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The Influence of Water Quality on the Structural Development of Vessels: Smart Dimensioning Process

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Abstract

In fact, it is pivotal the development, use, and management of the best and most suitable coatings to be supplied to vessels—especially those designed for long journeys; not only to increase their stability and safety but also to minimize their maintenance cost. In this regard, it should be also considering the function, the vessel typology and its routes, as well as the quality of the waters by which it will navigate. Topics that are critical to promote a better dimensioning process of vessels. Thus, the present chapter, *via* an extensive literature review articulated with practical approaches, aims to define relevant directions for vessels structural development processes regarding the water quality (sea or river waters), where they will outline their routes. Therefore, the study looks for a relationship between the vessels structural coating design process and the quality of the water where they navigate. Moreover, such a process not only will optimize/minimize the costs with the periodic maintenance of the vessels linings, but also to relate it with its routes—contributing to the revitalization of their structural dimensioning.

Keywords: dimensioning, vessels, water quality, management of maritime transportation navigation routes

1. Introduction

Nowadays more than ever has increased the need to preserve the environment, in that sense this chapter intends to make a slight contribution to this issue.

It is never too much to emphasize the importance of the sea, which occupies about 71% of the Earth's surface, has an enormous importance in life on Earth. Suffice it to say, that 70% of the oxygen produced on Earth is generated by the marine phytoplankton, being a crucial element for the existence of life. The sea has a fundamental and decisive importance in the climate that surrounds the Earth for example the cloud formation process, fundamentally based on seawater evaporation, then filtered, and transformed into freshwater. Data provided by USGS Water Science School [1].

Water is precious because life could not exist without it. Life was born has a result of water, from plants to animals to humans [2].

Another colossal factor inherent to the sea are the winds, necessary to the pollination of the plants, originated from the variation in temperature between the land and the sea. Moreover, water transportation has a huge impact in socio-economical life of humans, although in recent centuries has contributed less positively to the environment.

Furthermore, recently the sea and the oceans have a more important role energy wise, with a very promising future as an ecological renewable source. Additionally the sea hosts offshore wind farms and there's an increasing trend from several countries to use floating solar plants.

Maritime transportation has played an important role in international goods transportation. Large ships have a massive load capacity and consume large amounts of fossil fuels to operate high-energy consumption entails high pollutant emissions that have adverse impacts on the marine and atmospheric environment and on public health.

In order to minimize potential impacts, enhance environmental opportunities and provide an environmentally sustainable waterway system, it is necessary to identify, quantify and predict vessel effects and their potential ecological impacts [3].

According to Andria et al. (2008), monitoring and modeling studies are useful and suitable tools for assessing the environmental pollution. In this regard many studies have been made, however in order to mitigate this problem, it will require the implementation of more eco-friendly coatings and more resistant to seawater erosion.

Globally, coastal water quality is deteriorating due to anthropogenic influences [4].

Unfortunately, despite everything previously mentioned, human activities still negatively influence water quality and aquatic ecosystem functions, resulting in a decline of water quality, biodiversity, loss of critical habitats and an overall decrease in the quality life of all species. Although this effect is more meaningful in some regions, it affects the populations around the globe.

The overall objectives of the casuistic approached is to determine the extent to which the vessels have unfavorably contributed to the increase in pollution and to provide some guidelines regarding the structural design processes in order to mitigate the harmful consequences of the non-preservation of our planet, particularly for navigable waters.

2. State of the art

2.1 Maritime transportation

Maritime transportation plays an important role in the world merchandise trade and economics development. Most of the large volume cargo between countries like crude oil, iron ore, grain, and lumber are carried by ocean vessels [5].

According to UNCTAD (United Nations Conference on Trade and Development) Review of Maritime Transport [6, 7], Maritime transport is the backbone of international trade and a key engine driving globalization. Around 80% of global trade by volume and over 70% by value is carried by sea and is handled by ports worldwide. These shares are even higher in the case of most developing countries. Only to demonstrate the importance of maritime transport to humankind, specifically the sea born trade, here are some facts illustrated in **Figures 1, 2 and 3**.

