Speed-Cost Analysis of Inland Water Passenger Transport in Bangladesh

By

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CERTIFICATION OF APPROVAL

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It is hereby declared that this thesis work or any part of it has not been submitted elsewhere for the award of any degree or diploma.

Dider Ahmed

To The Almighty

To My Parents

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ABSTRACT

In passenger transporting, waterways are the safest and cheapest means of transport system worldwide. It has been pragmatic in recent years that in Bangladesh this transport system are suffering the insufficiency of passengers or unable to attract more passengers to travel on vessels for which many reasons can be pointed out; while there is a abundance of passengers on road transport. Though Bangladesh is a reveric country, the potentiality of its rivers has not been utilized properly. Its water transport system is still very much ordinary if it is compared with the road transport. The conveniences in the journey are not growing up with the same pace of road transport. But there is still a lot of demand for water transport among people. Water transport must create an attention of the passengers for many reasons such as to provide cheap, relaxed and economical journey; to lessen traffic congestion on road and thus to reduce heavy road and rail network infrastructure development and maintenance cost.

In this project work, Journey time by water vessels has been considered as one of the parameters which are vital factors on drawing the attention of passengers. For a fast journey, a vessel needs to have a better speed. Increasing the speed of a vessel will also make the operational cost high. It has been tried here to find the minimum Required Fare Rate (RFR) of a conventional vessel, the RFR that will make the journey time on water equal to that of road on a specific route. From the RFRs on water and road, it will be possible to have a suggestion about the present conventional passenger vessels regarding whether they are suitable to compete with road vehicles.

A model passenger vessel has been chosen for this purpose. Theoretical naval architectural procedures have been followed to determine its hydrostatic properties and also the resistance of this vessel has been determined to indicate the required output power of prime movers. An estimation of construction and other operating cost of the vessel have been made to get the RFR and then it has been compared with road transport.

Current state of passenger vessels and water transportation gathered by interviewing related community has been discussed here. This should provide a basic ground up on which further workings might be carried on.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND AND PRESENT STATE OF THE PROBLEM

Bangladesh is a land of river and her rivers are the lifeline of the nation which provides the cheapest means of transportation. The country has about 5968 k.m. of perennial (Rainy season) & 3600 k.m (Dry Season) water ways [1] & [2]. Over 88.6 million passengers are carried each year over waterways by motor launch on 230 routes [1] & [2].

Total of 310 numbers of rivers and numerous canals of Bangladesh made it possible for inland passenger vessels to be the number one transport system of choice for some special regions of this country [2]. But recently, other mode of passenger transport such as road is playing a significant role in this area. The reason of this growth may be attributed to lesser time taken by road vehicles in comparison with water vessel. That's why people prefer road to water transport.

As per Bangladesh Inland Water Transport Corporation (BIWTC) and Bangladesh Road Transport Corporation (BRTC), the fare rate for water and road transport is Tk.0.51 and Tk.1.05/passenger-km respectively [2]. Now, if we consider a specific route, say Dhaka to Barisal, for both water and Road, the distance is 174.0 km on waterways [1] and 249 k.m on road including a ferry crossing [3]. Average speed in both cases is approximately 17.4 km/hour and 50 km/hour considering the present time of journey for water and road is 10.0 and 6.0 hours respectively.

In spite of having a lower fare rate than that of road, water transport remaining at the same old position, is loosing its competitive edge with road transport. not being able to provide less time of journey with conventional speed. It may be noted from above discussion that journey time on water is much higher than that of road. Since year 2002-03, the volumes of passenger movement by waterways and total number of registered passenger vessel are decreasing, while for road, these numbers are increasing [2] & [3].

Now, if the passengers are to be attracted to waterways for an economic and contented journey, inland water passenger transport must achieve an enhanced speed to compete with road vehicles. As higher speed reduces the time of journey, an effort may be carried out to improve the speed of our inland passenger vessel. Obviously it increases the operating cost due to higher rate of fuel consumption/km. But there is still a provision to allow this higher cost because apparently the present fare rate for water is much less than that of road.

The main focus of the current project work is to find out the optimum speed for which the water transport fare rate equals that of road transport. It may be noted that water transport is more environmental friendly than road transport [7]. If large number of passenger movement occurs by water transport, then it would help reducing traffic overcrowding on road as well as the environmental pollution.

1.2 OBJECTIVE OF THIS PROJECT

The main objective of this study is:

- to find the optimum speed of a specific passenger vessel based on fuel consumption and other operating expenses in comparison to road transport.
- to calculate minimum required passenger fare that might make the water transport feasible.

The outcome of the proposed study would be a feasibility report that would recommend whether the project is viable in fulfilling passenger demand that would attract them to use water transport as first priority.

