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Concept of an Electric-Powered Passenger Vessel in Bangladesh

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ABSTRACT

In Bangladesh, the current trend in shipbuilding relies on diesel engines for propulsion. Unfortunately, these engines produce a significant amount of CO_2 and greenhouse gas emissions, which is a concern both locally and globally. To find a better solution, it is necessary to design waterborne transportation with electric propulsion. Although electric propulsion requires a larger initial investment, it proves to be more cost-effective in the long run compared to diesel-based systems. Electric propulsion is highly efficient, with an energy efficiency of 85%, more than double that of diesel engines. Moreover, electric propulsion systems are compact and lightweight, allowing for an increased payload capacity. Another advantage of electric propulsion is its potential for automation and further development. However, building sufficient infrastructure for electric vessels requires careful consideration in Bangladesh. To explore the economic feasibility, this study focuses on the design of a conceptual electric vessel for inland routes in Bangladesh, accommodating 100 passengers. A cost analysis is conducted to compare the two propulsion systems. By examining the costs involved, this research aims to provide valuable insights into the viability of electric propulsion in Bangladesh's water transportation sector. The findings of this study will contribute to the ongoing discussions on sustainable transportation solutions, particularly for inland waterways in Bangladesh..

1. Introduction.

Inland waterborne transportation has been a key driver of sustainable and advanced economies for centuries, offering a popular means of travel. When designing modern commercial vessels, choosing and optimizing the propulsion system is a critical decision. Currently, diesel engines are commonly used as the propulsion system for new ships. However, the widespread use of diesel engines in waterborne transportation leads to significant emissions of greenhouse gases, including methane and CO_2, which are released into the atmosphere. These emissions result from the consumption of fossil fuels. According to the (Fourth Greenhouse Gas Study 2020, n.d.), the shipping industry accounted for approximately 2.89% of the total global human-related CO_2 emissions in 2018. This amounted to around 1,056 million tonnes of CO_2. It is important to focus on the environmental impact caused by the shipping industry, with the traditional diesel engine being a major contributor to these emissions. Between 2012 and 2019,

According to the website "The Global Economy," the data of Bangladesh experienced a rapid increase in greenhouse gas emissions, in line with the global trend (Bangladesh Economic Indicators | TheGlobalEconomy.Com, n.d.). As both global and local emissions continue to rise, the importance of alternative energy sources, renewable energy, and improved technologies becomes evident. However, regardless of technological advancements in water transportation, if fossil fuels are used as the energy source, CO_2 and greenhouse gas emissions will persist. Bangladesh has committed to reducing greenhouse gas emissions by at least 5% and ideally 15% by 2030, as stated in its nationally determined contribution (NDC Roadmap and Sectoral Action Plan – Nature Conservation Management, n.d.). In order to achieve this target, designing vessels with electric propulsion is essential. The increased power consumption of diesel engines leads to higher fuel consumption and CO_2 emis-

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sions, thereby reducing the Energy Efficiency Design Index (EEDI) of the vessels (Karim & Hasan, 2017). In contrast, electric propulsion systems, including motors, batteries, and inverters, do not emit any CO_2, resulting in a zero EEDI for electric ships. Electric vessels offer additional benefits such as a cleaner propulsion space, reduced noise, and vibration. Furthermore, the potential for automation and further development makes electric propulsion highly promising.

2. Design.

2.1. Principal particulars.

The determination of the vessel's principal particulars was carried out using two methods: empirical formulations and corresponding ratios from the book Ship Design Methodologies of Preliminary Design by (Papanikolaou, 2014). For this particular vessel with a passenger capacity of 100, the inland shipping regulations dictate a crew size of 10. To calculate the preliminary weight and displacement, various factors were considered, including the distance and voyage time, the weight of passengers' luggage and belongings, water requirements for drinking, cooking, and washrooms for both passengers and crew, the weight of batteries and electric equipment, reserve water, and cooling water for auxiliary machinery. Through multiple iterations, the dimensions obtained from both methods were converged upon, resulting in the determination of the preliminary principal particulars. These particulars are presented in Table 1.

Table 1: Principal Particular of the vessel.