2.2 Pollution caused by shipping activities

The main components of ship resistance consist of resistance due to wave resistance, pressure resistance, and frictional resistance. With the improvement of

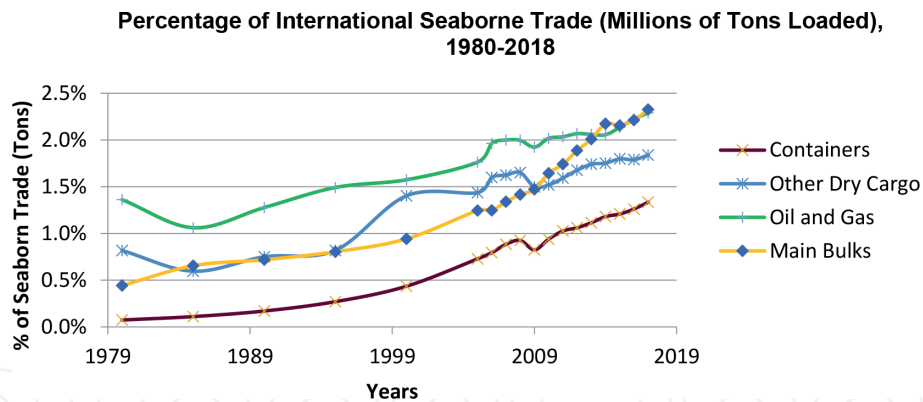


Figure 1.
Percentage variation through the years by category of international seaborne trade.

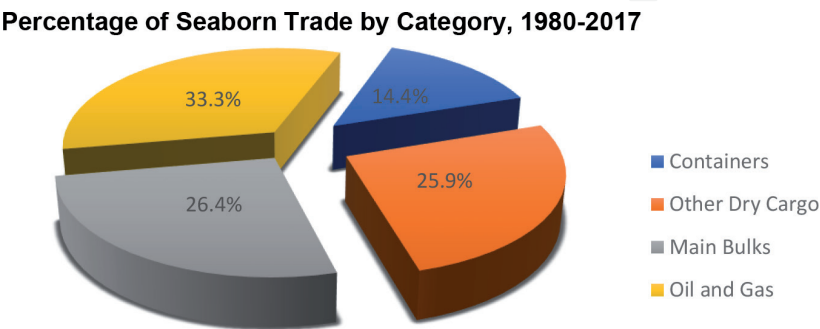


Figure 2.
Percentage of seaborne trade by category from 1980 to 2017.



Figure 3.
Amount of seaborne trade in million-tons by category from 1980 to 2017.

hull form optimization techniques, the wave and the pressure components could be less than 20% of the total drag in most modern ships. Therefore, the advantage from the reduction of the remaining frictional drag would be enormous [8].

The CO₂ emission from international marine bunkers in 2014 was estimated 626.1 million tons. Considering the conversion ratio 3.17 between CO₂ emission and fuel consumption [9], this amounts to 197.5 million tons of fuel consumption, which corresponds to approximately 60 billion US\$/year. Thus, 10% reduction of frictional drag would lead to saving of 4.7 billion US\$/year.

A large number of vessel worldwide still uses non-eco-friendly paints. In a sea environment, paint erosion is inevitable. Therefore, these type of paints must be replaced sooner rather than later, in order to reduce its negative footprint in marine ecosystems. In the specific case of Madeira Island, there are two main ports, an industrial one, the Port of Caniçal and a mainly touristic one, the Port of Funchal. Besides that, there is a significant amount of fishing, touristic and recreational

shipping activities in Madeira, which proves, the need to ascertain the type of ink most used, the periodicity with which the maintenance is made, how degraded the coatings are.

The vessels that least care about the esthetics of the ships, are those of industrial character as well as those for fishing activities. This seems harmless, but has serious environmental implications, on the one hand polluting the sea, another of the implications is that the degradation of paints causes a significant decrease in the speed of navigation and consequently an increase in the fuel consumption, thus polluting the air and increasing the already uncontrolled use of fossil fuels. Although the scenario is already bad, its worse than it seems, since the vessels that consume more fuel are the ones previously mentioned, for example the cargo ships transporting astronomical loads, would benefit and much of a more restrictive and periodic maintenance. In this regard, it matters to apply higher quality (in an ecological point of view) coatings, with less friction. This type of measure will allow lowering the consumption and increasing the efficiency. The above is explained is presented in **Table 1**.

According to consultant Det Norske Veritas, fuel costs constitute the largest expense of shipping companies and the drop in oil prices has brought some relief to the reduction in freight rates, caused by the excess of capacity and slowdown in

NSTM rating	Description	Increase in power at 15 kn
0	Hydraulically smooth surface	0.00%
0	Typical as applied antifouling coating	2.00%
10–20	Deteriorated coating or light slime	11.00%
30	Heavy slime	21.00%
40–60	Small calcareous fouling or weed	35.00%
70–80	Medium calcareous fouling	54.00%
90–100	Heavy calcareous fouling	86.00%

Table 1.
The effect of the roughness of the coatings on the power increment required for a speed of 15 knots.



