The Evolutionary Path Towards Maritime Autonomous Surface Ships (MASS)

K.A.D. Natasha Athukorala (BScC-551-18-05/0088)
natasha.bernadette@gmail.com
BSc (Hons) Logistics and Transportation
Department of logistics and transportation Faculty of Humanities and social sciences
CINEC Campus Malabe, Sri Lanka

I. ABSTRACT

The maritime shipping industry holds a significant coverage of 90% of global commodity trade throughout the world. The increment of global trade has resulted in a new paradigm shift perpetually concerning the usage of greener, safer and efficient use of fuels within maritime transportation as a countermeasure as per the initiations on international regulations and policies. Maritime Autonomous ships (MASS), extends as a ship to which to a varying degree can function independent of human interaction. The article is aimed at advantages, opportunities and threats, present challenges and status of marine autonomous surface ships, the risks and safety issues that have been encountered throughout the evolution of the MASS. The research further discusses reviews and analysis of the policies and procedures, technological countermeasures and human factor involvement within the development of MASS.

Keywords: MASS, Unmanned Vessels, Technology, Projects, Regulatory scope.

II. INTRODUCTION

Rapidly evolving technology has resulted a sequel onto a new paradigm shift perpetually concerning the usage of greener, safer and efficient use of fuels within maritime transportation as a countermeasure as per the initiations on international regulations and policies. Drawing back to the history of the present evolving technology, the initial footsteps were taken in the 18th century, the industrial revolution adapting to the mechanized power systems, vessels were powdered aiding coal as an energy source. Within the 1900's invention of diesel engines and usage of oil as an energy source upshot the efficiency, reliability of maritime transportation. With the introduction of the 1970's the computerized operations of vessels were formed as an initiation towards the digital revolution leading ahead in automation, cyber physical systems in aid of shipping.

The present-day prosper of the maritime industry thrives on a phase of extensive outspread on a global scale, shifting onto a new paradigm of a future of automated machine intelligent unmanned vessels. The possible radiation of the evolution of autonomous vessel control has reached the scope globally as well as systematically. Thereby the research aims on investigating causes, ways, techniques and risk management relevant to the hurdling shift towards maritime autonomous surface ships (MASS).

Advantages and disadvantages of adopting towards maritime autonomous ships. The advantages include, elimination of human error, increasing the safety of lives, utilizing the ship space in adopting various designs, reduction of high maintenance costs and equipment, eliminating the lack or shortage of ship crew issues and reduction of total operating costs. On the other hand, the disadvantages of MASS include, the vulnerability and risk of computer and system hacking or hijacking, high initial capital investments, unpredictable safety risks, risk of employment for seafarers in the maritime industry, risk of monitoring and offshore facilities provided.

Mass Autonomous Surface Ship definition extends as a ship to which to a varying degree can function independent of human interaction (IMO 2018). Interrogation on investigation of emergence of autonomous shipping, (Yemao Man, Monica Lundh, Thomas Porathe 2014), present speculations on the need for autonomy. The requirement of mitigating the future risk of shortage of seafarers within the working environment, the efforts on cutting down on the costs of transportation, the need of reduction of noxious emissions and of improving the safety measures and congestion elimination in shipping.

Consideration on the regulation aspect of ship automation, the strategic plan of IMO (2018-2023) has made way towards a strategic path of integrating new and advanced technologies within the regulatory framework. The regulatory framework involves in stabilizing the benefits procure from fast pacing technologies against the safety and security concerns, environmental impacts, global trade facilitation, transport cost considerations and the impact towards both marine and land operations. Within the year of 2017, with a forwarded proposal by a number of member nations, the IMO's Maritime Safety Committee (MSC) agreed on further investigation of the issues related upon the MASS on its agenda. The issue would be in a form of scoping exercise in determining the safety, security, environmental impacts and operations of the MASS that would be introduced in the IMO's instruments. As the scoping exercise is on the progress, IMO aims on completion of scoping exercise by 2020 (IMO 2018).

As of the 100th conference held by the Maritime Safety Committee (MSC) of the International Maritime Organization, which was held in May of 2018, four degrees of automation was discovered for the purpose of scoping exercise.