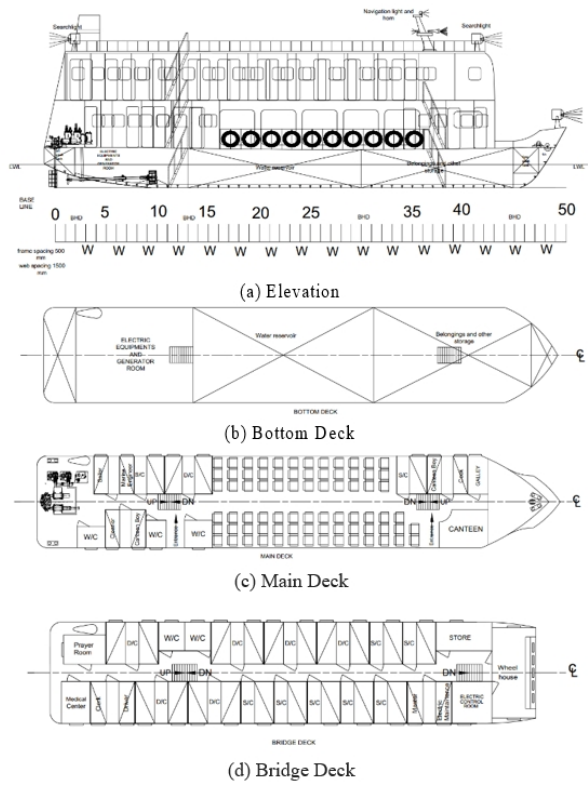
Items	Values
Length Between perpendiculars, L_{bp}	23.8 meter
Length Overall, L_{oa}	25.6 meter
Breadth moulded, B_{mld}	4.5 meter
Design Draft, T	1.12 meter
Displacement	64.7 tonnes
Block Coefficient, C_b	0.52
Service Speed, V	15 knots
Break Power, P_b	260 kW

Source: Authors.

2.2. GA plan, Lines Plan, and Midship Section Drawing.

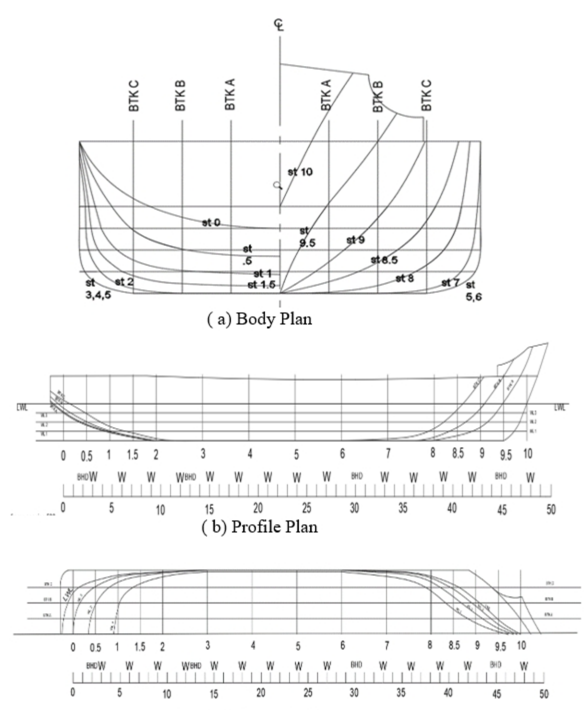
When designing the general arrangement (GA) plan of the vessel, multiple crucial parameters were taken into consideration. The plan needed to ensure sufficient space for passengers while complying with the requirements set by the International Maritime Organization (IMO) and the classification society to ensure optimal comfort and safety. Figure 1 illustrates the general arrangement of the vessel, showcasing the spatial arrangement for various components. In terms of the hull shape, several iterations were conducted to achieve the desired hull coefficients. Figure 2 displays the lines plan of the vessel, providing a visual representation of its hull shape.

Figure 1: General arrangement of the vessel (a, b, c, d).



Source: Authors.

