand, the maritime trade is expected to grow and this is sure to create more job opportunities.

## REFERENCES

Burmeister, H.-C. *et al.* (2014) 'Autonomous Unmanned Merchant Vessel and its Contribution towards the e-Navigation Implementation: The MUNIN Perspective', *International Journal of e-Navigation and Maritime Economy*, 1, pp. 1–13. Available at: https://doi.org/10.1016/j.enavi.2014.12.002.

DNV GL (2018) *Remote-controlled and Autonomous Ships in the Maritime Industry*.

DNV GL (2020) *The ReVolt: a new inspirational ship concept*.

Freyja, L., and T.K. (2020) 'Global Marine Technology Trends Autonomous Systems', *University of Southampton journal*.

Ghaderi, H. (2019) 'Autonomous technologies in short sea shipping: trends, feasibility and implications', *Transport Reviews*, 39(1). Available at: https://doi.org/10.1080/01441647.2018.1502834.

*Global Marine Technology Trends 2030* (2015). Available at: https://www.lr.org/en/knowledge/research-reports/global-marine-technology-trends-2030/.

IMO (2017) *Report of the maritime safety committee on its ninety-eighth session*. Geneva.

IMO (2021) *Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS)*. London.

Kim, T. and Mallam, S. (2020) 'A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations', *WMU Journal of Maritime Affairs*, 19(2), pp. 163–181. Available at: https://doi.org/10.1007/s13437-020-00203-1.

Komianos, A. (2018) 'The Autonomous Shipping Era. Operational, Regulatory, and Quality Challenges', *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 12(2), pp. 335–348. Available at: https://doi.org/10.12716/1001.12.02.15.

Lang, D. (2020) *Update on the Worldwide Supply and Demand for Seafarers*.

Porathe, T., P.J., and M.Y., (2021) 'Situation Awareness in Remote Control Centres for Unmanned Ships.', *In Proceedings of Human Factors in Ship Design & Operation, London, UK. Maritime Economics & Logistics*, pp. 116–135.

Rødseth, J. (2021) 'Towards Shipping 4.0. Proceedings of Smart Ship Technology', *Royal Institution of Naval Architects. IEEE Underwater Technology.* [Preprint].

Schröder-Hinrichs, J.-U., Hollnagel, E. and Baldauf, M. (2012) 'From Titanic to Costa Concordia—a century of lessons not learned', *WMU Journal of Maritime Affairs*, 11(2), pp. 151–167. Available at: https://doi.org/10.1007/s13437-012-0032-3.

Taufer, C. and, K.A., and B. (2019) 'A Protein Structure Prediction Supercomputer" Based on Public-Resource Computing', in *Workshop on High Performance Computational Biology (HiCOMB'05). Maritime Economics & Logistics*, pp. 243–257.

Terninko, J. (2018) *Step-by-Step QFD: Customer-Driven Product Design, Second Edition*, *Step-by-Step QFD: Customer-Driven Product Design, Second Edition*. Available at: https://doi.org/10.4324/9780203738337.