Title

Autonomous ships and sustainability.

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1.Title

Autonomous ships and sustainability.

2. Table of content.

3. Acknowledgements.

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4. Abstract

This literature review aims to analyze and comprehend the MASS (Maritime Autonomous Surface Ships) and if there is a relationship with sustainability, what characteristics and elements can be considered more sustainable against the manned ships, understand what are the most important forces that are moving the development of this kind of ship, and what would be the possible economic benefits of the implementation of this technology in the maritime industry.

5. Keywords.

Maritime Autonomous Surface Ships MASS, sustainability, CO_2, fuel efficiency, literature review, AI, autonomous system.

6. Abbreviations:

AI: Artificial Intelligence.

AGI: Artificial general intelligence.

BDA: Big Data analytics.

CO_2: Carbon dioxide.

DL: Deep learning.

HFO: Heavy fuel oil.

IMO: International Maritime Organization / (French: Organisation maritime internationale).

IoT: Internet of things.

LNG: Liquefied natural gas.

MASS: Maritime Autonomous Surface Ships.

ML: Machine learning.

OA: Ocean acidification.

OPEX: Operating expenses or expenditures.

PRISMA: The Preferred Reporting Items for Systematic reviews and Meta-Analyzes.

RES: Renewable energy sources.

ROC: Remote Operation Centre.

STCW: The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers.

USV: Unmanned surface vehicle.

7. List of tables and figures:

8. Introduction:

Introduction to MASS and general concepts.

What is autonomous surface ships (MASS)?

Autonomy starts with a navigation, guidance, and control system together with for a dynamic unmanned vessel and algorithm (Fung, 2019). The main objective of the technology MASS is to develop unmanned navigation through an artificial intelligence, and a certain point develop a completely autonomous vessel that can operate completely by itself, analyze information, take decisions to avoid hazards, and at the same time be more efficient than the manned traditional ships.

What is sustainability?

The concept of sustainability was originally coined in forestry, where it means never harvesting more than what the forest yields in new growth (Kuhlman, 2010). Sustainability can be considered as the capacity to improve and conserve the material or conditions for a long term, for example a industry that cares about the environment and replenished the resources consumed in the operations.

Why is important have a sustainable business strategy in the maritime industry?

The maritime industry affects in multiple ways the environment such as the emissions and their effect in the atmosphere, this eventually can increase global warming and in the long term this can permanently affect the living creatures in earth. For the same reason the IMO (International Maritime Organization) has taken actions to reduce the number of emissions in the ships, these mandatory measures will force the maritime firms to become more ecologically sustainable and in order to keep the vessels operating the firms will have to adopt new technologies to follow the mandatory restrictions.

Having a ecological sustainable business model will help future generations to have a better quality of life, reduce the negative effects in the ecosystem and allows the firms to follow the regulations and keep their operations.

9

Research question

Can the MASS be considered more sustainable and what are the possible benefits of the uses of MASS over traditional vessels?

9.1

Hypothesis and Justification of the study.

IMO limited marine fuel sulphur content in both Sulphur Emission Control Areas (SECAs) and Nitrogen Oxide Emission Control Areas (NECAs) to 0.1% (wt. %) by 2015, and to 0.5% globally by 2020 (Chun, 2019). The IMO created new restrictions that will force the maritime industries to reduce the level of emissions in their ships, but why and what are the possible benefits of doing that? And one of the most popular topics nowadays in the maritime industry is the MASS, and the firms that are developing this technology promote it as zero emissions and eco-friendly, that made me question why MASS is becoming more and more relevant, and how exactly the technology can transform the maritime industry, and the possible linkages with sustainability.

Can this type of ship be considered sustainable? What are the benefits over the traditional vessels? Why is important to have a sustainable maritime industry? How exactly this technology can contribute to this? In general this are the most relevant reason behind this study.

Why is important to have a sustainable industry?

It is an urgent task to reduce the dependence of fossil fuel by vigorously extending the using of renewable energy, and it is of great importance to the future of all human beings. (Huang,2021). The maritime vessels use fossil fuels such as Heavy fuel oil (HFO) that is one of the most common fuels in the industry, the use of this kind of energy is not sustainable in the long term because is a limited resource and affects the environment, these fossil fuels produce pollution and huge amounts of CO_2 (Carbon dioxide).

The global air temperature has continuously increased, resulting in a more dangerous world (Chen, 2023), there are multiple theories that speculate about the impact of the C02 in the environment, one of the most popular and accepted theories is the relationship between global warming and the levels of C02 in the atmosphere. The CO_2 can affect the environment in multiple ways, such as the C02 can generate and "hole" in the atmosphere and that hole will increase the radiation in the earth, and then there will be multiple negatives effects such as floods, increasing temperatures, radiation, acid rain, alterations in the ecosystems, etc., affecting all the living forms in the earth.

It is important to consider what will happen in the upcoming years if the levels of C02 keep increasing, and find alternatives to substitute gradually the use of fossil fuels, in the short term the effects can be imperceptible but the future of the next generation can be compromised if nothing changes. And one of the alternatives that can facilitate the transition to reduce the emissions is the MASS technology and systems, the combination of them with alternative fuels can transform the maritime shipping into a completely sustainable and eco-friendly industry.

The autonomous surface ships (MASS) and the possible benefits of using them in the maritime industry to create a sustainable industry.

What can be considered an autonomous surface ships (MASS)?

Autonomy starts with a navigation, guidance, and control system together with for a dynamic unmanned vessel and algorithm (Fung, 2019). The main objective of the technology MASS is to develop unmanned navigation through an artificial intelligence, and a certain point develop a completely autonomous vessel that can operate completely by itself, analyze information, take decisions to avoid hazards, and at the same time be more efficient than the manned traditional ships.

In order to have an AI (artificial intelligence) that can replace manned operations, the ship will require multiple sensors to analyze the information and take multiple decisions in base of that, such as navigation systems, engineering functions, and communication systems. This will also open the alternative to use the systems and operate the ship remotely.

Navigation systems: Such as a radar, visual cameras, sonar, etc. With that information provided the AI will be able to avoid collisions, trace a trajectory, manoeuvre, detect the optimal route, among other things.

Engine monitor: Systems that allow the analysis of the engine and its functions such as: full consumption, speed, temperature, emissions, etc.

Communication systems: Such as harbour communication, identification, emergency and safe communication, etc.

The combinations of all of these systems aims to improve the ships operations by the uses of AI and semi-automatic systems making the ships more sustainable, reduce the crew and the operation cost, and reduce the emissions following the IMO regulations.

9.2 Are autonomous ships sustainable?

In theory, if the ship have less crew then it will be more sustainable, it will have more space and produce less waste, at the same time the payload optimization will increase the efficiency in the operations and consume less fuel, this can be considered more sustainable and more efficient than the old ship models, then it makes sense develop a completely autonomous vessel that can operate with minimal intervention of humans. Also, the majority of the MASS models that are under development aims to be zero emissions so subsequently they will be sustainable, these two facts can transform the industry into a more eco-friendly business.

9.3 What are the possible benefits of using MASS technology?

One of the most obvious benefits of having an unmanned MASS ship is reducing the crew aboard, this reduction of space required for the crew and cost in salaries, have multiple benefits such as a reduction of the weight required for the cabins, restaurants, toilets, etc. Also reducing the necessities for food containers, refrigeration, and the space that all of these elements will take in the ship and can be replaced for extra containers or fuel tanks. By decreasing the number of people on the ship is also possible to decrease the cost in the operations of the ship operations and use the space of the ship more efficiently.