Degree one	Ship with automated processes and decision support: Seafarers are on board to operate and control shipboard systems and functions. Some operations may be automated and at times be unsupervised but with seafarers on board ready to take control
Degree two	Remotely controlled ship with seafarers on board: The ship is controlled and operated from another location. Seafarers are available on board to take control and to operate the shipboard systems and functions
Degree three	Remotely controlled ship without seafarers on board: The ship is controlled and operated from another location. There are no seafarers on board
Degree four	Fully autonomous ship: The operating system of the ship is able to make decisions and determine actions by itself

Figure 1:IMO's Four Degrees of autonomy

Further, Lloyd's Register of Shipping (UK) introduced more prominent definitions of the degree of automation identifying the level of automation (AL) from scale of level 0 to 6 including the advancements, the degree of human involvement and the locations where the assistance is functioned.

Figure 2: Autonomy levels proposed by Lloyd's Register of Shipping (UK)

Autonomy Level (AL)		Details
AL0	Manual - No autonomous function	—
AL1	On-ship decision support	All actions at the ship level are taken by a human operator, but a decision support tool can present options or otherwise influence the actions chosen, for example DP Capability plots and route planning.
AL2	On and off-ship decision support	All actions at the ship level taken by human operator on board the vessel, but decision support tool can present options or otherwise influence the actions chosen. Data may be provided by systems on or off the ship, for example DP capability plots, OEM configuration recommendations, weather routing.
AL3	"Active" human in the loop	Decisions and actions at the ship level are performed autonomously with human supervision. High- impact decisions are implemented in a way to give human operators the opportunity to intercede and override them. Data may be provided by systems on or off the ship.
AL4	Human on the loop – operator/supervisory	Decisions and actions are performed autonomously with human supervision. High impact decisions are implemented in a way to give human operators the opportunity to intercede and over-ride them.
AL5	Fully autonomous (& rarely supervised)	Unsupervised or rarely supervised operation where decisions are made and actioned by the system, i.e. impact is at the total ship level.
AL6	Fully autonomous (& with no supervision)	Unsupervised operation where decisions are made and actioned by the system, i.e. impact is at the total ship level.

Source: Compiled by MGSSI based on a report by Lloyd's Register of Shipping (UK), "Autonomous Shipping 2019 and Beyond" (January 2019), and a Japanese-language report by Japan's Ministry of Land, Infrastructure, Transport and Tourism, "Challenges and Direction of Initiatives for Autonomous Ships" (December 2017).

Figure 2: Autonomy levels proposed by Lloyd's Register of Shipping (UK)

Considering on the air and road transportation, sea transportation holds a significance of conveyance of large capacities of commodities and as being the cheapest and the convenient mode of transportation. The first and the foremost concept of autonomous ship building was proposed by the KONGSBERG originated from Norway where Yara Birkeland will be the world's first vessel in operating fully automation with the notion of zero emission and sustainability. Further the world's first automated ship possesses a cargo carrying capacity of 120 TEUs with the aim of reducing the emission of NO2 and CO2 as limiting the emissions of diesel-powered truck transport by 40,000 trips annually. As the green initiative aids in engaging with the UN sustainable development goals, it happens to be a major influence in mitigating the road congestions as well as improving the safety measures (Kongsberg 2017). As the initiatives are being taken in the year of 2017, the inauguration of the ship will take place in the year of 2020 as proposed (Yara 2018). As per the ship intelligence of Rolls Royce, Mikael Mäkinen, President, Marine states, "Autonomous shipping is the future of the maritime industry. As disruptive as the smartphone, the smart ship will revolutionize the landscape of ship design and operations". As the Rolls Royce and the KONGSBERG operates as the Europe's largest leading companies in the maritime play, Japan has also taken the initiative in the revolutionary path of automated ships where the Nippon Foundation's report was qualified as "Future 2040, The Future of Japan Created by Unmanned ships" which was produced in April 2019, assuming the ships are newly constructed in 2040 and will be operated with complete automation. The economic impact of unmanned vessels were recorded as 9,550,915, 900.USD as of 2040. Japan industry initiatives are taken through various organizations such as Mutsubishi, Nippon Yusen, Mitsui and CO and Nippon Kaiji Kyokai. The below chart illustrates companies and their investments on MASS.