1.3 OUTLINE OF METHODOLOGY

The study has followed the steps outlined bellow:

1. Selection of a passenger ship as model that is plying in waterways presently and then determining its overall acquisition and operational cost to find out the minimum Required Fare Rate (RFR).
2. Assessing capital amortization using Net Present Value (NPV) of equal annual payments and scrap value of the ship.
3. Estimation of optimum speed against a specific RFR and to compare it with that of road transport.

CHAPTER 2

ANALYSIS OF PRESENT CONDITION

2.1 STATISTICAL HIGHLIGHTS

Some of the recent data available from Bangladesh Bureau of Statistics (BBS) can be analyzed and presented in tabular form here to have a better understanding of the scenario involved in water and road transport sector of Bangladesh.

Table 2.1: Summary of value added of transport sector at current price

For public sector (Million Taka)

Items	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Land Transport:	**188693**	**240961**	**268602**	**293742**	**328407**	**368526**	**409120**
Bangladesh Railway	3450	3252	3566	3812	3895	4137	4411
Mechanized Road Transport	122601	167236	188815	206496	230122	258759	286206
Non-Mechanized Road Transport	62611	70473	76221	83434	94390	105630	118503
Water Transport:	**27245**	**27925**	**28857**	**29941**	**31370**	**33067**	**34860**
Mechanized water Transport	18698	19681	20937	21801	22916	24291	24294
Non- Mechanized Road Transport	8547	8244	7920	8140	8455	8776	9106
Total (of all transport and communication sectors)	255237	311122	344442	382890	432057	49084	548274

Source: Bangladesh Bureau of statistics, Statistical Yearbook of Bangladesh. 2008

This table shows the amount of value added by water and land transport. There are other sectors contributing to value addition to this table such as Air transport, Communication. Support Transport Services and Storage. From this table it is seen that water transport lags far behind the road transport in recent years in terms of value addition to transport sector. So, there is a lot of potentiality to improve the contribution of water transport by utilizing river ways properly.

Table 2.2: Rate of Fare and Freight of different modes of transport (public and private)

Name of Transport corporation	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Fare in Taka per passenger per kilometer.							
BRTC	0.62	0.72	0.72	0.72	0.78	0.87	1.05
BIWTC	0.26	0.29	0.29	0.29	0.42	0.42	0.51
Freight per ton per kilometer in Taka							
BRTC	1.50	1.50	1.50	1.50	2.47	2.58	3.04
BIWTC	1.25	1.25	1.25	1.25	1.25	1.25	1.25

Source: Bangladesh Bureau of statistics, Statistical Yearbook of Bangladesh, 2008.

BRTC: Bangladesh Road Transport Corporation.

BIWTC: Bangladesh Inland Water Transport Corporation.

This table shows that the fare rate for passenger and freight rate for cargo carrying are much less in water transport than in road transport, for the public sector.

The Fare rate of passenger vessel for private sector, fixed by BIWTA, is as follows [4]:

For 1st 100 km:

Deck Class: 1.18 taka/k.m.

1st Class: 3.54 taka/km

For Excess of 1st 100 k.m:

Deck Class: 0.88 taka/k.m.

1st class: 2.64 taka/ km

In actual practice passengers don't pay the fare as decided by BIWTA. In fact, the owners take much less fare than that is shown above, due to their business policy.

Table 2.3: Transport Statistics

Source/ Capacity	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08
Organized Road Transport:							
Bus/Minibus	**29717**	**31848**	**33302**	**34388**	**35349**	**36526**	**37906**
Micro-Bus	14743	16244	17359	18826	20998	23637	26484
Trucks	48763	50786	52951	55082	57399	59674	61717
Jeep	10790	11009	11172	11386	11704	12090	12506
Organized Water Transport:							
BSC vessel nos	-	13	13	13	13	13	-
BIWTA vessel nos	-	208	194	194	194	195	-
Private Vessels:							
Cargo	-	1647	1795	1842	1853	1898	-
Passenger	-	**2136**	**2119**	**2095**	**2082**	**2075**	-
Total	-	3783	3914	3937	3935	3973	-

Source: Bangladesh Bureau of statistics, Statistical Pocket Book and Statistical Yearbook of Bangladesh, 2008