The AI will also avoid human errors, there are multiple risks and errors that the humans can make during the ship operations such as a mutiny, miss calculations, negligence, bad practices such as corruption. In overall the safety of the operations will be significantly improved, the perception and analysis of big data of the AI to avoid collisions and calculate the optimal route, this give it the possibility to outsmart the human reasoning, by making faster and more efficient decisions than the humans.

9.4 What are the possible linkages between a sustainable strategy and MASS?

My hypothesis is that there are multiple linkages between sustainability and MASS, for example, the uses of an AI and autonomous systems can reduce the percentage of crew required to operate the vessel and at the same time reduce the space required for them allowing the vessel to carry more containers or other stuff. This reduction of crew aboard will reduce the waste generated by them.

Another link that I can perceive is the optimization of fuel and more precise and efficient routes, the calculations make by an AI will be faster and more exact than the calculations make by normal humans, it will also be cheaper substitute an expertise in the subject by a computer, this reductions will allow the firms to use better their resources and follow the IMO regulations, by doing that they will be more sustainable than the old manned ship.

9.5 How can MASS improve the ship operations?

The autonomous systems can be used to decrease the human operations or use their time more efficient, certain operations can be automatized or semiautomated, opening the possibility to be controlled by an AI or simple algorithms that can facilitate the operations, for example, to control and regulate the temperature of a LNG tank, make better maneuvers or calculate more efficient routes. The algorithm that constitute the AI can analyze more information than the humans, and in base on that information take better decisions, evolve constantly (machine learning), make a faster and more efficient decision, avoiding human errors. The combination of multiple technologies in the MASS can create a more efficient ship that will not really on crew onboard, some of the technologies that can be integrated are Big Data Analytics, AI, advanced sensors, and machine learning . This can allow the AI to be more efficient than a human expert, and then the operations will be more efficient and sustainable.

Main technologies that can use to make more sustainable ships.

Artificial general intelligence (AGI) is the ability of an algorithm to achieve human intelligence in a multitude of tasks. (Feynman, R., 2022). An algorithm can analyze more information than humans and take faster and better decisions, AI systems can solve multiple tasks or specific problems such as container planning and organization, route calculations, fuel and emission optimization, the perception of the multiple sensors allows the AI to be at multiple places at the same time and manager all the board systems in one instant, with that information and the capabilities to analyze more information than humans, in combination with the abilities to make calculations impossible to humans, it is reasonable consider it a better option than manned ships.

Machine learning.

ML is a scientific field that can provide learning from real measurement data based on the historical data of a system (Wilson, 1999). The possibilities to generate and algorithms that can emulate the human intelligence and gradually improve its accuracy in specific tasks is an option to reduce fuel consumption in the maritime industry, the combination of an AI and machine learning can be used to optimize the ship fuel consumption and at the same time reduce the emissions, by feeding the algorithm with the data generated from the ships it will find a solution to be more efficient.

The AI with the integration of sensors can perceive and analyze more information than the humans, all of this information can be used to control completely the operations of the ship, such as collision avoidance, route planning and optimization, fuel and emission optimization, board systems, trajectory, communications, etc. With all of these systems, it will allow the remote operation from the ship, this level of autonomy will reduce the number of personnel required to operate the ship and at the same time allows the navigation of multiple ships in one location, and reduce significantly the operation cost and space required in the ship for the crew, taking all of these possibilities in consideration have make consider the MASS are a more sustainable and efficient alternative than the traditional ships.

9.6

Importance of Sustainability.

One of the main concerns nowadays worldwide is the environment and the impact that emissions are having in the earth, petroleum and oil fuels are fuels normally used in the maritime industry and they have a negative effect in the atmosphere, marine ecosystem, air quality, and human welfare, the emissions generated will cause irreversible problems for humanity in the future, for this and other reasons the International Maritime Organization (IMO) has adopted mandatory measures to reduce the emissions. Considering all of these factors this study will analyze the possibilities and benefits of replacing the traditional ships with autonomous vessels and how the maritime autonomous surface ships (MASS) can be considered or not a more sustainable solution.

Impact of emissions maritime industry.

Shipping is an activity responsible for a range of different pressures affecting the marine environment, air quality and human welfare. (Ytreberg, 2021). The emissions are affecting the world in multiple ways, contributing to the climate change, contaminating the maritime eco-system, increasing the alkalinity in the water, and generating a negative impact in human welfare.

Climate change also has noticeable negative impacts on other parts of the planet, like changes in ecosystems and desertification, rise in sea level, flooding, and drought (Hisano et al., 2018; Ouhamdouch et al., 2019), there are multiple theories and hypothesis about the relationship of emissions and climate change, but there is something indisputable and there is the fact that the CO2 emissions have multiple negative impacts worldwide, taking in consideration the multiple problems that are generated with he climate change such as droughts, floods, massive changes in the environment, etc, it’s reasonable try to find a solution to mitigate these problems.

The oceans comprise large natural carbon sinks, having already absorbed around 26% of the anthropogenic (excess) CO2 emissions (Figuerola et al., 2021). A huge part of the emissions are absorbed in the ocean this have multiple effects in the seawater such as the fluctuations in the pH, levels of alkalinity this is called ocean acidification (OA), this effect have a negative impact in some maritime species, at the same time the change in the chemistry in the ocean is generating a change in the ecosystems where some plants and animals benefits of it and in contrast other species are damaged by them, causing this an irreversible change in the ecosystem.

MASS and sustainability.

The three-pillar conception of (social, economic and environmental) sustainability, commonly represented by three intersecting circles with overall sustainability at the centre, has become ubiquitous (Purvis, 2019). In order to implement a sustainable strategy there are multiple factors to take in consideration, in this conception by taking in consideration the social, economic and environmental as equal it will be possible to determine the true benefits and possibilities of implement a new technology.

There are multiple things that will persuade the firms to spend money in a technology only for the sake of being eco-friendly, but if the 3 pillars work together it will make it a reasonable decision, what will happen if the social pressure demands the firms to use sustainable materials and reduce their waste, or if the government force the companies to follow strict restrictions about waste, emission, pollution, etc.

By considering sustainability not only a reduction in emissions but also taking in consideration the three dimensions: environmental, economic, and social, it will make it possible to have a realistic point of view and not an idealistic conception that will be never implemented, where the cost of doing it will make the company go to bankrupt. By considering this a sustainability it will be possible to develop a strategy that can be implemented and see the true benefits and reasons behind the implementation of a new technology that can resolve the necessity.

IMO normative.

IMO adopted the first set of international mandatory measures to improve ships' energy efficiency on 15 July 2011 (IMO, 2023), the International Maritime Organization "IMO" is a specialized agency from the United Nations, and the main regulator and enforcer of regulating shipping worldwide. Since the year 2011 the organization has stipulated obligatory standards to reduce the emissions and mitigate the impact that they have in the environment, forcing all the shipping industry worldwide to renew their ship fleet or find a way to reduce the pollution that their ships are generating.

The short-term measure is aimed at meeting the target set in the IMO Initial GHG Strategy – to reduce carbon intensity of all ships by 40% by 2030, compared to 2008. These will be mandatory measures under MARPOL Annex VI (IMO, 2023). By considering this a mandatory law to all shipping firms worldwide, in order to reduce the air emissions from ships a huge investment will be necessary and at the same time it will cause a change in the industry, forcing the companies to develop a technology that can reduce the emission, renew the fleets, or go out of business.

By taking in consideration the IMO regulations and the cost that it will represent to the maritime companies, it generates a favorable scenario that will improve the interest to the development of new technology, the adoption and implementation of different ideas, and in general increase the interest for the MASS, this scenario will reduce drastically the problems that any new technology will have to face in order to be adopted, and also it is causing positive speculation about the role that they will have in the future in the industry.