Industry Initiatives	
Mitsui O.S.K. Lines, Mitsui E&S Shipbuilding (marine transportation/shipbuilding)	● A research consortium comprised of MOL, Mitsui E&S Shipbuilding, and others started developing the technological concept for an autonomous maritime transport system in August 2017. The group is expected to develop the technology concept for highly autonomous ships, and formulate a development roadmap for the technologies necessary for the realization of autonomously operated vessels. ● In September 2018, MOL carried out a pilot project by installing Rolls-Royce's obstacle recognition advisory system (IAS: Intelligent Awareness System) on its passenger ferry "Sunflower."
Nippon Yusen (marine transportation)	● From June 2016, started a "study on collision risk judgement and the autonomous operation of ships". Development of functions to facilitate assessment of the risk of collision with other ships, remote maneuvering from land during emergencies, and development of equipment to transform navigation instrument information into AR. ● In July 2018, started development of a ship operations support system for coastal ships, using AI as a core technology, and developed a system to reroute ships using AI in congested waters around Japan. A demonstration in actual waters is planned for 2021.
Mitsui & Co. (trading company/cooperation with overseas companies)	● In April 2019, began development of an automatic navigation system for large merchant ships in collaboration with ST Engineering, a major engineering company in Singapore, and Lloyd's Register of Shipping (UK). A test run was carried out in Singapore, one of the most congested ports in the world.
Nippon Kaiji Kyokai - ClassNK (ship classification society)	● In June 2018, announced the "Guidelines for Concept Design of Automated Operation/Autonomous Operation of Ships." The elements to be considered in the conceptual design were compiled from the viewpoint of ensuring the safety of autonomous ships. ● The purpose is to develop a conceptual design of an automatically operated ship based on appropriate and sufficient considerations given to safety, while giving the assumptions that seafarers perform a wide variety of onboard work, and that autonomous ships are studied based on various concepts, common basic elements that should be considered regarding safety are clarified.

Figure 3: Industry initiatives of Japan

Another project that has been proposed by the European Commission in development of the technological aspects of autonomous ships is the Maritime Unmanned Navigation through Intelligence in Networks (MUNIN) assessing the technical, legal and economic feasibility of adopting towards maritime vessel autonomy. The aim of the project spreads out as adopting the majority of the equipment and parts of the ship to be controlled autonomously with bare minimum human involvement. The European maritime transport industry further sets its objective on operating in a sustainable manner by reduction of operational expenditure, reduction of environmental impacts and attracting maritime professionals. Further the MUNIN concept emphasis on development of technical support systems such as advanced sensor modules, autonomous navigation systems, autonomous engines and monitoring systems and a shore control center with minimum crew utilization. Further, testing operations on deep sea navigation system, remote maneuring support system, maintenance interaction system and energy efficiency system in maintaining the sustainability of the project are to be observed and recognized.

As per the International Chamber of Shipping, maritime shipping domains in 90% of the global shipping. Due to the outbreak of the COVID 19 pandemic, cargo and passenger ships were withheld from the international ports where over 300,000 merchant seafarers were restricted and had to remain on sea beyond the contracted sea time. The pandemic outbreak further caused repercussions in holding the MASS projects where Yara Birkland launched in Romania was to be operated and tested by May 2020, though the pandemic caused major delays and restrictions in construction and testings.

The study aims at concerning the present challenges and status of marine autonomous surface ships, the risks and safety issues that have been encountered throughout the evolution of the MASS. Further the study pursues the identify and interpretation on what are the current measures that have been taken by the shipping industries on mitigating the errors in the evolutionary process of autonomous surface ships, the stages and the developments of MASS within the shipping industry and businesses, advantages and technological advancements.