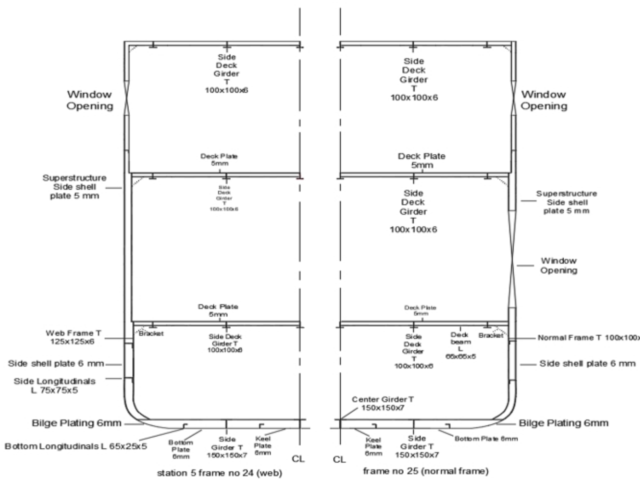
Figure 2: Lines plan of the vessel (a, b, c).



Source: Author.

As the vessel is designed to be operated in inland routes, the scantling of structural components is determined based on the guidelines provided in the rulebook ”RULES FOR BUILDING AND CLASSING STEEL VESSELS UNDER 90 METERS (295 FEET) IN LENGTH (2019)”. The dimensions of plates and sections are sourced from standard catalogs used in the industry. Figure 3 depicts the midship section of the vessel, providing a visual representation of the structural arrangement.

Figure 3: Midship section of the vessel.



Source: Authors.

2.3. Cost Analysis.

The cost estimation for the propulsion system of the vessel carrying 100 passengers is divided into three parts: battery cost, propulsion machinery cost, and charging infrastructure cost. To meet the requirement of 260-kilowatt brake power, a permanent magnet AC motor is chosen, along with a DC to AC inverter. A battery set capable of delivering power for a 7-hour trip is selected, resulting in a rated battery capacity of 1820 kilowatt-hours with a suitable C-rating. Additionally, other necessary electrical equipment is included. The cost summary for the electric propulsion system is presented in Table 2.

Table 2: Cost summary.

Item	In USD
Battery Cost	2,900
Propulsion machinery cost	17,000
Charging infrastructure cost (Shore charging)	11,75,350
Total	11,95,250

The pricing may vary over time, region, and brand.

Source: Authors.

To provide an approximate cost comparison between conventional diesel engine propulsion and electric propulsion, a 260-kilowatt diesel engine and its gearbox have been selected as a reference for the conventional propulsion system. While electric propulsion requires a larger initial investment, the charging infrastructure needs to be built only once for a port, resulting in potential long-term cost savings. Table 3 presents the approximate cost comparison between two propulsion systems. Furthermore, electric propulsion offers lower maintenance and operating costs, making it a more favorable option over time. A case study comparing an existing electric vessel named ”ELLEN” with a diesel vessel and a diesel-electric hybrid vessel, conducted by Abrahamsen in 2020, provides insights into the benefits and outcomes of electric propulsion.

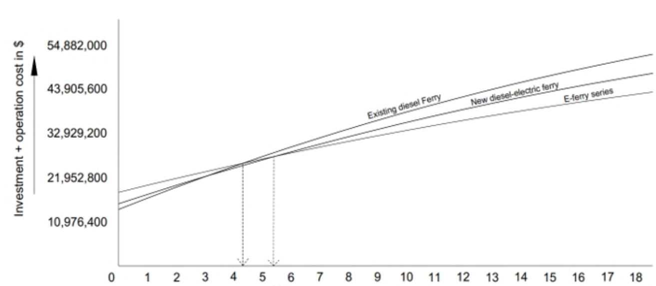
Table 3: Approximate cost comparison.

Item	Diesel Engine Based propulsion (in USD)	Electric propulsion (in USD)
Propulsion machinery cost	15,000	17,000
Battery Cost	--	2,900
Charging Infrastructure	--	11,75,350

Source: Authors.

So, electric propulsion has larger initial investments however the charging infrastructure needs to be built only once for a port. But due to lower maintenance and operating cost, electrical propulsion provides a better outcome in the long run. Figure 4 shows the case study of an existing electric vessel called “ELLEN” with a diesel vessel, and a diesel-electric hybrid vessel (Abrahamsen, 2020).

Figure 4: Cost case study between different types of vessels.