The environmental policy is causing changes in the maritime industry, opening the industry to new fuels, technologies and methods to reduce the emission, and a demand for more eco-friendly solutions, one of the options is the automatization of ships, with these facts there is a possibility to develop, adopt and improve MASS, it is making it a reality and a sustainable alternative that can disrupt the maritime shipping industry forever.

With a review of articles related to the topics, it will be possible to determine the true potential and applications of the technologies developed until the actual year and the possibilities in the future. Not only see the benefits in the environment but also analyze the true economic benefits and social acceptance of the new technology, and have a perspective if the industry (ship owners and investors) are really committed to investing in the technology and changing their fleets for MASS.

10. Research Method:

The literature review has multiple purposes and benefits such as: provide evidence in the selected field, analyze and compare data, and have the capacity to engender new ideas and directions for a particular field (Snyder, 2019).

Using this method, in conjunction with the database Oria (the USN Library online) that contains links to some of the most relevant literature databases, books, magazines, etc., will provide to the reader a general understanding of the main ideas and concepts, the relevance of the technology, the limitations and the possible linkages with sustainability, and at the same time generate new ideas, for all of these reasons the literature review have been chosen as the methodology to conduct this research.

Study method:

Why use a systematic literature review?

To analyze, and determine if the MASS can be considered sustainable or not, I will use a systematic literature review, using only academic articles from the website Oria that will fill the criteria **(1)**, it will be possible to have a general understanding of the possibilities and limitations of the technology.

A literature review has multiple benefits: A) "by reviewing and reporting on all prior literature, weaknesses and shortcomings of prior literature will become more apparent." (Denney, 2013), B) Advance understanding in a field of research (Ader, 2008), C) Is accepted to be a research methodology in its own right (Boland, Cherry, & Dickson, 2017). For all of these reasons, I consider it a good approach to resolve the research question and will provide a summary for further studies.

Approach:

The methods and results of systematic reviews should be reported in sufficient detail to allow users to assess the trustworthiness and applicability of the review findings (BMJ, 2021), in order to understand completely the uses of this new technology (MASS) and the linkages with sustainability, it will be important to synthesize findings of previous studies and then it will be possible to generate new ideas.

By following the guideline, recommendations, and procedures (2) from PRISMA (The Preferred Reporting Items for Systematic Reviews and Meta-Analyzes) it will be possible to resolve the research question and at the same time provide a database for future research in the field.

To have a clear structure the literature review will use the following flow table (Snelson, 2016) that was used in his thesis.

Stage 1 Pres-Search	Identify and test keywords. Identify Database.

Stage 2 Search	Search Databases Import citations into bibliographic management software.
Stage 3 Data Cleaning	Remove duplicates. Screen and select articles.
Stage 4 Analysis	Qualitative content analysis. Round 1: review and tagging. Round 2: review and coding.

(Table 1) Review process.

Search Strategy:

Pres-search.

The database that will be used in the pre-search and searching stage will be only academic articles from the website Oria, that fit the criteria: (table 2) Are written in English, have open access, only peer-reviewed articles, articles written after the year 2012, and articles that have linkages between MASS and sustainability. To make it easier for the readers, I decided to only use one database in this case Oria, basically because is the main recommendation by the institution where I am studying (USN The University of South-Eastern Norway/Universitetet i Sørøst-Norge). Oria has access to multiple academic websites, journals, books, articles, magazines etc, this will make possible have enough data to answer the research question, and another benefit of using only one database is that it will be possible to use the same keywords and criteria to see the evolution in the technology in the upcoming years.

	Inclusion.
1	Open access.
2	Articles that are written in English.
3	Peer-reviewed.
4	Wroten in the year 2012 or after.
5	Full Text Online

(Table 2) Exclusion criteria.

In order to determine the keywords for the pre-research, the process used the most common names and acronyms related to the maritime technology; MASS, Maritime Autonomous Surface Ships.

TITLE-ABS-KEY	Number of articles
Mass	841, 932
Maritime Autonomous Surface Ships	366

Autonomous AND Cargo	351
Autonomous AND Ship	1,191
Unmanned ships	620
Sustainability	255, 263
Sustainability And Maritime Industry	2, 707

(Table 3) Keywords.

With this population generated in the pre-research, it will be possible to have a general idea and perspective of what are the current status of the technology, the possibilities and if the MASS are considered sustainable or not. But in order to facilitate the extraction of information the sample will be reduced in the searching phase, by making different combinations of keywords and analysing the results of these combinations it will be visible the linkages between sustainability and the autonomous ships.

Searching phase:

	Searching Criteria. TITLE-ABS-KEY	Number of articles
Step 1	(Mass) AND (Sustainability).	8, 455
Step 2	(Ship or Mass) AND (Environment)	480
Step 3	(Ship or Mass) AND (Environment) AND (Maritime)	290
Step 4	Subjective analysis of the title and description of the articles.	40
Step 5	Quality approach to choose the most relevant articles.	11

(Table 4) Searching phase results.

During the first step using the keyword ((MASS) AND (Environment)) the engine suggested 8,455, the majority of the articles were not related to the maritime industry, for the same reason I changed the criteria to ((Ship or Mass) AND (Environment)) It was possible to reduce the size of the sample after by adding that keyword, and finally during the step 3 by adding the keyword “maritime” the sample was reduced to only 290, the reason behind choosing these keywords was to find the possible linkages between sustainability and MASS, with this small sample it was possible to read one by one the title of articles and determine what will be the most related to the study, and then choose the most relevant articles from the sample.

Quality Appraisal.

In order to determine the quality and relevance of the articles during the step 5, I make a small questionary to determine if they are related to autonomous technology in the maritime industry and if there is a kind of link with sustainability. (Chart quality)

Make 10 questions

1 The text is related to autonomous ships?

2 Does the text have a link to sustainability?

3 Does the text compare the difference between traditional ships and autonomous vessels?

4 Does the text show the current implementations of MASS in the maritime industry?

5 Does the text have relevant information?

6 Are the aims of the research easy to understand?

7 The research method and sample can be consider reliable?

8 Are findings clearly stated?

9 Do I accept their findings as true?

10 Is it possible to use the findings in the research?

And subsequently, to determine and categorize the relevance of every article on base on this, if they are related or not to the research question, every answer will represent a 10% in the scale of 0% to 100%. With only 3 possible answers to every question yes, no, or limited. If the answer is yes then it will represent 10%, if the answer is negative 0%, and if the answer is limited it will represent only 5%.

Stage 2:

Searching Phase.

After choosing the most interesting articles generated in the step 4, it was possible to reduce the sample to only 17 articles, and then it was possible to make a quality appreciation of them and read carefully all the articles in order to choose the most relevant and related articles, in the following table are the articles chosen in the step 5:

No	Title	Data Type	Year
1	Costs and benefits of autonomous shipping—a	Literature review.	2021

	literature review.		
2	A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations.	Delphi-AHP.	2020
3	A study on identification of development status of MASS technologies and directions of improvement	Case study.	2020
4	Creating value through autonomous shipping: an ecosystem perspective	Literature review.	2022
5	From captain to button-presser: Operators' perspectives on navigating highly automated ferries	Interview, Mixed-method.	2022
6	The environmental impacts of the "Maritime autonomous surface ships" (MASS).	Case study.	2020

7	Ammonia as a potential marine fuel: A review	Case Study.	2022
8	Intelligent Autonomous Ship Navigation using Multi-Sensor Modalities	Case study.	2019
9	Deep Learning for Safe Autonomous Driving: Current Challenges and Future Directions.	Caste study.	2021
10	A systematic review of human-AI interaction in autonomous ship systems.	Literature review.	2022
11	Machine learning approach to ship fuel consumption: A case of container vessel.	Case study.	2020