The significance of the study shatters into segments of various stakeholders such as to the maritime industry with the introduction of automation and digitalization within the maritime industry, for the economy and trade as in mitigating the costs of transportation, improve productivity, effectiveness and efficiency and to operate in a sustainable manner as well as to promote the values of digitized business trading, As for the navigators and seafarers in sharpening and making aware of their knowledge on the evolving technology and to adopt to future era of autonomy.

III. LITERATURE REVIEW

The article is based on the evolution of maritime autonomous surface ships, cascading down into major segments, technology, global trends and projects, safety and security measurements, impacts of MASS on individuals and the regulatory aspects regarding the evolution.

According to Mingyu Kim, Tae-Hwan Joung, Byongug Jeong & Han-Seon Park (2020):

Technological aspects of Maritime Autonomous Surface Ships

The immense challenges in MASS extend as in developing the technologies in demonstrating the automated vessels are safe in providing shore control centers (SCC) in the event of an emergency situation. Smart alarms over satellite information systems and senses are to be assigned within the SCC operations to be remotely controlled. The devices and equipment installed onboard will be monetized, integrated, collected and analyzed consistently. Autonomous vessels will also have a major impact on ship construction, port infrastructure facilities and services provided.

Global trends and projects on Maritime Autonomous surface Ships

Massive investments and developments have driven the MASS have elongated projects throughout the world in automation of shipbuilding. Organizations such as KONGSBERG, Rolls Royce, DNV drafts on developing unmanned, all-electric vessels by the end of 2020. Many transportations and logistics-based industries are further developing unmanned, automated port infrastructures in facilitating the process of MASS.

Impact of regulations on Maritime Autonomous Surface Ships

In contempt of the vast developing technology and science within the maritime industry, MASS will be resistantly subjected to international policies and regulations in operating safely and securely within the international waters. Regulatory Scoping Exercise (RSC) was accepted into the Maritime Safety Committee (MSC) in determining the safety and safety security environment in operating of MASS as per addressed by the IMO. The amendment of the conventions are vital tasks with the available time frame.

According to Koji Wariishi (2019):

Inclined levels of safety and efficiency have triggered the interest and need of automated ships to evolve in providing the solutions and responses to the potential threats and maritime accidents happening within the industry and in improving the safety and security of the working environment. The article further reviews on the challenges within MASS cascading down into technological challenges and regulatory challenges.

Technological Advancement and Impact

Further cascading down to three challenges, **(1) Fundamental need of infrastructure in ship to shore communication within the autonomous ships**, maintaining the cost effectiveness in communicating from on board to the port facilitation, stabilized and consistent support from the shore in remote manuring as well as in low latency communication. **(2) Equipment and measurements within onboard ship manuaring,** maintenance of highly accurate sensors that are eligible in detecting obstacles and collusion risks has become a challenge in MASS even though the navigational radars are presently being used, advanced technologies will be needed providing coverage over long distances. **(3) Technology adaptation in total automation,** high risk operations such as engine maintenance, deck section operations, towering and mooring will have to be done with the use of robotic and automated technologies.

The Regulatory Challenges

The existing legal framework is adopted for the manned ships with crew onboard, the autonomous ship will be in need of an initiative regulatory scope in exercising the international policies and regulations. Some international regulations include, SOLAS convention (Safety of Life at Sea) regulations on ensuring the safety by initiating standards on lifesaving equipment, shipbuilding structure and onboard communication devices. UNCLOS (United Nations Convention on the Law of the Sea) regulates on the duties, rights and obligations on navigational ships.

According to Dennis A. Pandeagua (2019):

Reviews on the significance of MASS within the perspective of the Philippines Maritime industry. The initiative of MASS will state on the future of maritime industry in Philippine especially on sectors involved in the maritime industry as the seafarers, seafarer training and education sector, the port facilitation as well as towards auxiliary business services. The study further investigates the perspective of business sectors on the impact of Maritime Autonomous Surface Ships towards the national economy. The key objective of the research lies on determining the nature of the operations of MASS within the global seaborne trade. The research further focuses on the challenges in implementation of MASS within the nation such as the public acceptance and perspectives and society, the reliability of functioning and operating, the safety measurements that may acquire in operating in the common sea, as well as the strategies that may lead to a secured trading environment mitigating maritime catastrophes and distress. Another challenge that has been encountered was the Philippine government plan in addressing the application and implementation of MASS impacting the industry of seafarers, by implementing maritime education not as a "tertiary education" but as a "basic education" capitalizing the educational scope such as science, technology and engineering. The function and the outlook of the maritime industry of Philippine with the introduction of technology has also become a concern where the researcher perceives the aim of maintaining the competitive advantage of the technology and the maritime crew and labour suppliers by foreseeing and preparing in global shipping.