Figure 4.
Typical pollution sources from vessels.

global growth. According to the same source, reducing the speed of a ship by 10% can lower fuel consumption by about 30%.

Figure 4 shows that although the fuels and paints are the most preponderant pollutants, there are many more originated by vessels.

Based on the foregoing it is of paramount importance to preserve and protect this source of life, the next chapter aims to offer a small contribute to improve and optimize the shipping industry, giving continuity to the advances already made.

3. New trends and directions for a smart dimensioning process

3.1 Smart design

Smart design - Smart design consist of a combination of techniques and tools which aid smart product design, including computational intelligence, SBD, design automation, e.g. In this case, by automating the simulation of product scenario using SBD and computational intelligence techniques, it can helps in the rapid testing and development of innovative design, which in turn translate to better products and revenue [10].

Some cruise ships companies are genuinely concerned with the negative impact caused by vessels, for this reason, it is beneficial that they have already managed to combat and reverse this trend. For instance Holland America ms *Oosterdam Ship* has done a very thorough job considering every aspect aboard their vessel and improvements for both energy efficiency and waste reduction. The implementation of Black water treatment system. In addition, they have reduced their 8 tons of waste generated each day by working with their supply chain, waste does not go overboard. Another significant measure was the incorporation of environmental officers on every cruise as well as staff eco-educated.

In an increasingly less utopian perspective, ships design should take into account the reduction of their own weight, as well as the use of materials that do not rust. Another key issue that has been addressed is the reduction of drag effect. It matters that coatings, fluctuation capacity and the aeronautical itself must be astronomically optimized. An additional key factor is the energy consumption of ships, the ship designer in this decade and in the future has the duty to select environmentally friendly engines and the ship itself has to be an autonomous power generation center. Robotics and current informatics will be the best means to increase productivity, maintenance and construction of ships, but this collaboration between man-machine has to be regulated in order not to cause unemployment, but rather help reducing the workload of employees. Lastly, but not least important, water and waste treatments should exponentially reduce their effect, aiming for ships to operate equivalently to Smart Cities, thus equipped with latest generation WWTP (Wastewater Treatment Plant) as well as SWTP (Solid Waste Treatment Plant).

3.2 Lightweight materials launched for shipbuilding

Sustainable solutions such as lightweight construction techniques and advanced materials are in demand, e.g. as the RAMSSES Project (Realization and Demonstration of Advanced Material Solutions for Sustainable and Efficient Ships) has the strategic objective to obtain recognition and an established role for advanced materials in the European Maritime Industry. Image credit: Evonik number of container ships in operation is constantly growing in response to the global volume of commercial trading. Ships equipped with the new hulls will be less expensive to operate relative to steel construction due to lower fuel demands and increased cargo capacity.

Fiber-reinforced composites do not rust, and their excellent resistance to seawater will translate into a reduced need to renew protective finishes and extended maintenance intervals.

Applying lightweight (primarily organic) material to high performance monohull sailing hulls/decks has resulted in a proportional increase in beam. Fully loaded container ships have a very broad “sail” area, so some amount of broadening of hull beam may be expected. Due to this structural modification, the navigational routes, ports and channels, which will be used by these vessels, will have to adapt quickly and at last resort to carry out the necessary construction works.

3.3 Super hydrophobic coatings

One of the super hydrophobic coating known is AIRCOAT (Air Induced friction Reduction Coating), works similarly to Salvinia leaves by creating a thin air layer that acts as a physical barrier between the water and the outside of the ship. This particular coating helps to reduce fuel oil consumption and gas emissions, as less energy will be required to move the ship forward, making transport more sustainable. The air barrier created by AIRCOAT will also help reduce the attachment of bacteria and algae that cause fouling. The corrosion of metals can produce a premature failure of metallic components, resulting in financial losses, environmental contamination, as well as injury or death [11, 12]. There's a much higher number of super hydrophobic coatings in the market, never the less the accession in the naval industry is still very distant from the desirable.

