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AN OVERVIEW OF PRESENT STATUS OF INLAND VESSELS IN BANGLADESH BASED ON FORMULATED ENERGY EFFICIENCY DESIGN INDEX

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ABSTRACT

In Bangladesh, there are more than 10,000 different types of ships plying all the year round, but performance of these ships in terms of CO_2 emission is not known and regulation related to the energy efficiency for inland ships still does not exist. In this paper, an attempts have been taken to assess the present situation of inland class vessels in terms of Energy Efficiency Design Index (EEDI). Using a developed database of inland vessels in Bangladesh, EEDI references lines for different types of inland vessels of Bangladesh have been formulated. Then a comparison of the EEDI reference lines has been made with other countries EEDI lines. The present status of existing inland vessels in terms of EEDI has been investigated. The results indicate that most of the existing vessels (around 60%) do not meet the current EEDI baseline and hence new regulatory guideline will be necessary for achieving EEDI compliance in near future. Furthermore, some recommendations have been proposed for improving existing situation of CO_2 emission keeping in mind socio-economic and technical factors in Bangladesh.

Keywords : *Inland Waterways Vessels, CO_2 emission, IMO, Energy Efficiency Design Index (EEDI)*

1.0 INTRODUCTION

From the global freight transport perspective, maritime transport is still recognized as an energy-efficient means of transportation compared to road and air transport, due to its large carrying capacity and low fuel consumption per ton cargo transported. Generally maritime transport is considered as the major facilitator of trades among different nations, regions and continents. Taking the advantages of trade liberalization, telecommunication and international standardization, this maritime transport has increased by 250% following the same rate as global Gross Domestic Product (GDP) over the past 40 years. According to the first greenhouse gas study by IMO, ships engaged in international trade emitted 1100 Mt CO_2 in 2007 (3.5% of global emission). Although this emission reduced to 938Mt CO_2 in 2012, but considering a business-as -usual scenario with a tripling in world trade and no further mitigation measures taken, future emission is expected to increase by 250% over the period 2012-2050 [1]. Despite the fact that ships are generally very efficient vehicles for transport, there is still significant potential for further improvements of their efficiency and thus in order to control emission from shipping, the ship Energy Efficiency Design Index (EEDI) has been formulated by the IMO Marine Environment Protection Committee (MEPC) as a measure of the CO_2 emission

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performance [2]. The basic formulation of EEDI is based on the ratio of total CO_2 emission per ton cargo transported and nautical mile sailed and it can also be regarded as an indicator of energy efficiency of a ship and ship propulsion. It was mandatory by new ships by the IMO in 2011 as a means of reducing the carbon footprint from shipping. Several attempts have been made to establish a reference values for seagoing vessels with respect to energy efficiency index [3,4,5,6 & 7]. Recently, European countries have been trying to propose some reliable tools for benchmarking efficiency and carbon emissions for their inland vessels similar to already accepted approach for seagoing ships [8,9,10 & 11].

Bangladesh is criss-crossed with a network of huge no of rivers, canals, creeks and water bodies, which have occupied about 11 per cent of the total area of the country. Since long, this river network has been regarded as safe and cost-effective route in Bangladesh. The inland waterways comprise a total length of nearly 6000 km of navigable waterways. More than half of the country's total land area is within a distance of 10 km from navigable waterway. Due to cheapest, safest and reachable means, the Inland Water Transportation (IWT) sector has become one of the major means of transportation of the country. The IWT sector carries over 50% of all arterial freight traffic and one quarter of all passenger traffic each year. Moreover, more than 80% of petroleum product is transported all the year round through the inland tankers [12]. Although, there are more than 10,000 different types of ship plying all the year round in Bangladesh with the addition of 200-300 different types of vessels every year, but performance of these ships in terms of CO_2 emission is not known and any regulations related to the energy efficiency for inland waterway ships still does not exist. At the same time, no suggested benchmark has been available so far that could be used for assessing of the energy efficiency for inland vessels of Bangladesh.

On the other hand, the land area of Bangladesh is very small, only 144,000 square kilometers but population is very high (around 160 million). In fact, Bangladesh is one the densely populated countries in the world and due to its favorable geographical location, different types of vessels are plying very close to the populated area all the year round using inland waterways. As a result, there is a chance of more adverse impact on population due to pollution made by these vessels. On the other hand, the continuous growth of country's economy with up gradation of standard of living with increasing per capita income [13], the people of Bangladesh have become more conscious about environment and environment pollution nowadays. As a result, it is very essential to know the status of these inland vessels in terms of emission and propose some guideline for improving the situation if necessary.