Elucidating on the opportunities and threats, evidence of autonomous operations of Rolls Royce, the general manager, Mr. Lindborg noted on an AI automated intelligent awareness system experimented as a development stage of MASS, that provided further benefits to the maritime industry. The intelligent awareness system is to be contemplated as one of the beneficiary systems of advanced technology in providing safety to the vessel as well as a sensor to the ocean surrounding, aiding the decision making of the crew (The KRIST Law Firm, P. C., 2019 cited in *Dennis A. Pandeagua 2019*). As 80% of the marine accidents were caused due to human error, autonomous vessels will aid in mitigating the errors as well as will be a safer option in international trading.

Since implementation and enacting of international maritime regulations have become a challenge in MASS, as per Professor Husebe of the Senior Legal Counsel of Japan Association of Marine Safety, it is said that MASS have given a stimulea in pioneering the autonomous ship operations. Professor Husebe also mentioned that counties such as Denmark, Finland, Norway, China and Singapore are being adopting to domestic automated ship operations within the territorial waters without waiting for international regulation enactments.

According to L. O. Dreyer, H. A. Oltedal (2011):

Reviews on the safety challenges encountered in adopting towards Maritime Autonomous Surface Ships cascading down into three major categories which are technological, human factors and procedural factors.

<u>Technological challenges</u>

The technological challenges sections onto (1) Hardware, where the necessary sensor system is measuring the variations on board as well as outside of the vessel. Communication capability is also a challenge which is ensuring the reliability and communication capability within ship to shore facilitation. Fire safety is also a hardware concern in formulating technical systems aiding the automated fire prevention systems. (2) Software, regarding the decision system and potential software errors and malfunctions and the reliability of cyber security. Challenges regarding decision system, in ability of MASS to mitigate collusion and congestion in accordance with COLREG. Software errors and malfunctions, although the constancy and efficiency of the software used in technology of MASS is of great importance to safety, there are high tendencies of software errors presenting within the automated control system.

<u>Human Factor Challenges</u>

Human factor challenges include the challenges related to training and human centered designs that has become a concern in implementing MASS. (1) Training, states in a few different articles e Man et al. (2018) provides evidence in requirement of necessary competencies of training that to be required for MASS operating. The research is further evident by further discussion on implementation of new training systems will have a constructive effect on stakeholders on safety of MASS with proper training procedures (Wrobel et al., 2018a). (2) Human design center, where there is no crew stationed on-board, the complete avoidance and limitation of human interactions in the workplace is a mandatory concern. The representation of information and data analysis should be maintained in a user-friendly manner which is challenging with the location constraints.

Procedural Challenges

A key procedural challenge is dealing and anticipation of undesirable and unpredictable situations. A few unpredictable events would be the communication errors and disconnections and the measurements in coping with the situations. With the unavailability of crew, the vessel will be wholly operated with the digitized maneuvering system. Adjustments and breakages will have to be mitigated and corrected.

According to Callum O'Brien (2018),

Elucides on the advantages and disadvantages of adopting towards maritime autonomous ships. The advantages include, elimination of human error, increasing the safety of lives, utilizing the ship space in adopting various designs, reduction of high maintenance costs and equipment, eliminating the lack or shortage of ship crew issues and reduction of total operating costs. On the other hand, the disadvantages of MASS include, the vulnerability and risk of computer and system hacking or hijacking, high initial capital investments, unpredictable safety risks, risk of employment for seafarers in the maritime industry, risk of monitoring and offshore facilities provided.