3.4 Energetically autonomous ships

Research on ship routing and scheduling has blossomed during the last decade. Comparing to the former decade its volume has more than doubled, and the same is true for the variety of research outlets. The research seems to be catching up with the increasing world fleet and trade. Problems of wider scope have been addressed, specifically liner network design, maritime inventory routing, and maritime supply chains [13].

Ship routing has a major role in fuel consumption and performance of vessels, nowadays, fortunately, autonomy and total energy efficiency are increasingly close, there are already several companies working in this direction.

One example that proves the course of this trend is Yara Birkeland, which will be the world's first fully electric and autonomous container ship, with zero emissions. With this vessel, Yara will reduce diesel-powered truck haulage by 40,000 journeys a year. It scheduled to set sail in 2020 (**Figure 5**).

According to Secretary General Kitack Lim (2017), “The seven strategic directions point us now towards more effective rule-making and implementation processes by integrating new and advancing technology to respond to our challenges, among others, to increase ship safety, including addressing new emerging technologies such as autonomous vessels”.

This leads to new challenges and some controversy, but we need to move forward so the use of hi-tech is the answer to achieve the excellence at the rate that environment needs.

3.5 Hi-tech in ship design

Building on the basis of cyber-physical production systems (CPPS) which merges the real and virtual space (“Industry 4.0: Challenges and solutions for the digital transformation and use of exponential technologies,” [14]).

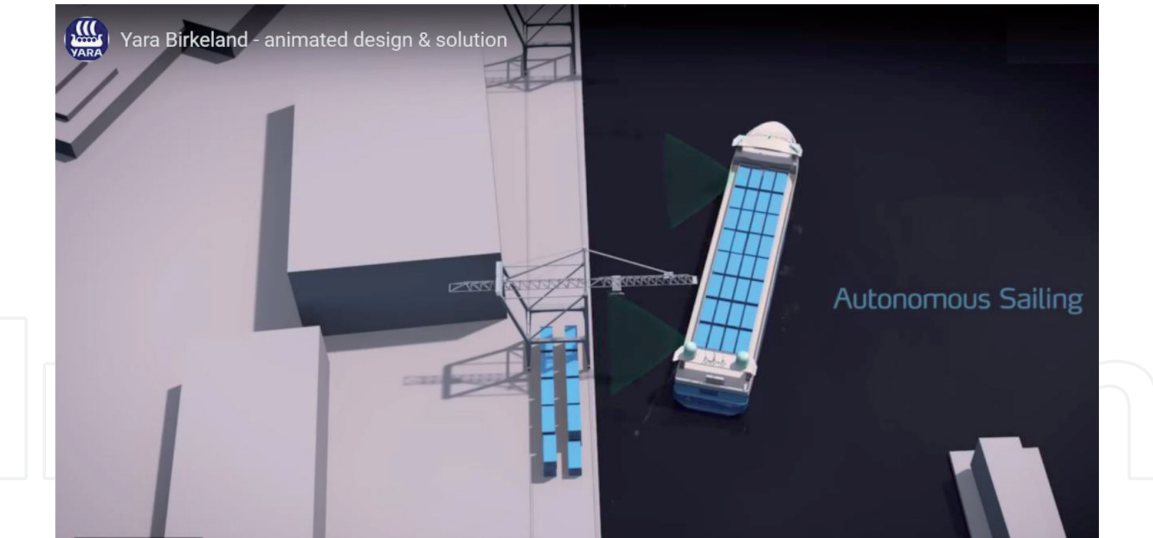


Figure 5.
Typical pollution sources from vessels. Source: Yara International ASA.

From the conception, to the construction and operational fazes we must use and enjoy the best that technological advances have to give, to achieve excellence results faster and more detailed.

One of the major evolutions in designing process was without doubt the use of CAD (Computer Assisted Drawing). CAutoD, commonly known as virtual rapid prototyping is an extension of traditional Computer-Aided Design (CAD) [15].

According to Ang et al. [10]. It makes use of biologically inspired machine learning techniques such as an evolutionary algorithm (EA) to intelligently search and evaluate the design space for innovative and optimal solutions. Coupled with powerful evaluation tools, this forms a close loop to fully automate the design process.

Nowadays, designers can count on the work excellence and speed that BIM (Building Information Models) has come to bring. Building Information Modeling (BIM) is a process used by Architecture Engineering Construction (AEC) stakeholders, which simulates a construction project in a multi-dimensional digital model and provides multitudes of project benefits from project inception to its occupancy [16]. This is without doubt the path to follow to achieve faster and better projects, much easier to build and to adapt in case of necessity. Other powerful tool is 3D Laser Scanning & Reverse Engineering. Notably, 3D laser scanning techniques can provide an accurate surface of the tested elements consisting of point clouds, which can reflect the actual spatial performance of the element. In addition, point clouds can be transformed into actual models and compared with design models through reverse modeling [17].