BSC: Bangladesh Shipping Corporation

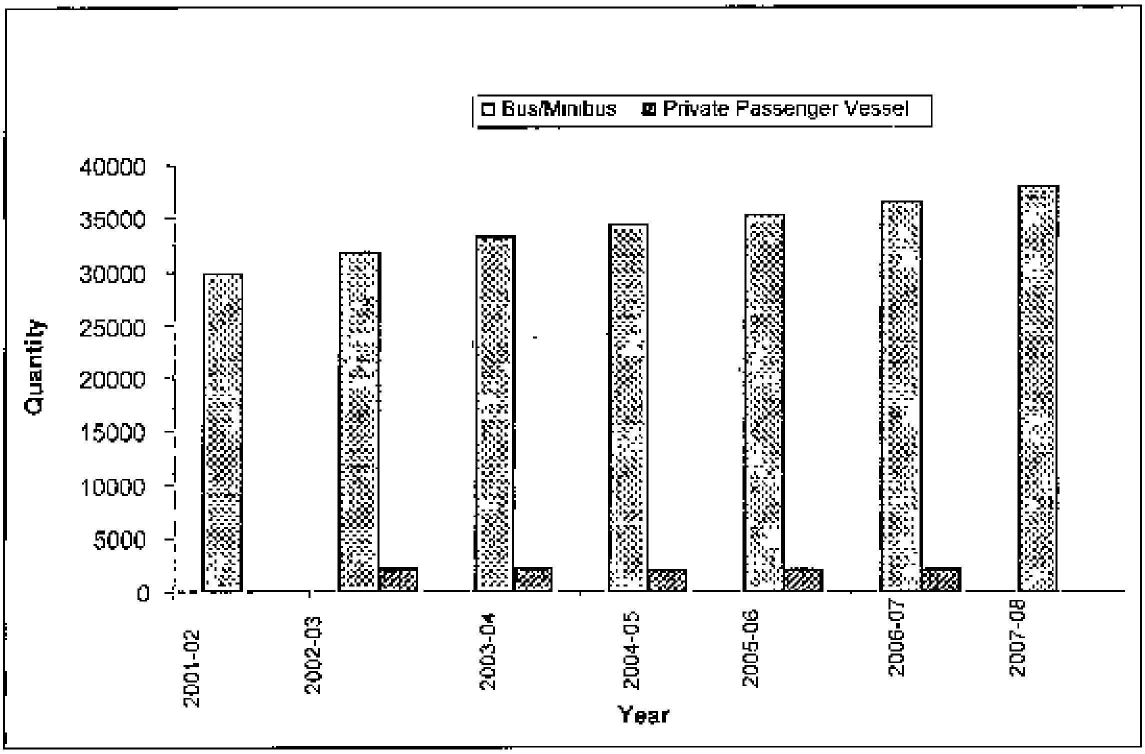

Figure 1: Transport Statistics: Road Vs Water

From this bar chart, it can be noticed that the number of Bus/ minibus on roads are increasing over recent years, but the number of private passenger vessels are decreasing while this number should have been increased also, if not the same. This implies that the demand of water transport is reducing day by day and the same is increasing on road or people are diverting from water to road transport.

2.2 EXPOSURES ON PRESENT WATER TRANSPORT CONDITION

Many important aspects of existing water transport and vessels have been figured out by interviewing few officials, learned and experienced persons involved in this sector. These are discussed below:

2.2.1 SIZE OF PASSENGER VESSELS

There is still a lot of demand among people for water transport. But journey on water has to be safe, comfortable and speedy to attract passengers. In past few decades marine accidents (Capsizing of ship, Collision etc) are one the major concerns among the people, though the number of accidents are less than that on roads. But due to large number of casualty in a single accident, usually occurred with smaller vessels, people have fear in their mind about water transport. Relatively small sized vessels are more vulnerable to marine accidents. That's why adequate number of passengers is not available to journey on them to make the trip profitable. So, relatively large sized vessels are replacing the smaller sized vessels resulting in contracting the total number of passenger vessels. But big size vessels are not suitable to ply in every corner of the country over narrow and shallow river ways in many locations. Also, larger size vessels take longer time to reach the destination.

2.2.2 NUMBER OF PASSENGER VESSELS

Number of passenger vessel needs to be increased as it will reduce traffic volume on roads and thus potentiality of rivers are used. It will help taking away pressure from road transport. After the construction of proposed Padma Bridge, traffic volume is likely to increase on that route. If a modern and timely water transport system is in operation, then it will help to reduce traffic volume on road attracting people for a safe and comfortable journey on water. Presently, according to many people, the business of water transportation is down comparing past days as (a). Price of marine fuel is high, (b). Fare rate can't be increased. This leads to reducing the number of passenger vessels. In these conditions, there is a necessity to balance between government fund allocation on road and water transport.

2.2.3 DESIGN OF PASSENGER VESSELS

Inappropriately designed relatively small vessels are vulnerable to accident. But big size passenger vessels will cause trouble to other vessels at daytime if it plies with high speed on river as it will make large wave in water of which other small vessels might not withstand. At night, larger vessel may run on rivers with high power engine(s) with high speed because of less traffic on rivers at night. Smaller vessels could be solution to this problem. So the stability and safety of small vessel have to be ensured. Also, small vessels can achieve high speed easily if they are constructed with a fine hull shape. But a vessel with fine hull shape needs more depth at midship for retaining the stability. On the other hand, depth of the rivers restricts the vessels to have a proper design that could ensure sufficient stability. Draught of a vessel is one of the main components on which stability of a vessel depends. Inadequate depth of the rivers does not allow the vessel to ply with sufficient draught. This makes problem for the vessels regarding stability.