From this perspective, the objective of this paper is to review the present scenario of inland vessels in terms of CO_2 emission, analyze the results, propose and develop a reliable tool for benchmarking energy efficiency and carbon emission of different types of vessels considering existing socio-economic and technical factors of Bangladesh. In addition to that, some recommendation has been put forward to overcome the situation in the long run.

2.0 OUTLINE OF THE METHODOLOGY

Primary data and information about different types of inland vessels of Bangladesh had been collected through interacting with structured, unstructured and open ended questionnaires from various government shipping organizations, private organization including shipyards and ship design houses. In this respect, main types of inland vessels of Bangladesh such as cargo ships, oil tankers, passenger vessels, ferries and sand carriers had been taken into consideration. A database had been developed considering main principal particulars of the ship, its speed, engine type, engine power, type of the fuel used etc. for more than three thousand vessels plying in inland routes of Bangladesh.

Specific fuel consumption (sfc) of engines had been collected from engine catalog data as well as field data. Relevant ship drawings and some other documents had been collected. Some commercial ship design software had been used to do performance analysis in order to improve the energy efficiency index. Moreover, construction materials, propulsion system, hull coating along with quality control of shipyard and regulatory authority had been assessed and collected relevant information from there. The awareness level of different stake holders including ship designer and design approval authority have been assessed regarding recent energy efficient regulation.

Secondary data and information had been collected from both external and internal means such as journals, thesis, books, reports, ship owner associations, enlisted ship design houses, related private organizations, web sites and other sources.

3. 0 FORMULATIONS OF EEDI FOR INLAND VESSELS

3.1 Development of Reference Line

In this study the reports of MEPC 66 [2] were used as the basis for the calculations. According to IMO, the energy efficiency of ships is defined as the ratio of the mass of CO_2 emissions from main, auxiliary engines and additional shaft per unit of transport work for a particular ship design.

Hence EEDI can be defined as:

$$\mathrm{EEDI}_{\mathrm{attained}} = \frac{\mathrm{CO_2\,Emission}}{\mathrm{Transport\ work}}$$

$$= \frac{\mathrm{Power} * \mathrm{Specific\ Fuel\ Consumption} * \mathrm{CO_2\ Conversion\ Factor}}{\mathrm{Capacity} * \mathrm{Speed}} \qquad (1)$$

$$= \frac{\mathit{Emission\ from\ Main\ Engine} + \mathit{Emission\ from\ Auxiliary\ Engine} + \mathit{Emission\ for\ running\ shaft\ motor} - \mathit{Efficient\ Tech.Reduction}}{\mathit{Capacity} * \mathit{Reference\ Speed}} \qquad (2)$$

EEDI values for different types of ships have been calculated on the basis of developed database for different ships of different capacities. Then from average index values, exponential regression line has been drawn. The regression line expresses the baseline value, which can be calculated by using the following formula:

$$\text{Reference line value} = a \times b^{-c} \qquad (3)$$

The values of a, b and c of equation (3) have been determined from the database developed for different types of ships such as cargo, oil tanker, passenger, ferry and sand carrier. It is to be mentioned here that for calculation of EEDI reference lines of passenger vessels & passenger ferries, gross tonnage (GT) has been considered for calculation of EEDI. On the other hand 100% of deadweight has been used as capacity for other vessels. The calculation of EEDI has been performed for 75% of MCR of engine and with corresponding evaluated ship speed and the value of MCR has been obtained from power speed curve supplied by engine manufacturer. Adopted value of carbon emissions factor (C_F) for diesel fuel was 3.2 t CO_2/t fuel, as recommended by IMO.

The values of a, b & c for different types of inland vessels for Equation (3) have been summarized in Table 1. It is to be noted here that EEDI values of inland vessels for different cargo/passenger capacities (in terms of DWT/GT) have been calculated to formulate the reference line. On the basis of the calculated results, a power series regression line has been drawn to show the co-relation of the data. In Table-1 R^2 describes the correlation of the baseline value and the value close to 1 or -1 represents a high degree of correlation. Scatter values which are more than two standard deviations from the regression line are removed, and a new regression line is calculated. This ensures that erroneous data are excluded from the calculation. Moreover, in Table 1, the term "Population" means numbers of vessels have been taken in this study and "Excluded" means the number of vessels that have been deducted from this study. This formulated line will give different values of EEDI (CO_2 in gm/tone.mile) for different capacities and will be used as a reference value so that any vessel should be designed in such way that EEDI value should be less than or equal to that particular value.