Figures 6–9 make a comparison between a project in the past century and these days (2018).

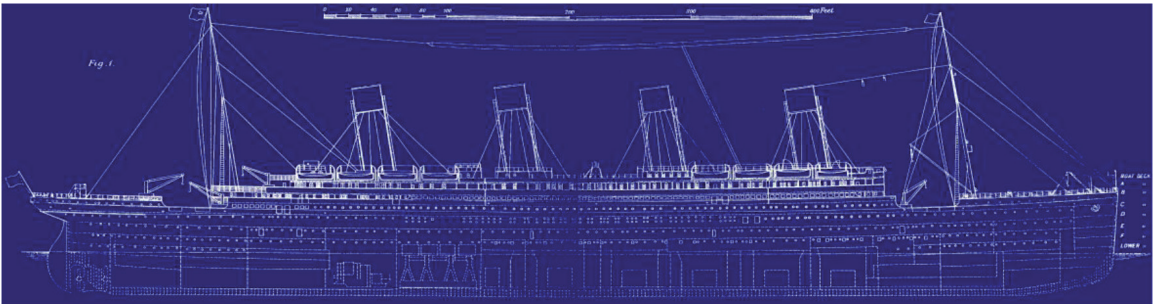


Figure 6.
Hand-made original blueprint of titanic provided by ultimate titanic.

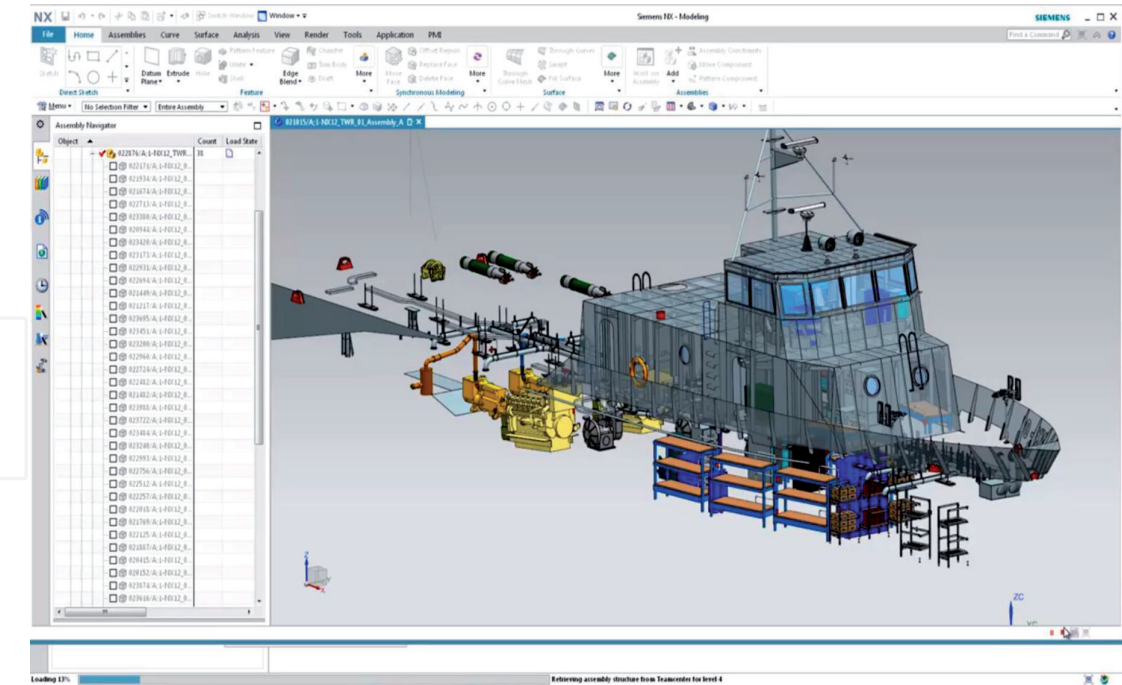


Figure 7.
BIM based ship design in NX-12 software by CAMdivision.

