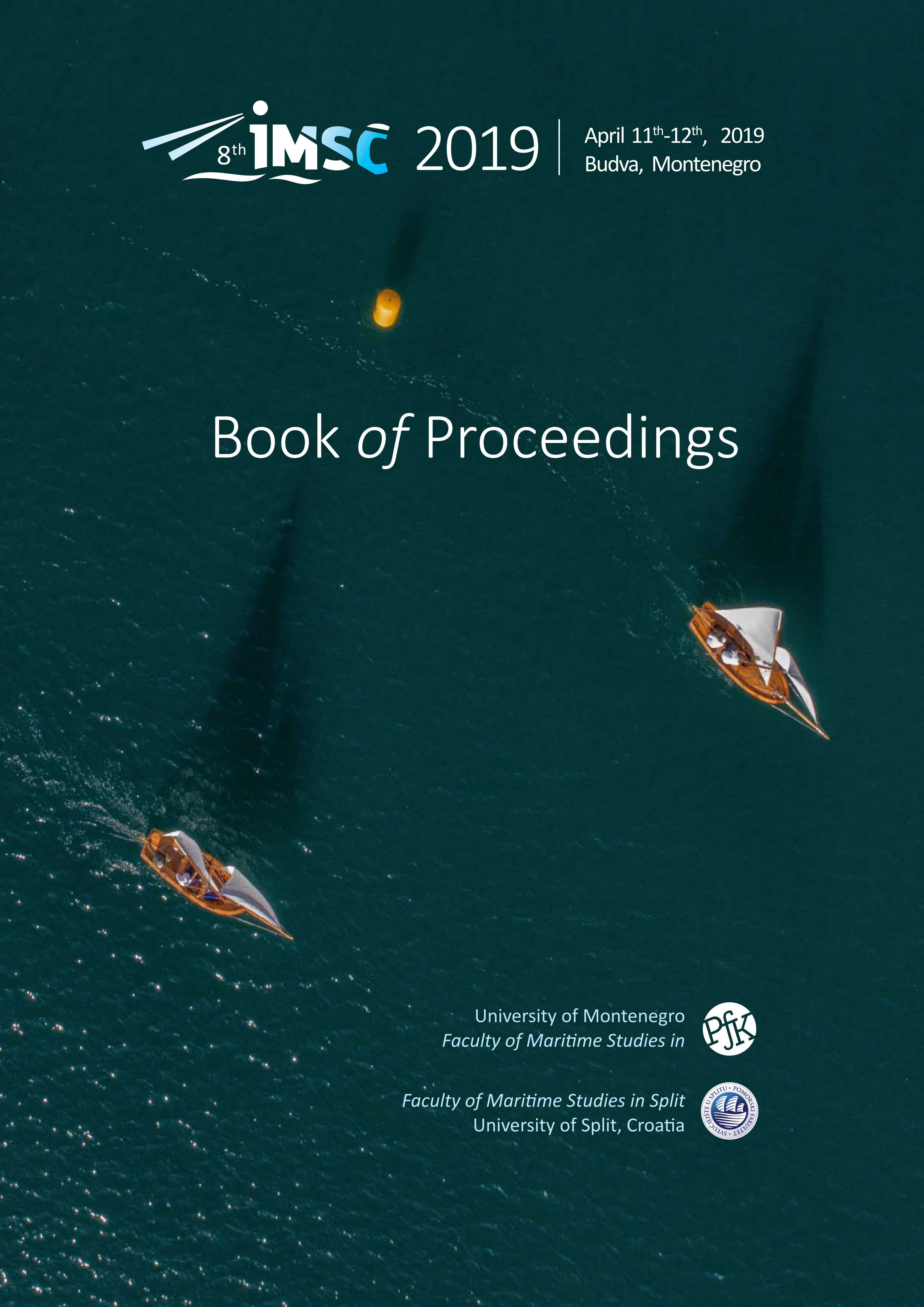

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Potential to Reduce Environmental Pollution from Ships Through the Modular Concept Approach

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Abstract

In the current practice, ship design is generally approached with the aim of keeping building-cost at the minimum, often forcing low-cost designs and low value-added market solutions. This is particularly true for small-size passenger vessels designed for short-sea shipping which are usually built by small shipyards which cannot sustain high costs of innovation and investments in education and research. In addition, unlike other transport modes, vessels are generally produced in small series and the investment cost has a strong impact on the initial vessel cost. Therefore, ships are often based on previous concepts and designs with essentially no modernization, thus leading to poor energy efficiency improvements, high vessel life-cycle costs and significant environmental impact.