IV. METHODOLOGY

The Article Design

The framework of research is mainly based on the analysis of the evolution of the Maritime Autonomous Surface Ships, the impact of the autonomous ships towards the maritime industry, the challenges and risks that have been encountered that have been further emphasized on the literature review. Nevertheless, several conceptual aspects have been further discussed and analyzed. The article mainly aims on the evolutionary process, the technological advancements, procedural and legislative policies and measurements, human factor challenge, the advantages of autonomous surface ships and challenges and countermeasures that have been taken in mitigating the repercussions.

The Adopted Sources of Data

The article is based on the evolutionary field of study, Maritime Autonomous Ships (MASS) within the maritime and shipping industry. The research is completed based on secondary data collection which is relevant to the subject area aiming majorly on the advantages, technological, procedural and human factor aspect analysis, the challenges and risks encountered, the measures and recommendations that have been elucidated further.

Strategies and Methodology Search

The secondary data has been gathered through global search platforms such as the google scholar, journals and article pages of International Maritime Organization Website, Autonomous ship building project proposed websites such as the Rolls Royce, KONGSBERG and the Nippon foundation. The aimed keywords in the process of analysis were, Autonomous Maritime Surface Ships (MASS), Unmanned Ships, technological advancements, advantages and risks and challenges.

V. ANALYSIS

The data analysis is perpetrated on different aspects and forms relevant to the development of Maritime Autonomous Ships. The present scenario of maritime surface ships up to date, the challenges and impacts of MASS at present and the impact of the advancements towards the human factors such as seafarers, shipping companies and ship builders, the outlook of the maritime industry on the procedural, legal and technological advent of MASS. As the major grounds on the introduction of MASS is based on the reduction of the maritime accidents which has been caused 80% due to the human factors, in inefficiencies of ship maneuvering and due to the inadequate consciousness. Nevertheless, the increment of the global maritime transportation has led to a tight market for the seafarers where in particular with the aging of seafarers within the industry, automation may aid in eradication of inefficiencies and improve the flow of smooth transportation.

Figure 4: Economic cost of Somali Piracy from 2010-2016

The economic loss of Somali piracy has been continuing throughout the years of 2010 to 2016 where in 2016 it has been counted as 1.3 billion which may have resulted in changing of routes incurring a greater delivery cost and lengthy voyage time. Thereby the vessel autonomy also aids in the reduction of risk of piracy where in an instance of the vessel being unmanned, there will be no risk of piracy along ship routes and crew hijacking. As the regulatory scoping of ship automation has become an invincible matter within the maritime industry, the IMO's committees and subcommittees have been organizing a scope of regulations in revising further on autonomous ship building and operating where in 2019, Maritime safety committee (MSC) confirmed a revision of genetic guidelines on development of safety goals and the operational requirements in gathering the entire scope and the lifecycle of maritime autonomous surface ships. Goal based standards (GBS), Software Quality Assurance (SQA) and risk measurements have also been concerned throughout the regulatory scoping. As well as the degree of automation can vary depending on the level of operation, as fully automated or fully remote control at ranging levels due to the advancement of technology within the maritime industry and the unpredictability of variation drove IMO's regulations to be Goal based standard.

Table 2. Work for the regulatory scoping exercise (IMO 2018a, 2019b).

Task	MSC 100 (Dec. 2018)	MSC 101 (June 2019)	ICG/WG (Sep. 2019)	MSC 102 (May 2020)	MSC 103 (Nov./ Dec. 2020)
Framework (definitions, list of instruments, etc.)	×				
First step (identification of provisions in IMO instruments)	×	×	×	× (if required)	
Second step (analysis to determine the most appropriate way of addressing MASS operations)		×	×	×	× (if required)
Interim guidelines for MASS trials		×			

Figure 5: Regulatory scoping exercise of IMO

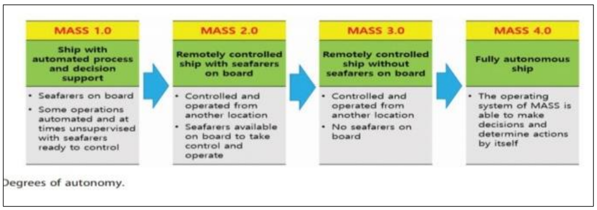

Figure 6: Degrees of autonomy

The market for autonomous ships is projected to be 5.8 billion USD in 2020 and within the year of 2030 the market is demanded to be 14.2 billion USD at the rate of compound annual growth rate of 9.3% from the years of 2020 to 2030. The key factors that drive the market for autonomous ships include the procedural development of autonomous ships, the increment of investments in autonomous ship projects, and the elevation of demand and awareness of the maritime autonomous surface ships.