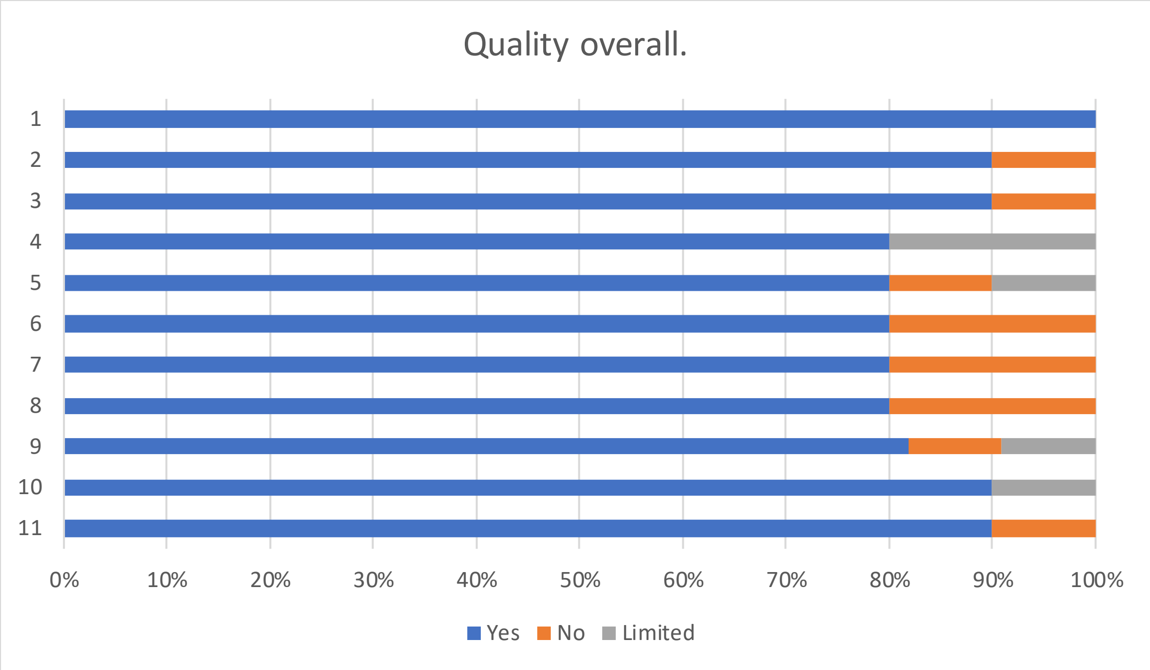
(Table 5) Selected literature.

Chart quality

No		**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**	**Q7**	**Q8**	**Q9**	**Q10**
1	Costs and benefits of autonomous shipping—a literature review.	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

2	A Delphi-AHP study on STCW leadership competence in the age of autonomous maritime operations.	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
3	A study on identification of development status of MASS technologies and directions of improvement	Y	Y	Y	Y	Y	Y	Y	Y	N	Y
4	Creating value through autonomous shipping: an ecosystem perspective	Y	Y	L	Y	Y	Y	Y	Y	L	Y
5	From captain to button-presser: Operators' perspectives on navigating highly automated ferries	Y	N	Y	Y	Y	Y	Y	L	Y	Y
6	The environmental impacts of the “Maritime autonomous surface ships” (MASS).	Y	Y	L	Y	Y	Y	Y	L	Y	Y
7	Ammonia as a potential marine fuel: A review	N	Y	Y	N	Y	Y	Y	Y	Y	Y
8	Intelligent Autonomous Ship Navigation using Multi-Sensor Modalities.	Y	N	Y	Y	Y	Y	Y	Y	Y	Y
9	Deep Learning for Safe Autonomous Driving: Current Challenges and Future Directions.	N	Y	Y	Y	Y	Y	L	Y	Y	Y
10	A systematic review of human-AI interaction in autonomous ship systems.	Y	Y	Y	Y	Y	Y	Y	Y	Y	L
11	Machine learning approach to ship fuel consumption: A case of container vessel.	Y	Y	Y	Y	Y	N	Y	Y	Y	Y
Y= Yes N=No L=Limited information.											

(Table 6) Chart Quality**.**



(Figure number 1) Quality overall.

Figure 1 depicts the relevance of the articles according to the criteria in the quality appraisal, if the fit or not with the quality questions, the articles were some statements are not completely clear to answer the question are marked as limited.

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11. Literature review:

Reviewed literature.

Article	Country	Purpose	Design	Outcomes
(Ziajka- & Montewka, 2021)	Poland.	Analise the possible benefits of using autonomous ships and the challenges.	Exploratory.	The paper speculates about the cost of autonomous ships and the possible benefits in the operations.
Kim, & Mallam, S. (2020)	Germany.	The role that the autonomous ships will have in the future and the perspective of the operation staff.	Single case study.	The perspective that the management and operations staff have about the MASS, and the possible competence and role that they will have in the future.
Chae, Kim, M., & Kim, H.-J. (2020)	Korea.	Determine the technological development and current status of autonomous systems in the maritime industry.	Exploratory.	The article allocate the current implementation of autonomous systems, limitations, issues and benefits.
Tsvetkova, & Hellström, M. (2022)	United Kingdom.	Recognize the value and the economic effect that autonomous systems are having in the industry.	Exploratory.	The outcomes of the paper highlight the benefits of MASS over manned operations, and the possible disruption in the industry that the technology will have in the upcoming years.

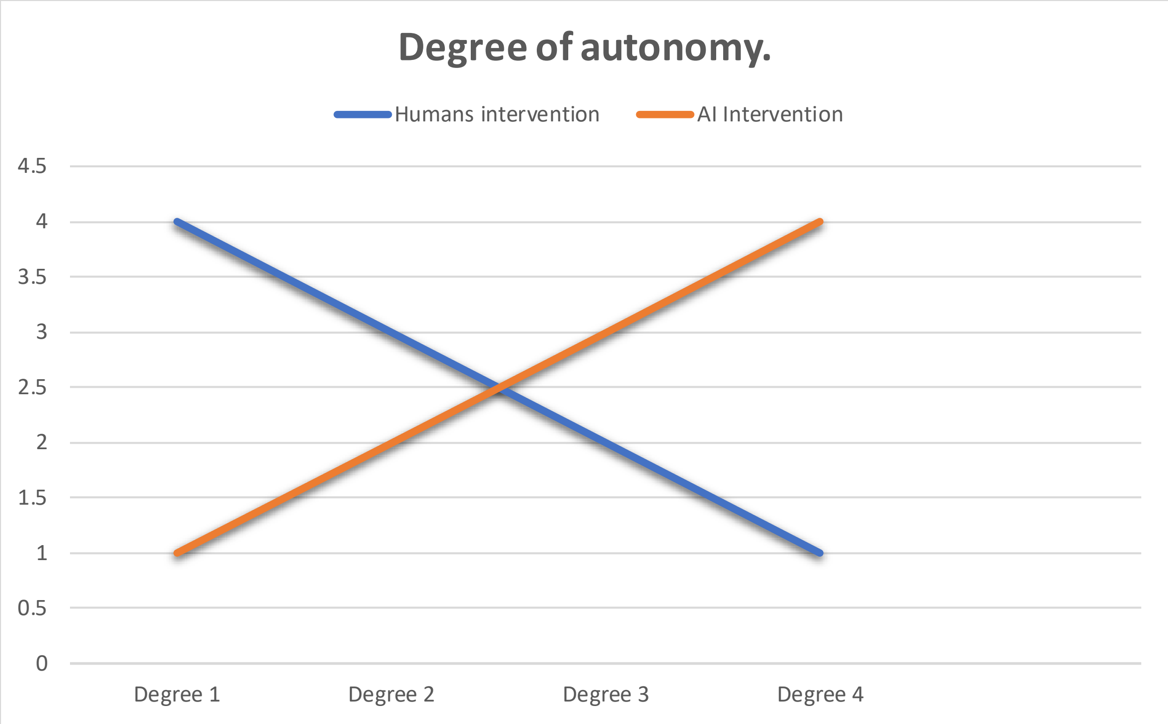
Veitch, Christensen, K. A., Log, M., Valestrand, E. T., Lundheim, S. H., Nesse, M., Alsos, O. A., & Steinert, M. (2022)	Norway.	Analyze what is the seafarer's role and perspective in automated navigation, benefits and drawbacks.	Single case study.	The study highlight some of the benefits and drawback of autonomous technology, the perception of the operation workers about the technology and their role in AI systems.
Zanella. (2020)	Brazil.	Determine what are advantages and disadvantages of the autonomous ships and the impact that they will have in the environment.	Exploratory.	The results of the paper analyze about how autonomous vessels can improve the ship operations and the possible benefits to the environment.
Veitch, & Andreas Alsos, O. (2022)	Netherlands.	The interaction in human-AI interaction on MASS.	Exploratory.	The article analyzes what is the role of the humans in the autonomous vessels. Description of the technology and the main obstacles.
Machaj K, Kupeck J, Malecha Z, Morawski A.W, Skrzypkiewicz M, Stanclick Machaj, K., Kupecki, J., Malecha, Z., Morawski, A.,	Poland.	The uses of ammonia in the maritime industry.	Single case study.	The article studies the possibilities of using ammonia, and describes what are its benefits and cons in comparison with other fuels.
Wright, R. Glenn.	Poland.	AI in the maritime industry and the uses of sensors to self navigation.	Single case study.	Uses of AI in the navigation systems, what can be considered autonomous, and the uses of sensors to optimize the operations.
Khan Muhammad;Amin Ullah;Jaime Lloret;Javier Del	The United States of America.	The implementations AI in the car industry, the	Single case study.	The article explains the actual status of the AI in the car industry, the uses of deep learning, safety standards