The new regulations in shipping sector demand energy efficiency improvements, but the stakeholders lack in providing support in achieving these requirements. In order to increase competitiveness, changes are required not only in individual stages of a shipbuilding process, but integrally throughout the production process. Conventional design and production paradigm can be changed by developing a modular concept in ship design. The aim of this paper is to determine the potential to reduce environmental pollution from ships and thereby the externalities by applying modular concept for small passenger ships in the Mediterranean. This new concept for a high-efficiency passenger vessel class can facilitate the design process, reduce the initial cost of more technologically advanced vessels by allocating innovation costs to units in a much larger series, and thus prove as a viable and sustainable alternative.

Keywords: *small passenger ship, modular concept, energy efficiency, environmental pollution & costs*

I. Introduction

The majority of the cargo worldwide is transported by ships. The reason for this is that shipping is generally considered as the most efficient way to transport goods. This efficiency refers to the fuel oil consumption for a given economic output, where the economic output (sometimes called benefit for the society) is defined in tons and nautical miles of cargo transported. Cargo ships are powered by slow-speed super-long-stroke diesel engines with very low specific fuel oil consumption (SFOC). Also, the capacity of ships is very large, especially when compared with road vehicles or even trains. This leads to very low values of the fuel oil consumption and economic output ratios and very low cost of the transportation. On the other hand, any investment in innovative energy efficient technologies is perceived as a huge capital cost. Even more, since the shipping is considered as very efficient there is a very low awareness that any improvements are necessary at all. Hence, in the current practice, ship design is generally approached with the aim of keeping building-cost at the minimum, while the ship operation is approached with the aim of keeping fuel oil consumption at the minimum. These two aims are mostly opposed, so the most economic solutions are sought. On one side, low-cost designs and low value-added market solutions based on previous concepts and designs are often forced. On the other, the use of cheapest fuel oil and cheapest crew in the ship operation is forced.

This is particularly true for small-size ships. Usually, small-size passenger vessels designed for short-sea shipping are built by small shipyards. In addition, unlike other transport modes, vessels are generally produced in small series. As a consequence, the investment cost has a strong impact on the initial vessel cost. Therefore, high costs of innovation and investments in education and research is unsustainable from the economic point of view. Ships are often based on previous concepts and designs with only slight modifications required by the ship-owner with essentially no modernization. This leads to poor energy efficiency improvements, high vessel life-cycle costs and significant environmental impact. The aim of this paper is to propose a change in the paradigm of the ship design through introduction of modular approach. In the next section the main characteristics of modular approach are outlined. After that, the environmental impact of such approach is estimated as well as the potential to achieve sustainability is discussed. The conclusion section provides the main findings of the paper including the guidelines for further research in the application of modular approach in small ships design.

II. MODULAR APPROACH

Modular approach is well known in many industries, with broad application in automotive industry. The idea is to offer customers a range of products with different user characteristics, but with the similar basic design. This allows customers to make certain modification to the design, i.e. to personalize the product, but with the majority of the design left intact. Modular approach is a sort of a compromise between mass production and tailor production. In mass production all the products are identical. This reduces the price of the product, but does not allow for any changes thus making the product less attractive to customers. In tailor production the product is completely defined according to customer wishes, but then the price is significantly higher. When modular approach is used, the main components of a product are mass produced, while the final assembly is then according to customer needs. In fact, if all components are defined in advance, it is possible to mass produce every component (which is usually the case) which limits the final selection, but further reduces the price of the product.

Similar approach could be applied in shipbuilding industry (Fig. 1). In a sense, it is already applied, although at a very low level. For example in ship power systems it is already possible to combine different components available in the market (such as engine, generators, gearboxes, shafts, bearings etc.) to build the power system. Some companies offer "a complete solution" for which they guarantee the optimum performance. But these "complete" solutions are complete within themselves and not within the entire power system. The interaction of different components in the entire system is usually not tested (before the ship trials), so in order to make the correct combination, specific knowledge and experience is required. For larger ships and bigger shipyards with many employees this does not provide a serious issue. But for smaller vessels built in small shipyards this can present a challenge. Hence, small shipyards are restricted to the production of ships for which they have positive feedback in a hope these ships will remain attractive for the market in the future. Also, they hope any future modifications will not affect the ship exploitation characteristics negatively. The idea behind this paper is to develop a series of small passenger vessels based on the modular approach which would present a true innovation in the market.