3.2 Reduction of EEDI reference line value for different phases

After adopting the Energy Emission Design Index by the IMO in 2011, it was decided that more stringent emission factor would come into play phase by phase. This implies that in coming years, EEDI will be tightened to keep pace with the technological innovations. The planned time period for Phase -1 is from 1st Jan 2015 to 31st Dec 2019. For Phase -2, it is from 1st Jan 2020 to 31stDec 2024 and for Phase-3, it is from 1st Jan 2025 to onwards. The formulated reference lines shown in Table 1 for different types of inland vessels have been considered here as reference line of Phase -1. It is assumed that Phase - 2 and 3 will force an EEDI reduction of 20% and 30% respectively from formulated reference line of phase-1 for different ship types similar to the ocean going ships' EEDI proposed by IMO.

Thus the attained EEDI shall be calculated for Phase -2 & 3 as follows:

$$\text{Attained EEDI} \leqq \text{Required EEDI} = (1-X/100) \times \text{Baseline value} \qquad (4)$$

Where X is the reduction factor to be considered for calculating EEDI for the reference value of Phase - 2 & 3.

Figure 1 shows phase wise EEDI reference line reduction value for inland cargo vessels of Bangladesh as an example.

Table 1: Reference line parameter value for different types of inland vessels

Ship Type	L/B ratio	EEDI range	Parameters			R^2	Population	Excluded
			a	b	c			
General Cargo	4.7-6.8	30-150	15831	DWT	0.789	0.2615	351	16
Oil Tanker	3.9-7.3	40-150	950.93	DWT	0.406	0.4132	85	5
Passenger	4.5-7.36	10-350	42477	GT	1.1015	0.6806	90	13
Passenger Ferry	2.0-4.9	500-1200	$9X10^7$	GT	2.204	0.7914	36	2
Sand Carrier	3.25-6.9	50-400	2261.7	DWT	0.595	0.2592	2095	18

4.0 COMPARISON AMONG VARIOUS COUNTRIES INLAND VESSELS EEDI REFERENCE LINES

European countries particularly Denmark and Netherlands have for a long time been concerned about the energy efficiency of ships for their inland shipping and they have already developed some reference line for their inland shipping. In this study Denmark & Netherlands formulated EEDI reference lines have been compared with the formulated EEDI reference line of Bangladesh (phase –1) to see the comparative results for cargo ship and oil tanker [8,9]. In Figures 2 and 3, such a comparison has been shown for cargo vessel and oil tanker. It has been observed from these two Figures that EEDI reference lines for cargo vessel & oil tanker of Bangladesh lies much above than Denmark and

Netherlands. It is also observed from the comparison that for relatively higher capacity, the difference becomes narrower for both case.