Ser;Victor Hugo C. de Albuquerque.		actual status of the technology, and future challenges.		and what are some of the future challenges/
Tayfun Uyanık, Çağlar Karatuğ, Yasin Arslanoğlu	Turkey.	Optimization in navigation through the uses of AI, machine learning, and probability models.	Single case study.	The article explains how it is possible to reduce the fuel consumption through the uses of mathematic algorithms models, and the benefits of machine learning in the AI systems.

(Table, 7) Highlights of the reviewed literature.

12. Findings:

First is important to identify what can be considered an autonomous ship, there are multiple levels of autonomy, "In the year 2017 at the 98th Session of the MSC, the IMO defined the degrees of autonomy identified for the scoping exercise" (Zanella, 2020), it goes from degree 1 to degree 4, where the level of autonomy increase in the relationship of the decisions that the AI can take by itself and decrease according to the level of human intervention in the decision making, while in contrast a degree 1 is a ship where the seafarers operate the majority of the functions and only a few of them are automated. "(Degree One); a remotely controlled ship with seafarers on board, A fully automated ship is considered degree 4, (Degree Two); a remotely controlled ship without seafarers on board (Degree Three); and a fully autonomous ship (Degree Four)" (IMO, 2023). Following these different levels of automatization the capabilities and functionality of the ship will be drastically affected, in the next chart (Degree of autonomy chart 1) is a representation of the IMO classification of MASS ships in a scale of 1 to 4 where 1 represents a low level of intervention while four 4 represent a high level of intervention, this aspect needs to be considered in order to comprehend and determine the true potential of the MASS.



(Figure 2)

Degree of autonomy, based in IMO classification of MASS.

12.1 Why MASS are more sustainable?

Possible benefits for the environment.

The advantages of using autonomous ships, concerning the protection and preservation of the marine environment, are concentrated in two main areas: the reduction of pollution by vessels; and the reduction of human error (Zanella, 2020), firstly the autonomous systems are reducing the number of crew aboard and at the same time they waste generated for the humans is reduced, all the waste related to human activities such as garbage, human waste, etc, and at the same time a reduction in the resources required to keep the crew abroad such as: the heating system, air ventilation, fuel consumption (reduction in the weight of the ship), etc.

The introduction of MASS into the operation is mainly related to the assessment of the economic benefits of them, simultaneously ensuring the proper level of safety (Ziajka & Montewka, 2021) With the reduction of crew abroad, there will be also a reduction in all the waste generated of human activities, this includes the plastic waste and debris produced, also there will be a reduction in resources consumed during the operations, and finally atmospheric pollution, the MASS with more modern technology and more efficient systems will reduce drastically the pollution generated by the ships. This will also allow the ship to have a more efficient design and carry more cargo, fuel, solar panels, batteries, etc., this will allow the firms to be more efficient in their operations, improve their profits and follow the emissions restrictions.

12.1.2 Why MASS can be more efficient?

From the economic perspective, there are multiple benefits over manned ships that can reduce drastically the operation cost, “These include reduced operational, voyage and crew costs; increased safety of operations; and earning potential from new vessel designs”, (Tsvetkova, & Hellström, M., 2022), the combination of this benefits are making possible the development and implementation of this systems in the maritime industry, however, this is only a speculation as is recognized in the previous article, some of the reasons are that the technology is under development and the economic data from the companies is restricted.

Crew salaries can account for up to 45% of the total operating costs of a Panamax bulk carrier (Kretschmann et al. 2017), takin in consideration this it will be a huge save for the firms the implementation of AI systems and the use of full autonomous ships over the traditional vessels. These savings will be exponentially increase in the big firms year after year, at it will exponentially increase in relationship with the number of vessels, the possibility to improve the profits and be more efficient are facts to take in consideration.

The reduction of the OPEX (operating cost) that are all the operation cost such as fuel, cargo handling, port cost, etc, are expected to be reduced drastically in the long term with the autonomous systems, while on the other hand and CAPEX (capital cost) the cost to buy the ship is more expensive than the traditional vessels, the saves that can be generated during the operating time of the ship eventually will result in a bigger saving than buy a new manned ship, taking in consideration that the salaries and the fuel represent around 80% of the operating cost according to the case study in the article “Costs and Benefits of Autonomous Shipping—A Literature Review, page 7” (Poznańska, 2020) of a bulk cargo.

The autonomous vessels with the absence of crew aboard can use more efficiently the space in the ship, by using all the space related to the living quarters like the food installations, and human facilities, this will allow the ship designs to increase the cargo capacity and the possibilities to increase slightly the speed also reduce the safety standards. All of these facts combined can be considered an advantage that the MASS ships have over the manned ships, and in contrast, the main disadvantage is that all the repair and maintenance will need to be done in the docs.

12.1.3 Fuel efficiency.

“An improvement of the marine vessel's fuel consumption will provide efficiency and profitability in ship management since fuel cost is one of the biggest operating cost.” (Karatuğ Çağlar & Arslanoğlu, 2020), the implementation of an AI combined with machine learning will allow to the ship to calculate the optimal route, and reduce drastically the fuel consumption, this has been particularly difficult to calculate for the multiple variables that can affect the speed and fuel consumption, such as engine rpm, weather condition, ocean currents, port traffic, piracy risks, etc. However it is possible to use multiple algorithm models have to calculate a optimal solution, the combination of an artificial intelligence with machine learning will allow the ships to generate better and more efficient routes, improving the current average time in the routes and reduce drastically the operating cost in the long term.

Through the data acquisition, the mathematics models can speculate about the optimal route by analyzing the correlation between the variables and the ship's capabilities, this process would require several highly qualified people and a lot of time, in comparison the AI will be cheaper, faster, and more precise. The combination of machine learning with autonomous navigation will open the possibilities to self improvement, better decisions, reacting models to abnormal conditions, and reduce the probabilities of errors.