Source: Abrahamsen, 2020.

An important point of discussion is the shift from using diesel oil to electric power in the conceptual electric vessel. As of February 2023, the price of electricity is 7.86 Tk BDT (0.073 USD) per kilowatt-hour, while the price per liter of diesel oil is 109 Tk (1.01 USD) (Retail Power Price: Hiked Again, in Just 3 Weeks - Dhaka Evening, n.d.) (Gasoline and Diesel Prices by Country | GlobalPetrolPrices.Com, n.d.). Considering that

1 liter of diesel oil has the energy equivalent of approximately 10 kilowatt-hours (The Number One Resource for Sustainability in UK Tertiary Education | Sustainability Exchange, n.d.), the corresponding electricity price is 78.6 Tk BDT (0.73 USD), resulting in a cost-saving of 30.4 Tk (0.28 USD) per liter. This makes electric propulsion more cost-efficient. Safety and health considerations are also important. As the vessel is fully electric, fire hazard prevention measures are crucial. Fire detection sensors and a water-cooling system are installed, and vents are constructed for battery gas ventilation from the battery storage to the deck. All crew members are trained in fire prevention and firefighting. The electric vessel offers a safer respiratory environment for the crew, as there is a significant reduction in pollution compared to conventional marine diesel engines. Fully electric vessels have zero emissions and a clean propulsion space, minimizing the risk of respiratory health-related issues for the crew. From a structural standpoint, there is minimal difference between a conventional diesel engine and a fully electric vessel. The weight of steel, wood, and outfitting is similar for both cases. The only difference lies in the machinery weight and the stiffening method. However, through analysis of various electric vessels worldwide, it has been determined that a diesel engine propulsion system capable of delivering a specific amount of brake power weighs more than an electric propulsion system delivering the same power. The reduction in weight allows for increased payload capacity and, subsequently, greater profitability for the vessel owner.

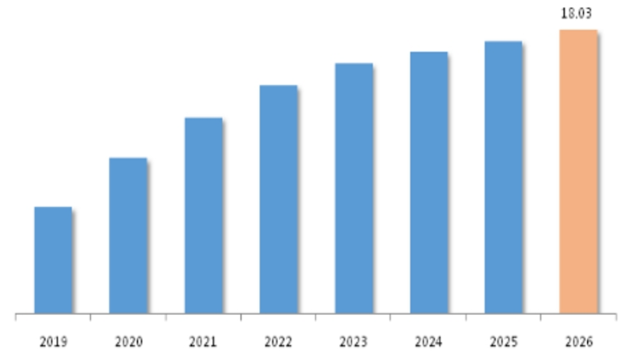
3. Results and Discussion.

Electric propulsion offers several advantages over conventional diesel propulsion. With increasing environmental concerns, the global market for electric ships is expanding significantly. From Figure 5, it is projected that by 2026, the global electric boat market will reach a value of approximately 18.03 billion (Global Electric Boat Market Size, Trend Analysis, Market Competition Scenario & Outlook, 2021-2026, n.d.). The cost of components for electric propulsion systems may vary across different brands and suppliers. Accurate pricing information can be obtained through further data collection, assessment, and inquiries. Additionally, the establishment of a charging infrastructure would require a certain level of funding. Currently, the shipbuilding trend in Bangladesh does not involve electric propulsion. However, if shipbuilders in Bangladesh start showing interest in electric vessels, it would greatly enhance the scope of this study. As the world increasingly adopts eco-friendly solutions, electric shipbuilding emerges as a viable option.

Conclusions

The cost-benefit analysis of electric propulsion, utilizing a conceptual vessel designed to accommodate 100 passengers, demonstrates the advantages of choosing an electric propulsion system over a conventional diesel-based system. Despite the numerous benefits offered by electric propulsion, the feasibility of its implementation in Bangladesh is hindered by the lack of interest in electric shipbuilding within the country. However, on a global scale, the electric shipbuilding market is experiencing rapid growth. Encouraging shipbuilding industries in Bangladesh to adopt electric propulsion can yield substantial economic and environmental benefits for the country.

Figure 5: Global electric boat market analysis (USD in Billions).



Source: BlueWeave Consulting.

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