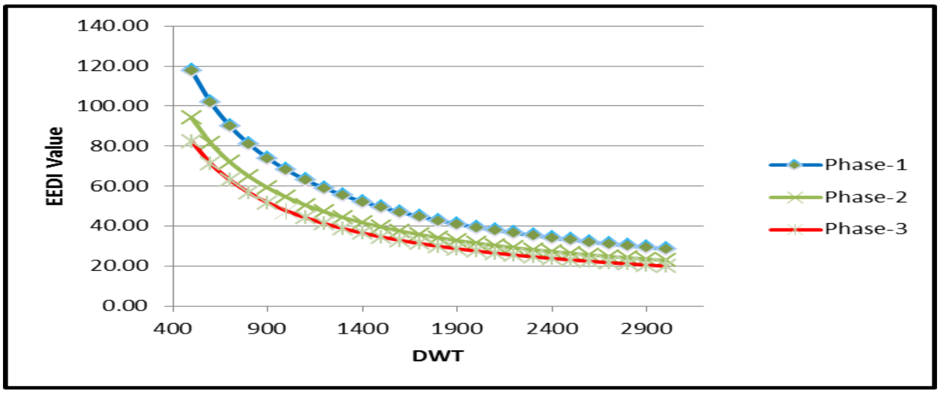

Figure 1: Phase wise EEDI Reference lines for inland Cargo Vessels

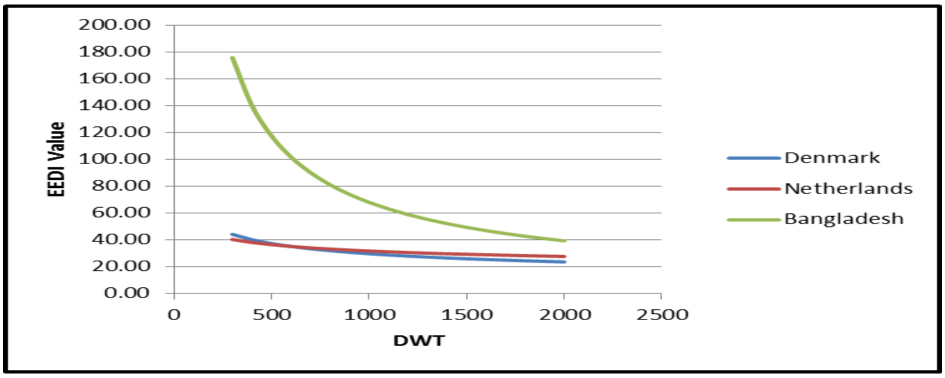

Figure 2: Various countries inland vessels EEDI reference lines for Cargo Vessel

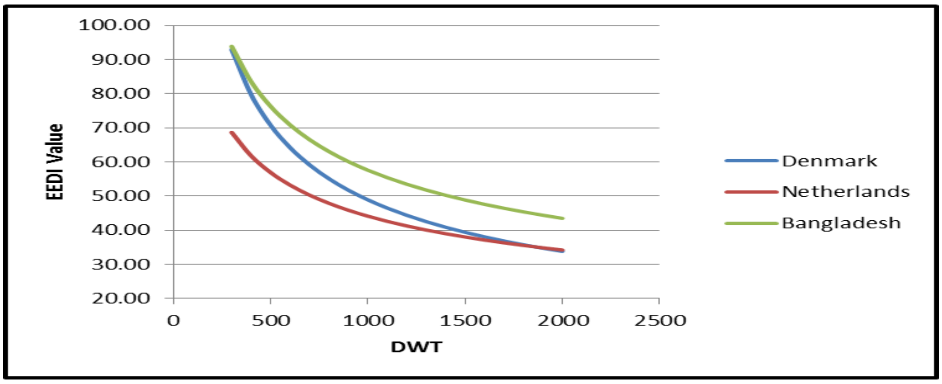

Figure 3: Various countries inland vessels EEDI reference lines for Oil Tanker

5.0 PRESENT STATUS OF INLAND VESSELS WITH RESPECT TO EEDI

There are more than 10,000 inland vessels plying in the waterways in Bangladesh but still there is no regulation for energy efficiency for these vessels. In this section, overall performance of existing vessels in terms of formulated value of EEDI will be examined. On the other hand, EEDI reference value will be more stringer in coming year. As a result, the performance of these vessels in terms of EEDI for Phase 2 & 3 have also been assessed to get clear picture of inland fleet in Bangladesh in case of enforcement of such stringent rule in near future.

Present status on EEDI with respect to vessel's length for cargo vessel has been shown in Figure 4. From this Figure, it has been observed that in Bangladesh most of the inland cargo vessels length is between 51 to 55 m. In this range there are presently 262 vessels out of them 85 vessels pass in terms of EEDI which is 32.5% of the total vessels of that range and EEDI exceed the required value in Phase 1 for rest of the vessels. For other phases, more vessels exceed the required EEDI value. It has been also observed that larger length vessels EEDI lies below the reference line. That means bigger length vessels are more efficient in terms of EEDI.

Present status on EEDI with respect to vessel's length for oil tanker has been shown in Figure 5. From this Figure, it has been seen that in Bangladesh most of the inland oil tankers length is between 31 to 50 m. In this range, around 50% of the total vessels have passed in terms of EEDI and the rest of the vessels exceed the required value of EEDI in Phase 1. As the phase increases more vessels exceed the required EEDI value. In vessel's length between 51 to 60m, most of the vessels EEDI exceed the reference line. In case of vessels length range between 61 to 80m, there is no such vessel which meets EEDI reference line.