12.1.4 Human error.

It is estimated that more than 80% of ship accidents occur due to human error (Zanella,2020), with the assistance of autonomous systems in combination with an AI, allow the analysis of better manoeuvres, and then the coalition rate will be will reduce drastically, combined with the possibilities to analyze and process more data this will be a huge improvement that will reduce drastically the accident related to human errors. The machine can operate 24hrs x 24 hrs with no rest, they are not affected by fatigue, stress, health problems, miss interpretation of the protocols, etc. The AI systems with the integration of different technologies such as machine learning will have multiple benefits such as the possibility to evolve constantly and learn for the decision taken by the operators, the previous collisions and accidents registered, replacing them or helping them to take better decisions.

The amount of information that the humans can perceive and analyze it is lower than the machines, the speed of processing information and the capacity to process bigger amounts of data can improve drastically the safety of the ship (avoiding collisions, make better routes, do better maneuvers, etc). In general a ship controlled by the on-board computer AI can take more accurate decisions than an expert sea captain, work without rest, and will be a cheaper alternative.

12.1.5 New designs for ships.

Looking back in history at the transition of fuels from coal to oil in shipping industries, boilers became smaller and ships could travel twice as far with great speed because oil has double the thermal content of coal (Kim, 2020). The autonomous systems will allow new designs for the ships, by reducing the space required for the seafarers and humans' necessities (ships with no warming systems, spaces with no oxygen, high levels of noise, etc) there will be new possibilities to use that space in different things such as an extra space for more containers, extra engines, sensors or fuel tanks, the possibilities increase with the level of autonomy of the ship, ships with less weight can be faster than their predecessors, ships that can stay longer in the sea will be more efficient, ships that can operate in different environments that can be dangerous for the humans (artic operations, zones with high levels of radiation, warzones, minus zero temperatures, high pression. etc) will be definitely more useful.

12.1.6 Combination of different technologies.

What are the possibilities of implementing the technology in the maritime industry?

The reduction in the operation cost and the reduction in human errors it makes reasonable the implementation of autonomous systems, but the in order to be adopted there are multiple barriers that can stop the adoption and implementation in the economic ecosystem. "The business ecosystem concept also comes close to the business model concept that has been used to analyze the commercial application of MASS" (Munim, 2019, as cited in Tsvetkova, 2022), as long as the firm have a perspective of how to use the technology and how to generate value using this technology there is a possibility to implement it in the ecosystem, however, the multiple regulations in the maritime industry has created a conservative environment, where the managers are afraid of make mistakes and become an early adopter of new technologies, however, the disruption and the impact that the autonomous technology will be affected and disrupt the rest of the industries and then they will see the true potential. The level of autonomy of the ship can also affect the results, a fully autonomous ship will allow the firm to open new routes, be more efficient in fuel consumption, safety, cheaper in operations, among other benefits will change drastically the industry and give to the firm and advantage against the competition, but it will require to develop an AI and autonomous systems, and in contrast, a vessel with a level 1 of autonomy will affect slightly the operations and possibilities, but at the same simple so much easier the implementation of a few autonomous systems.

12.2 Different technologies that can be used together in the MASS.

12.2.1 Navigation systems and sensors.

The captain with a giant screen which overlays the environment around his vessel with an augmented reality view can navigate confidently using the computer enhanced vision of the world with artificial intelligence spotting and labelling every other water user, the shore, and navigation markers (Wright, 2019). With more information available it is possible to take better decisions, one of the advantages of the AI over a human crew is the amount of information that a computer can analyze, another one is that having an AI can be significantly cheaper.

The sensors can be divided in shipboard sensors and environmental, the sensors allow the AI to perceive the information regarding of the environment and condition of the ship, and with that information, the algorithm can calculate the curse of action, avoid obstacles, reduce the speed, detect anomalies, etc. Environmental sensing are mainly focus on the perception of the environment and are divided in 3 main categories space, surface, subsea, and the onboard sensors monitor all the internal systems.

The manned ships rely in the information perceived by the crew onboard, how they interpret the environment and condition of the ship and then with that information they can take the best course of action, it can take years for a cadet to become a deck officer and they will never be as precise as a computer, the humans have limitations in the amount of information that they can perceive or comprehend, the bigger the data the more complex it will be to analyze it, a simple calculation that a computer can perform in seconds it can take hours to resolve by humans, like the case of weather predictions, route optimization, detect a malfunction in the systems, eco-sonar interpretation, etc.

DNV-GL claims that the average number of sensors will be between 15,000 to 20,000 on-board the ship to monitor the safety-critical and other relevant systems (Ziajka & Montewka,

2021) The combination of surface sensors (laser imaging, millimetre radar, infrared), subsea systems (eco sounder, sonars, underwater vehicles), space systems (satellites, meteorological, oceanographic, synthetic aperature) allows the AI to have an awareness of the environment and self navigate and be more precise that the humans, this is related to the different levels of perception achievable by the AI, this increase drastically with the amount of information received and how is processed by the AI, the are as huge gap between the data that can be analyzed and the complexity/speed of calculations that a computer can do in comparison with an average human.

For example the navigation or docking with a lack of visibility will be so much easier with multiple sensors, and the auto navigation systems, the AI will not be affected by fog or any other meteorological parameters such as rain, snow, etc., the implementation of sensors can be used by manned ship, but the interpretation of the data will be complex and will require extra staff, in contrast, the using of an AI will be cheaper and open the possibility to incorporate more functions.

Overall the AI allows the installation of more sensors, and this allows different levels of awareness, a perception of things that can not be traced by the manned ships, faster and more precise reactions, a reduction of human errors, and better navigation during bad weather.

12.2.2 Renewable energies.

"The rising share of renewable energy sources (RES) in the energy mix and the desire to reduce the emission of greenhouse gases and harmful substances have driven broad-based technological advances on a global scale" (Machaj, 2022). The most common fuel used in the maritime industry is HFO (Heavy fuel oil), but the international maritime organizations want to change that in order to prevent more damage in the environment, these mandatory restrictions have impulse the maritime industry to use different fuels, some of the most common and efficient alternatives to HFO nowadays are ammonia and LNG (Liquefied natural gas both of them produce fewer CO2 emissions and can be consider more sustainable and eco-friendly than the HFO.

The possibility to reduce drastically the emissions by combining LNG or ammonia as the main fuel can allow the firms to follow the regulations from IMO, the downsides of these RES are the combustion hazards, cost efficiency, and complexity to store them can be completely solved by the use of an AI. The AI can analyze and control multiple parameters of the LNG tanks such as temperature, pressure, levels, etc and take action instantly in order to prevent any leak. And the other main downside of this is that they will use more storage in the ship than the fossil fuels, but if the ship is unmanned or fully autonomist then it will have extra space, and also avoid the hazards to the crew of using that fuels.

12.2.3 AI IN Mass.

Advancements in Artificial Intelligence (AI) applications like collision avoidance and computer vision have the potential to augment or take over the roles of ship navigators. (Veitch, 2022), the most common uses of AI in ships is in the navigation systems, the AI can make multiple calculation that will be extremely difficult to the humans to avoid collisions and the role of the humans in this actions is partially limited, to only supervise the decisions of the computer and give it very specific task to do.

The AI can analyze more data than humans, with more systems and data that analyze the conditions of the sea theoretically the decisions will be better, however, the technology still has problems and need improvement to be completely reliable, as is explained in the article (Veitch, 2022) where the experiment occurred in a full-mission bridge simulator, the AI was used to determine the best trajectory while operators that where in other room that where measuring and analysing the decisions of the ship simply determined that it was not sufficient. The possibilities to improve the software, the capacities, the hardware, or the decision taken still be a possibility and the combination with different technologies can improve the results.