Fig. 1. Modular ferries as offered by Damen Shipyard (https://products.damen.com/en/ranges/modular-ferry)

A. Ship modules

The idea is that the ship will be made of three basic modules: ship hull, ship superstructure and ship power system. Ship hull would further be made of bow section, middle section and stern section. Depending on ship exploitation characteristics, i.e. ship speed and main particulars several options would be proposed. Ship superstructure would be developed with the aim of increasing the passenger's comfort, i.e. based on the habitability level required by the ship-owner. Ship power system would be defined based on two main parameters: the total power required and the maximum emission levels allowed. The modules will be developed based on the market needs which can be identified by analysing passenger ships built and sold on the market.

For this purpose, Review of Maritime Transport studies issued by UNCTAD are used. According to the UNCTAD Review of Maritime transport 2018 [1] passenger ships and ferries represent 0.3% of the world fleet deadweight tonnage, but 11.8% of the world fleet dollar value as it can be seen from the Fig. 2.

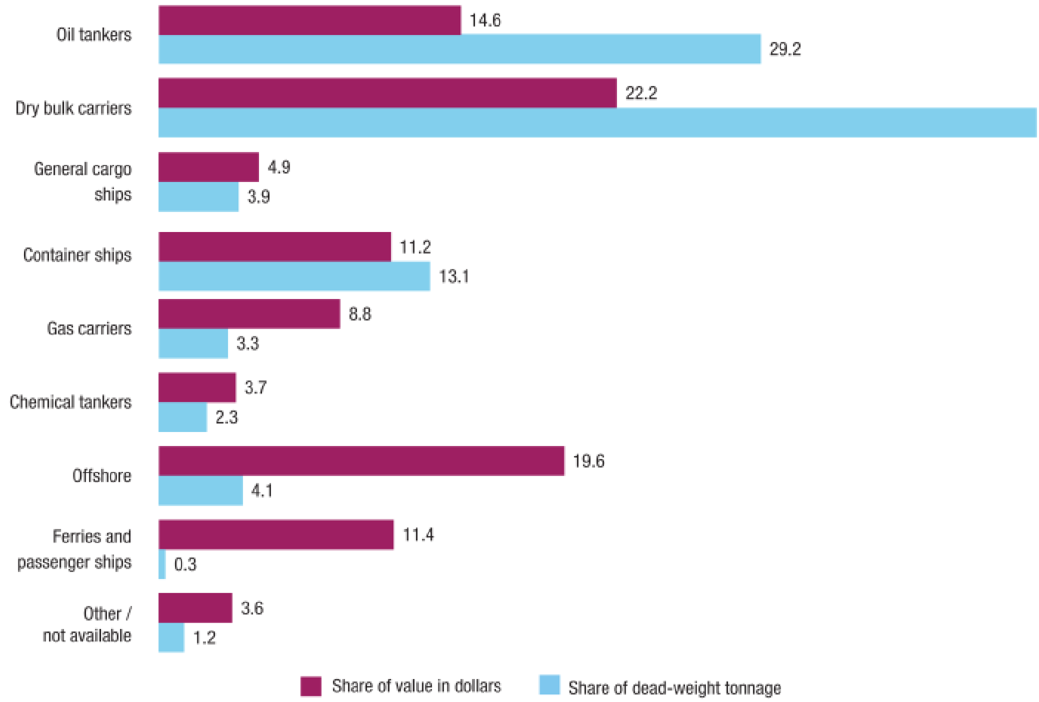

Fig. 2. World fleet by principal vessel type, 2018 (percentage) [1]

Fig. 3 shows passenger fleet size in the last 20 years in the capacity in DWT, as well as the increase in the percentage. These data are based on the UNCTAD reports. These reports are issued annually and provide data for that year and, as a reference, data for the past year. A notable increase can be observed throughout that period, apart from 2013. Until 2012 UNCTAD data were based on Lloyd's Register of ships database, while from 2013 data are obtained by Clarkson Research Service without a clear description on which ships are taken into account. The difference in the ships observed is a probable reason for this discrepancy. Nonetheless, the figure shows that the market is continuously growing and that any improvements in that segment of shipping will have positive impact on the overall energy efficiency performance. Also, UNCTAD studies contain many other data which are useful for the modular approach implementation. For example, it is interesting to observe that the average time passenger ships spend in port is relatively short, but the number of calls is of an order of magnitude higher compared to other ship types.