Present status on EEDI with respect to vessel's length for Passenger Vessel has been shown in Figure 6. From Figure 6, it has been found that in Bangladesh most of the inland passenger vessels length is between 41to 60m. In this range there are presently 69 vessels, out of them 42 vessels pass in terms of EEDI which is 60.8% of the total vessels of that range and the rest of the vessels EEDI exceed the required value in Phase 1. It has been also observed that larger length vessels EEDI lies below the reference line. However, in vessels length range between 71 to 90m, there is no such vessel which meets EEDI reference line.

Present status on EEDI for sand carrier has been shown in Figure 7. From Figure 7, it has been observed that in Bangladesh most of the inland sand carrier length is between 31to 35m. In this range there are presently 1729 vessels out of them 860 vessels pass in terms of EEDI which is 49.7% of the total vessels of that range and the rest of the vessels EEDI exceed the required value in Phase 1.

Overall, from Figures 4 to 7, it has been observed that with respect to vessel's length, in Phase-1, 40% vessels have been passed in terms of EEDI and 60% vessels have been failed. In Phase-2, 17% vessels have been passed in terms of EEDI and 83% vessels have been failed. In Phase-3, 9% vessels have been passed and 91% vessels have been failed.

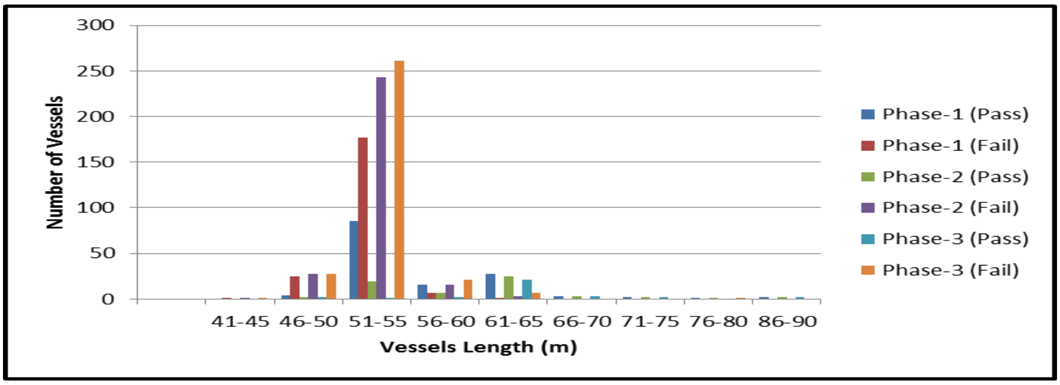

Figure 4: Present status on EEDI with respect to vessel's length for Cargo Vessel

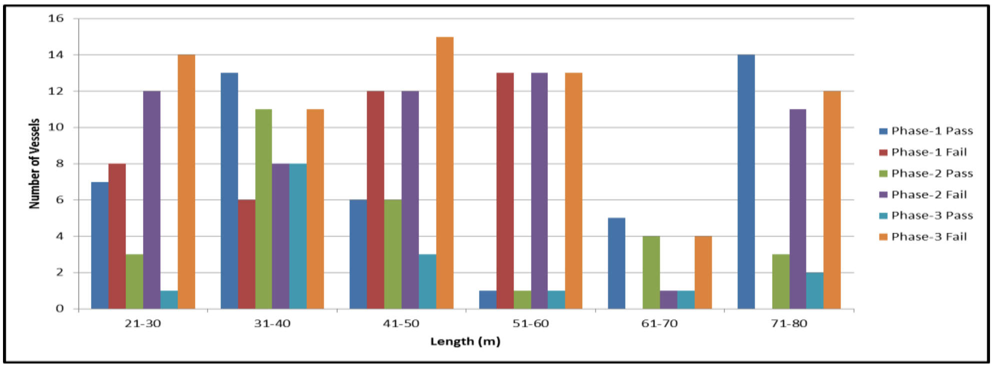

Figure 5: Present status on EEDI with respect to vessel's length for Oil Tanker

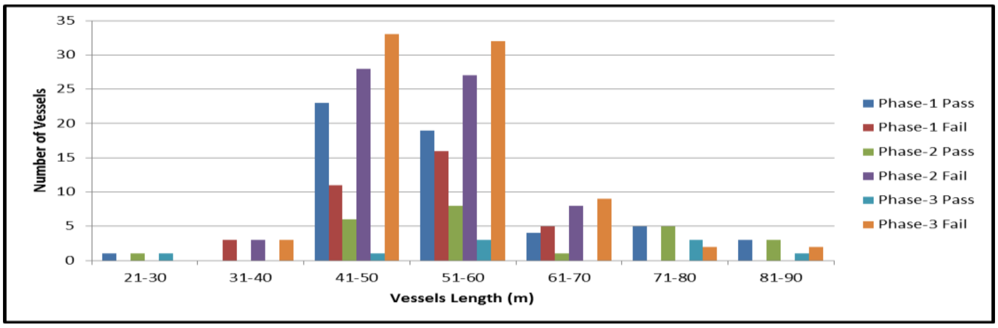

Figure 6: Present status on EEDI with respect to vessel's length for Passenger Vessel