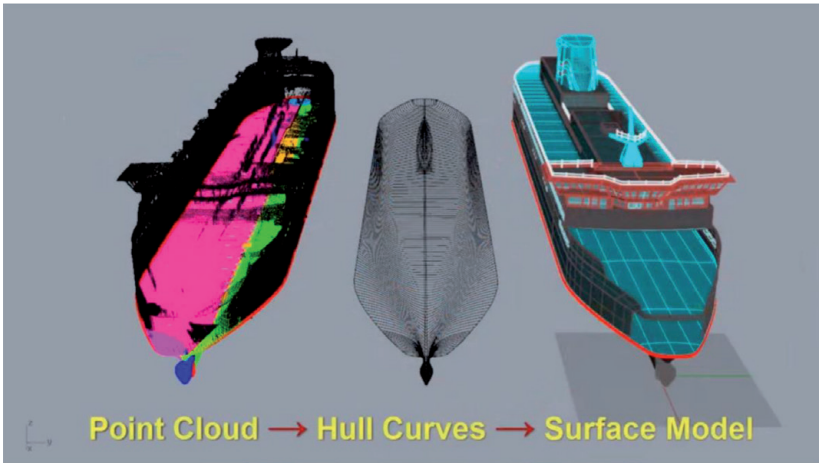


Figure 8.
3D laser scan & point cloud & reverse engineering by summit 3D.

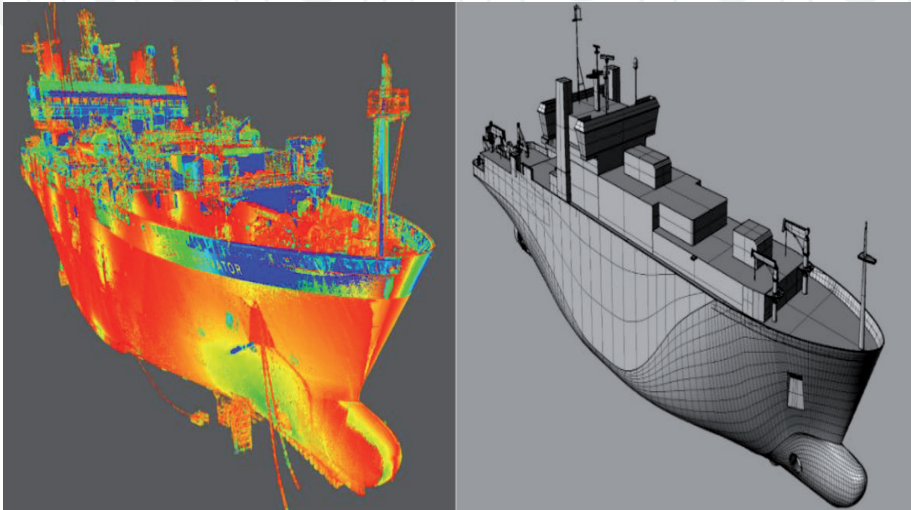


Figure 9.
3D laser scan & reverse engineering by SEVERNPARTNERSHIP.

4. Conclusions

In light of the above, it is possible to understand the importance of vessels and to aware, all the stakeholders involved in navigation, transport and design of ships, to work around a common goal: boosting performance and efficiency, ensuring the preservation of the environment.

Investigations must be carefully accessed before developing and launching products on the market. Simultaneously, the speed demanded is increasing, because the novelty of today becomes obsolete in little time.

Of course, these innovations are costly for businesses, never the less there's much to gain from them in a long term.

In addition, policy variables reflecting regulations at seaports affect port efficiency in a nonlinear way, its paramount to implement a global policy towards sustainability, regulating in very brief way the type of fuel used, CO₂ emissions, oil spills, the coatings used, waste waters and cargo residues discharges. Shipping design has to become smarter and more eco-friendly in order to increase vessels efficiency and to reduce their environmental footprint.

However, it is not enough to create rules behind rules, despite the excellent commitment of some governments and organizations, the most important guideline is to continue to raise awareness of companies and people more connected to this industry reprograming their way of acting and thinking. With this, it becomes possible achieving a utopia, in which the ships have zero emissions, their inks do not pollute, their maintenance is done with the proper periodicity, thus ceasing (partially) with the nefarious effect that our species has been provoking on the planet.

It should be noted that this type of measures will have to be implemented in the shipbuilding industry as well as in all industries.

As a final note, we will have to face the storms that lobbys enemies of the environment will cause and paddle against the tide of global pollution in order to achieve a better world.

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