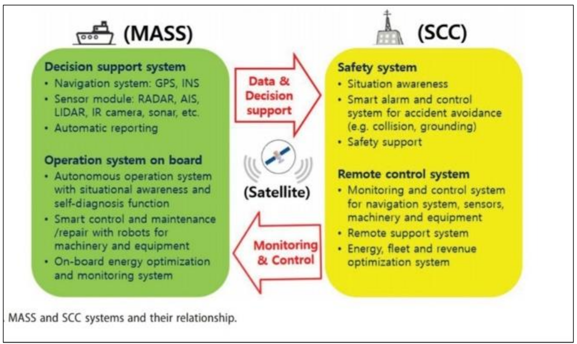

Figure 7: MASS and SCC Systems and Their Relationship

Autonomous ships feature similar technological adaptations such as the self-driven cars with the usage of a varying range of senses such as GPS, infrared cameras, Light Detection and ranging, RADAR systems, wind and pressure sensors where the newest technologies adopted are 4g networks providing ship to shore coverage up to 30,000 meters beyond the shore. In relation to the sensors that aid in monitoring and decision making though shore control centers in ensuring the reliability of sensors and assurance though design approval as well as by doing shore and on land inspections and periodical testings and observations.

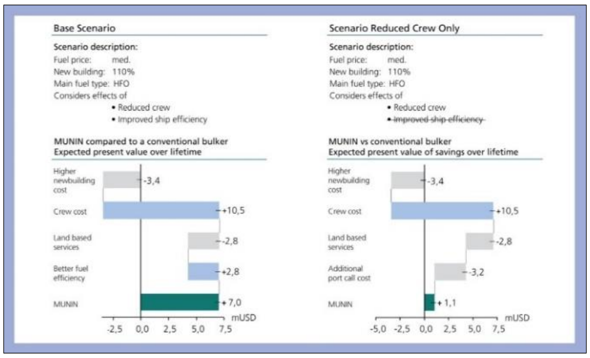

Figure 8: MUNIN vs Conventional Bulker Ships

The cost benefit analysis of the Maritime Unmanned Navigation Through Intelligence in Network (MUNIN) the cash flow financial analysis, a developed concept for a newly built autonomous bulker was put into observation. The testing emphasized on comparison of a conventional bulk vessel with the unmanned autonomous vessel, the autonomous vessel is highly commercially viable in several instances. As well as being a suitable tool in cost conserving due to the increased efficiency of ship to shore activities within the shore control centres and the port, autonomous ships are focused to be innovative in ship designing and reduction of emission, fuel and energy consumption and in reduction of the human factor error.

VI. FINDINGS

The article has provided the maritime industry a leading way towards a more sustainable and error free pathway within regard to autonomous ship building and autonomous ship operations. The conceptual and theoretical framework contribution aims on enhancing the overall knowledge and awareness of the development of Maritime Autonomous Surface Ships (MASS) and to elucidate on the advantages and disadvantages, opportunities and threats, the risks and challenges and the methodology in mitigating the negative outcomes through various aspects of technologically, legally and economically.

VII. RECOMMENDATIONS

Precise and comprehensive observance of relevant sources that may lead to potential vulnerabilities are a crucial measurement as it makes way towards the other key areas of risk mitigation, continuity of businesses, decision making which are critical areas in not only mitigating the risks and security issues but also the processes and procedures, navigational systems, resilience systems that aids the operations of MASS.

This incorporates notifying of planning assumptions in an event of decision making, at operational, strategic and tactical levels that aids in not only in the instance of an immediate incident but also in an instance of long-term preparation and planning.

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