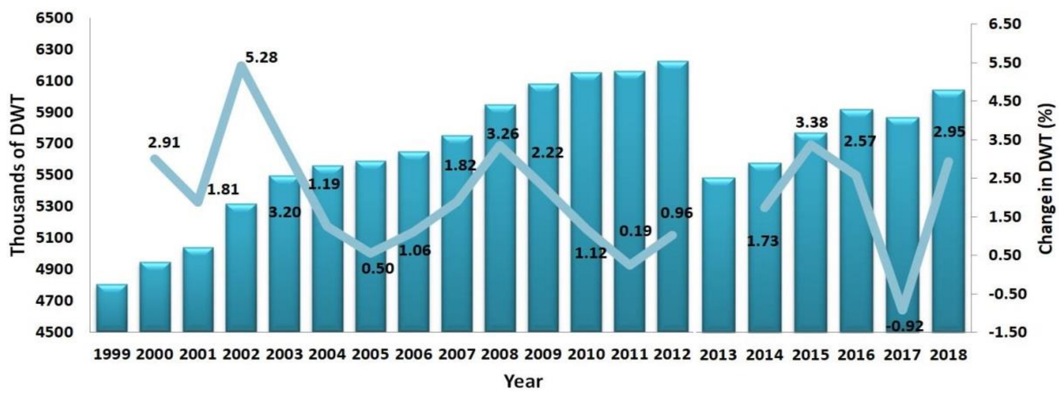

Fig. 3. Size of the world passenger ship fleet in thousands of tons of DWT per year

B. Ship power system module

Ship power system is conventionally divided into main power system (producing mechanical power for the propulsion system) and auxiliary power system (producing electrical and heating power to assist the main power system and for crew and passengers). Recently, the integrated and hybrid power systems have been developed and applied for ships, particularly passenger vessels [2]. Integrated power systems are characterized by the centralized production of the power required on-board, while hybrid ones are characterized by the use of different types of power sources. Their main characteristic is higher energy efficiency and lower gas emissions. The energy efficiency has become a requirement for larger vessels. Even though the implementation of this regulation is not mandatory for small ships, improvements in energy efficiency can have many benefits: lower costs due to lower fuel oil consumption and higher sailing range. Lower gas emissions contribute to the sustainability of the vessel, which can have positive impact not only for the environment, but also for the ship-owners in branding their ships as eco-friendly and thus attracting more passengers to choose their vessel.

III. ACHIEVING SUSTAINABILITY THROUGH MODULAR APPROACH

Sustainability implies three interrelated dimensions: ecological, economic, and social. Short-sea shipping presents great economic and social opportunity as it is labour-intensive, involves a wide variety of professions throughout entire maritime industry, from shipbuilding to shipping, insurance, brokerage and freight forwarding sectors, contributes to tourism, development of island agriculture accessibility of mainland market and services for islanders, and also for green innovation [3]

Green innovation here implies among others the product design. The practice of designing products and the processes for making those products in environmentally responsible ways is knows as Design for the Environment [4]. Its practice focuses on reducing the use of hazardous substances, minimizing consumption of energy and resources, reducing waste and expanding the lifecycle of products through recycling and reuse.

System thinkers may design components that can easily be separated and disassembled and the parts recycled. Furthermore, products can have longer lives when they are repairable, designed for easy replacement and designed so that broken parts can be reused or recycled. That is where the concept of modularity, a fundamental idea in the field of product design, presents its advantages. Modularity is not only good for business because of streamlining production processes, reducing the amount of inventory or making products easy to upgrade without needing to scrap large numbers of obsolete parts and thus providing economies of scale. Modularity is also the DFE and design for reuse because such equipment, in this case ships, are upgradeable.

In other words, developing a concept of modular ship hull, ship superstructure and ship power system is compliant with the principles of circular economy, industrial ecology, life-cycle design, eco-efficiency [5], dematerialization, product longevity, design for reuse and design for disassembly. In that respect appropriate environmental standards should be further developed by regulators and green public procurement promoted [6].

IV. CONCLUSION AND RECOMMENDATIONS

In this paper the potential to reduce the environmental pollution from ships and thereby the externalities by applying modular concept for small passenger ships in the Mediterranean are determined. As concluded from the UNCTAD reports, passenger ships fleet is continuously growing. Although its share in tons of deadweight is very low, the value of these ships is significant and therefore there is potential to implement new concepts such as modular approach. This new concept for a high-efficiency passenger vessel class can facilitate the design process, reduce the initial cost of more technologically advanced vessels by allocating innovation costs to units in a much larger series, and thus prove as a viable and sustainable alternative. Further research is required to define precisely technical characteristics of each module in order to achieve maximum benefit both for the ship-owners and for the environment.

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