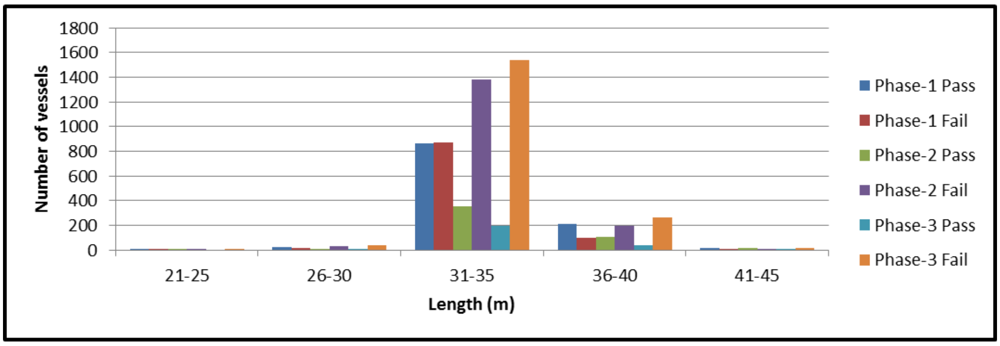

Figure 7: Present status on EEDI with respect to vessel's length for Sand Carrier

6. 0 CAUSES OF POOR PERFORMANCE AND SOME RECOMMENDED REMEDIAL MEASURES

According to the statistics of the previous section, it has been confirmed that overall scenario of inland vessels in terms of CO_2 emission is very poor. At present neither are there any rule exists nor are the designers aware of the fact about EEDI for designing inland class vessels. Even from the some case study, it is seen that the Class vessels registered for plying in inland routes in Bangladesh are not fulfilling the requirements of EEDI [14].

In case of Bangladesh, it is very difficult to improve poor performance of EEDI for existing ships in Bangladesh. However, the causes of such poor performance in terms of EEDI for existing vessels are given below:

- Existence of higher number of indigenous ship which are poor in design
- L/B ratio low
- Choice of low cost main engine which has relatively high fuel consumption.
- Very poor engine propulsion system
- Relatively high power main engine due to restriction of draft or shallow water effect

- Increase of the hull weight due to using scrap steel for construction materials
- Unconsciousness about current rules and regulations regarding energy efficient vessels

Generally, there are two options to improve or meet the EEDI requirement, one is technical and other is operational. Technically, reductions potential at individual measure level can be grouped under five main categories: hull design, power and propulsion, alternative fuels, alternative energy sources, and operations [1]. From the operational perspective, EEDI requirement could be met by energy optimal operation through adapting voyage optimization and improving logistics and also by reducing speed. It is found from the study that no single measure is sufficient by itself to reach considerable sector-wide reductions, rather a significant emission reduction over 75% is achievable by swift adoption and combination of a large number of individual dependent and independent measures [1].

In case of improving EEDI efficiency for existing ships of Bangladesh, due to the social and economical factors, there is a tendency to construct inland ship by using low cost materials which can save up to 30-40% of total construction cost [15]. According to inland ordinance of shipping in Bangladesh, it is allowed to use scrap plate & structural member collected from scrap ships and in that case scantlings of the plates needs to be increase 25% [16] and when the vessels are designed for coastal route trade, scantling of the plate needs to be increased additionally another 20%. It is found from the sample calculation of inland shipping weigh estimation that due to using scrap plate and structural member, overall weight of the ships may increase 5-10% and this overweight makes the fuel consumption higher. Even many ship owner use casting propeller which is made from taking replica from other propeller of ship without sufficient technical know-how. These types of propeller are very cheap compared to imported one. But, the propulsion system is not efficient and consequently, there is a tendency to use high power engine without bothering the fuel consumption of the ship.