12.2.4 LoT.

The potential to integrate MASS in the Internet of Things (IoT) within logistics and supply chains is yet another foundation of potential benefits (Tsvetkova, 2022). Another technology that can be integrated in the MASS is IoT (internet of things), What is IoT? IoT are physical objects with he ability to process data and do certain actions, this devices can be connected to a red that is controlled by the AI of the ship. The possibilities to semi automated certain actions of the ship systems onboard, and control parameters of the containers and tanks, using this technology will facilitate the ship operations, and at the same time it will help the AI interaction with the real world, or to receive more information by having more sensors with extra functions in the ship. For example the containers that have a cargo that requires certain parameters, such as a constant temperature, the regulation of the temperature can be fully automated by the AI with IoT gadgets, and also open more possibilities to transport more complex things that will require specific things, such as living creatures (that can be auto feed by LoT gadgets), plants (that will require certain levels of light, water, etc.), transport liquids that require a certain level of pressure or temperature, etc.

12.3 The potential economic value of the MASS.

From an economic perspective, the MASS can represent a huge reduction in the operation cost for the firms. Currently, crew salaries can account for up to 45% of total operating costs of a Panamax bulk carrier (Tsvetkova, 2022), if the same Panamax carrier will be completely automated the 45% of saving in the salaries, will represent a huge improvement in the incomes every year, and that kind of numeric values can be show to the stakeholders and investors show them how the revenue will be improved. This speculation about the bulk carrier is only based in the reduction of salaries, but the new ship design combined with a more efficient operator (AI) and new technologies in the ship will increase drastically that percentage of incomes, what will happen if now instead of having a carrier with a DWT 80,000 tonnes now have 20% of DWT capacity because now the ship does not require space for humans onboard. The same ship can now operate 24 hrs with no rest, so all the routes, times and operations will be drastically improved and all of these facts can give the firm a competitive advantage against the manned ships, in general, the cost-benefit of AI operations, the reduction in salaries, don't have the necessity to capacitate and train the seafarers, and more efficient routes can generate a huge economic advantage over the rivals.

Tesla's autopilot or Nissan's ProPilot can be regarded as level 2 because they can keep the car in the desired lane. (Muhammad et al, 2021), the firms that developed these technologies are leading the car industry and having a huge advantage in development and understanding of autonomous technologies, if there will be similar results as what happened in the car industry, it can be expected that the firm that early develop and adopt the AI will take over the market, generating disruption in the industry, making obsolete the old models, and not only that, at the same time generate a gap that will make it difficult to the rivals to copy or develop their own systems, giving the early adopters a sustainable business model for the upcoming years.

12.4 What is the current status of the technology?

Recently, significant improvements have been reported in the development of vehicular sensors for performing different simple and complex tasks including object detection (Muhammad et al, 2021), the current implementations of the AI in the car navigation systems have allowed the creation and commercialization of cars with driving assistance, the AI assistance can control minor tasks to allow the pilot to hands/feet off, the algorithms in combination with deep learning methods can recognize multiple parameters (traffic signals, object detection, vision of the environment, etc) and take a decision for safe-driving, this data analysis is based in the calculations of the variables that generate an understanding of the environment, traffic rules, and human behaviours.

At the current status in the car industry the AI still requires a human pilot at the wheel controlling the car, but multiple test are being conducted in order to improve the actions that the computer can take by itself and get the approval to commercialize it, it is expected that in the year 2030 the cars will be fully automatized where the drivers will not require any interaction with the vehicles.

Some companies like Tesla and Nissan, have successfully introduced in the market cars with these features and normalized the uses of AI navigation as safety in society, from the social perspective this has helped the image of the technology and what is the potential of it in other industries.

In 2017, two Norwegian companies Yara and Kongsberg announced plans to develop the Yara Birkeland, an autonomous cargo carrier servicing three ports in Southern Norway (Veitch, 2022). According to the developers of YARA it is expected that in the year 2023-2024 they will start the un-crewed operations supported by a ROC, it shows the current status of the AI technology allows the ship companies to create a fully automated ship, in other industries it had been successfully implanted at the degree of having a self-driving car that has systems to detect obstacles/threats, maneuvers to do obstacle avoidance, route calculations, etc, taking in consideration that there are more variables (obstacles, pedestrians, animals, etc) and regulations in the streets that in the sea, it is definitely possible to create an AI able to replace manned operations.

12.5 Possible challenges.

12.5.2 Maintenance of the ship.

"As there will be no seafarers onboard for maintenance and repair, preventative measures are essential to improve reliability in terms of hardware and software functions", (Kim, 2020) Depending of the level of autonomy it is expected that the number of people aboard will drastically be reduced for the same reason it will be difficult to repair the ship and do the maintenance it in an optimal way if for one reason one system has a malfunction or require to be fixed immediately, the lack of seafarers will make impossible to fix it onboard and the ship will have to stop in the nearest port, however in the other hand, this can be slightly reduced by using remote diagnosis and schedule periodically the maintenance to avoid this.

12.5.3 Cybersecurity.

As an autonomous ship will be operated in remote locations, the wireless communication systems between the ships and the SCC are crucial for their safe and efficient operation, (Kim, 2020) Another challenge that the remotely operated ships will have to face is cybersecurity, the possibility to change the route and hack the system is a serious risk to take in consideration, the low speed of the ship combined with the price of the ship and the shipment will make the ship a target for criminals, making crucial the development of a system to prevent these possible problems.

12.5.4 Operators opposition.

"Friction emerged between operators and developers of the auto-systems when the technology was perceived by the former as part of a misguided endeavour to replace human operators" (Veitch,2022). The operators perceive the AI systems as a threat for their current jobs and future in the industry, this can be a problem to implement the systems for the possibility of a strike or sabotage, this barrier can be related to multiple facts, but mainly for the lack of information. The engineers and operators don't understand completely the use and implementation of autonomous systems, and the different levels of automatization, the optimization of the multiple tasks using AI systems will make their job easier, but as long as they fear the new technology, they will reject it and never see the true benefits.

12.5.5 Mental underload.

Human factors experts have catalogued a multitude of complications arising from work with intelligent machines, foremost of which is the effects automation can have on their ability to pay attention (Veitch,2022). The operators will be delegated to new roles in the ships, this can generate boredom in the seafarers the AI will perform the majority of the process reducing the level of awareness, which can be a potential hazard in the case of a malfunction in the systems or if an emergency reaction is required. The dependency of technology will reduce the capabilities and experience of the operators, the functions that required an expert and complete concentration will become more passive, making them simple spectators or reduce their function to merely pressing buttons.

It can be expected that the operators will become less functional and experiment atrophying in their instincts, the mental underload will have negative effects, in order to reduce or minimize the risk related to it, it will be required to maintain a certain level of functionality an awareness in the operators.

12.5.6 Regulatory Obstacles.

Gaps in regulations for unmanned ships were identified as a major barrier to MASS system implementation in the analyzed studies (Veitch,2022). IMO and the majority of the conventions such as COLREGS, SOLAS, and STCW are predicated on seafarers being onboard the ship, this can be an obstacle that will tackle one of the main benefits of the MASS (reduction of humans aboard).

The current regulations limit the level of autonomy of the ship, and are forcing the human functions onboard and the multiple gaps in the interpretation of the conventions that can be used in favour of the seafarers to retain their jobs, even if they are less efficient or capable than AI who can operate the ship by itself, there are phrases in the convention that will force the firms to hire operators, this phrases can generate legal gaps, terms such as: seaworthiness or a personnel onboard, can be interpreted as an obligation to have people onboard even if they are not necessary for the operations in the MASS.