From the sample case study of different types of existing vessels as shown in Table 2, it is seen that keeping the displacement constant it is possible to improve CO_2 emission by adjusting principal particulars of the vessels particularly by improving L/B ratios, lowering B/T ratios, making the ship finer and reducing speed of the vessels. From the calculation, it is found that increasing L/B ratios from 10%- 20%, EEDI is improved only 2 to 10%. Again keeping the draft of the ship constant, it is seen that lowering B/T ratio around 5 to 10%, will improve EEDI value 2.3 to 11%. Again, decreasing C_B around 5 to 10%, EEDI is increased around 8 to 28% and whereas reducing speed from 0.5 to 1.0 knot, EEDI is improved 8.5 to 29%. From this calculation of three different types of inland ships in Bangladesh, it is confirmed that speed is the most sensitive parameter that have the greatest impact on EEDI. In case of new ship, all the parameters can be considered for improving EEDI, but in case of existing ship without modification, the scope of modifying principal particulars is very difficult.

It is also confirmed that most of the inland standard ships of different types use high speed low cost engine where the fuel consumption for new engine is relatively high. When the engine becomes older, the fuel consumption of the engine further increases. This will definitely impact the EEDI performance in the long run. It is possible to choose engine with fuel consumption relatively low and in that case EEDI performances improves a lot [14].

Table 2: Particulars of different types of inland ships

Type	L/B	B/T	C_B	Displacement (Tonne)	EEDI (Attained)
Tanker	6.10	2.50	0.857	4086	36.35
Cargo	4.86	3.94	0.857	3559	23.09
Passenger	5.97	7.65	0.85	1220	25.32

From the data collection regarding awareness of recent EEDI regulations for international shipping, it is found that many of the design houses along with ship designers are not aware of the fact that some stringent regulation regarding improvement of CO_2 emission for ships has come into force from 2013 and it will have serious impact in choosing and selecting hull and machineries in future ship design.

However, of all the measures, reducing ship speed can be good option for existing vessels in Bangladesh since it does not require any additional cost or any investment for improving technological development. Other options that may be suitable for inland vessels in limited scale are using renewable energy sources or switch to LNG fuel. But both are technically and economically challenging as it involves cost. From the case study of existing different types of inland ships, it is found that switching the fuel from diesel oil to LNG could improve the EEDI from 12.5% to 18.5% in terms of EEDI [14]. In case of reducing speed, it is important to note that already inland vessels' speed is low, mostly in the range of 8-10 knots. So, without strong motivation or adopting some mechanism from regulatory point of view, there is a little chance to reduce speed further. It is worth to mention here that many of the ships are already very old. So, phasing out of all very old aged ships phase by phase by adopting some policy guidelines could be a possible alternative.

7.0 CONCLUSIONS

In this study an assessment based on the formulated reference line for inland shipping in Bangladesh has been made in order to provide deep insight regarding status of CO_2 emission in terms of Energy Efficiency Design Index for existing operating vessels in Bangladesh. The following conclusions can be made on the basis of the study:

- Since the EEDI introduced by IMO for evaluation of energy efficiency of sea going vessels can't be used for proper evaluation of energy efficiency of inland vessels, developed EEDI can be used to calculate required EEDI value for different types of inland vessels in Bangladesh.
- Comparing the formulated EEDI baseline equations for Bangladesh with the lines formulated by other countries like Denmark & Netherlands, it is found that EEDI line for Bangladesh lies much above than that of other countries.
- From the investigation of developed database of inland vessels, it is found that most of the inland vessels in Bangladesh use higher main engine power than the required power found from the calculation. This arbitrary engine selection leads to higher EEDI value and thus inland shipping contributes to release relatively higher amount of CO_2 to the environment. Among the studied results, it has been found that passenger ferry shows the worst performance in terms of CO_2 emission.
- Since use of second hand materials increases the weight of main hull of the ship and thus increases power requirement as well as fuel consumption, so for the sake of more energy efficient ship, this practice should be discouraged.
- The EEDI is particularly sensitive to the service speed as the required power increases by roughly the cube of the variation in service speed. So, reducing service speed is the only viable option to improve EEDI for existing ship in Bangladesh from environmental point of view.
- The work present in this paper could provide more insight on emissions and energy efficiency in inland shipping of Bangladesh and could be useful for policy makers in assessing the industry to find out some cost-effective solutions or develop some regulations in order to reduce CO_2 emission from the inland shipping in Bangladesh.

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