12.5.7 Human Competencies.

"Given the impact of automation, the need to retrain or reskill the future operators would represent as a challenge for the industry" (Kim,2020). The operators will need extra competencies to hold their jobs if they want to be competitive, but the majority will be replaced which can generate opposition and conflict.

The seafarers will need more competencies to be competitive in the new era of autonomous shipping, some of the most useful skills are leadership and management, the manager of the ships will have always a certain power to take decisions regardless of the level of autonomy of the ship independently and the AI calculations, developing new capabilities and constant adaptation in the employees can ease the transition, reduce the opposition, and improve the operations.

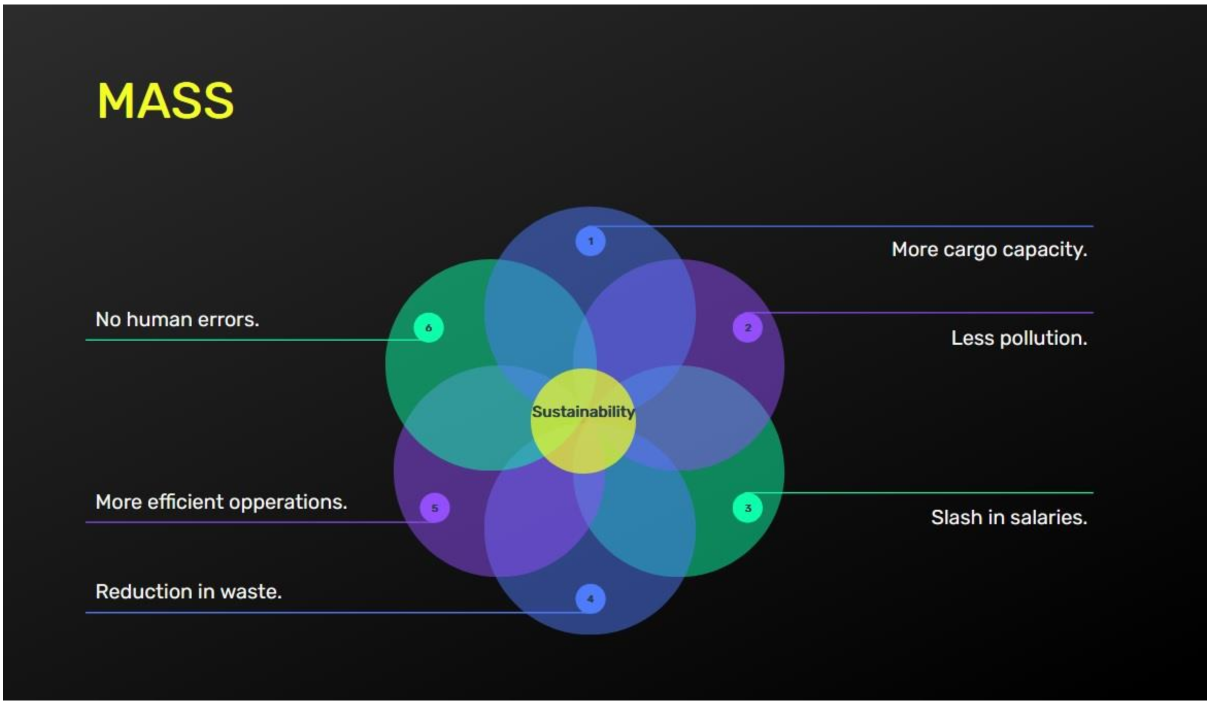
Having an awareness of the actual scenario and the ability to apply decision-making are perceived as necessary in the era of automatization, the sub-delegation of work will be easier with the assistance of the AI and autonomous operating systems, making it possible to one manager to control multiple ships at the same time, this will increase drastically the difficulty of the level of awareness and decision making, making it some of the new competences needed in a new era. Making it possible for an operator with enough training and capacitation to control efficiency multiple ships at the same time, or controlled remotely an USV (unmanned surface vehicle).

13. Summarise:

The following chart (table 8) recaps some of the most interesting findings in the study.

Economic value.	Eco-friendliness.	Improvement in operations.	
No crew salaries.	Fewer CO2 emissions.	More data analysis.	No human errors.
More cargo capacity.	No waste generation by the crew.	Faster calculations.	More capabilities in internal systems.
More efficient routes.	Fuel efficiency.	Faster reaction times.	Better perception of the environment.
Barriers.	**Current status of the technology.**	**Moving factors.**	
Regulatory obstacles.	Technology implemented in other industries.	International regulations.	
Operators opposition.	Multiple projects are ongoing.	New technologies.	
Cybersecurity.			
Conservative industry.			

(Table 8) Summarise of findings.



(Diagram 1) Relationship of sustainability and mass.

The Venn diagram, (Diagram 1) represents some concepts of MASS that working together can generate sustainability:

1- More cargo capacity (elimination of crew living spaces in the ships).
2- Less pollution (due to fuel efficiency and RES).
3- Slash in salaries (no crew salaries).

4- Reduction in waste (wastes generated by the crew).
5- More efficient operations (the AI can make more efficient calculations to optimize the use operations).
6- No human errors.

These are some of the reasons of why they can be considered more sustainable than the manned HFO ships, the diagram is a visual representation of some of the individual findings and how the integration of them in MASS can generate a sustainable ship, thinking not only in having an eco-friendly ship for the sake of following the regulation but also giving economic reasons to implement the new technology to the ship owners and stakeholders.

14. Limitations of the study:

Lack of information from the shipbuilders, developers and maritime firms about the current status of the technology, it makes difficult to have a clear vision of the current status, there are no public articles with detailed information that talks about the current projects, which makes it difficult to get enough reliable data. With internal data, it will be possible to make a comparison with the manned vessels and truly see if the ships are more sustainable or not.

15. Conclusion:

There are multiple links between sustainability and MASS technologies, having a fully autonomous ship controlled by an AI will allow more efficient and eco-friendly operations, by reducing the crew on board, the ship will have more space available (no need of space required in the human facilities) that can be used in more productive ways (more cargo, energy sources, sensors, etc), reduce the contamination generated by reducing the waste generated by the human activities and pollution, this will reduce the cost of the operations and at the same time make a more sustainable industry.

The use of autonomous systems and AI navigation is a more sustainable strategy that will allow the companies to follow the IMO regulations and reduce the damage that is generated in the environment. For example, a ship with an AI can calculate more efficient routes and optimize the use of fuel in real-time, this will improve the fuel consumption and reduce the CO2 generated, which will lead to improve the profits of the company. A fully autonomous ship will have more space available, which will allow the ship to use that space more efficiently, transport more cargo, have more sensors, or use alternative fuels (LNG or Ammonia) without any demerits (extra space, hazards), and then subsequently the CO2 emissions will be reduced drastically or even become zero emissions reducing the impact in the environment. The autonomous technologies can also allow the firms to have uncrewed ships and with that reduction in the cost of operations, it is an interesting alternative to replace the old ships.

With the current status of the technology, the limitations, and obstacles, it is possible to emulate the current technology in other industries into the shipping industry, for example, self-driving cars are a clear example of the uses of AI with autonomous systems, or the technology used in military drones allows the airplane to be able to operate without humans. The technology is there and there are some projects running but it will require time to be adopted in the industry, due to the gaps in the regulations of ship operations and the future opposition from the seafarers, but it is possible to develop a full autonomous ship.

I consider the MASS for these reasons a more sustainable alternative than the HFO manned ships and taking in consideration the mandatory regulations from IMO my speculations are that in the upcoming years, the majority of the vessels will be modified or replaced to use RES and this will open the possibilities to improve the maritime industry and adopt new technologies like MASS, then this will lead to a future where the manned ships will be replaced gradually by ships controlled by an AI and renovate the industry into a sustainable industry.

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