However, appropriately designed small vessels can come into operation for a speedy and safe journey.

2.2.4 NAVIGABILITY OF RIVERS

Due to natural causes, vast amount of silts are carried each year by rivers of Bangladesh which leads to gradual filling of navigable routes in rivers. To keep this water route navigable all the year round, dredging is necessary. Dredging works are expensive and the fund allocated for it is not sufficient [4]. This causes a serious problem for water transport. So it will be helpful to build/ design vessel compatible with shallow draft.

2.2.5 PASSENGERS' RESPONSE

As safety, comfort and time are the main characteristics of which passengers are concerned; they might be willing to pay a higher Fare than road fare. Properly designed small passenger vessels might be suitable for these.

2.2.6 GENERAL PRACTICES

In order to have a safe journey, certain rules and regulations have to be strictly followed such as:

-Rules for passenger loading and distribution have to be strictly followed.

-Life saving appliances has to be on board according to rules.

-Ship construction methods in local shipyard need to be modified.

-awareness among the passengers has to be raised.

-skilled sea cane and engine drivers. mechanized steering and rudder arrangement. appropriate propeller, estimation of power of the ship are necessary.

- using of correct scantlings and new steel plates

- Passenger Life needs to be insured on water instead of just compensation. Presently, ship owners are unwilling to get insurance for their ship due to high amount of premium.

-ship owners have to come up with up to date design concepts of their vessels that will meet all the requirements.

-Hull shape of present passenger vessels is not suitable to achieve a good speed because of faulty construction process such as absence of Lofting works and modern construction methods. If the hull shape is not properly designed and constructed according, the ship will encounter extra amount of resistance during service. This makes the final construction and operation cost high.

2.2.7 TIME OF JOURNEY

For long distance, such as Dhaka to Barisal, usually passengers are not willing to travel in day time. Most of passengers in that route are of deck class. They seek to travel for the lowest amount of fare. That's why they prefer decks of passenger vessel for an overnight journey so that they can utilize daytime for their work. If the journey time can be reduced, they might travel in daylight. They are likely to pay a higher amount of fare for a safe and speedy journey.

2.2.8 NEW CONCEPTS AND IDEA

There are not much alternatives for present conventional type vessels due to some natural constraints and socio-economic state. So, innovative ideas and concept in all the aspects are needed. Shifting from conventional ship design concept to modern and scientific concept, such as following models from other countries that are successfully operating their inland water passenger transport can be a good idea.

CHAPTER 3

DESCRIPTION OF TERMS AND METHODOLOGY

3.1 PRINCIPAL TERMS USED FROM NAVAL ARCHITECTURE

Naval architecture like all subjects has terms unique to itself. It is convenient to have a terminology and shorthand in the form of abbreviations and symbols. It is essential in the study of the subject to have a clear understanding of the meaning of various terms, abbreviations and the symbols used.

Displacement (Δ):

The weight of water displaced by a vessel. Displacement volume=$\Delta \times 35$ for salt water or $\Delta \times 35.9$ for fresh water (river water). Either V or reverse symbol Δ is used for displacement volume [5].

Lines Drawing:

The delineation of the ship's form in three planes or views. The longitudinal elevation is known as profile. The transverse sections are shown in the body plan and the horizontal sections in the half-breadth plan [5].

Offsets:

The horizontal and vertical distances of points on the moulded surface (i.e. the co-ordinates from reference planes). A table of offsets gives the half breadth at every station for each waterline and for the various decks. It also gives the heights of the buttocks and decks at each station above some suitable datum such as the top the keel amidship.

Midship Section:

The transverse section midway between the fore and aft perpendiculars.

Mid ship Section coefficient (C_m):

The ratio of the immersed Midship area A_m to its circumscribing rectangle, that is, C= A ÷ B.d. where **B** is the moulded breadth and **d** is the moulded draught [5].

Breadth (Moulded) B mld:

It is measured at amidship and is the maximum breadth [10].

Fore body:

The immersed body forward of the Midship section [10].

After Body:

The immersed body aft of the Midship section.

Load Water Line (L.W.L):

The load water line is the line at which the vessel is designed to float with the specified load or conditions [5].

Draught Moulded (d mld):

It is the distance of the top of the keel below waterline [10].

Depth Moulded (D mld):

It is the vertical distance at amidships from top of keel to the top of the deck beam at side or underside of deck plating at the ship side [10].

Perpendiculars:

Verticals to the water lines at two positions forward and aft. The fore perpendicular **(F.P)** is usually taken through the intersection of the fore edge of the stem and the summer load line. The aft perpendicular **(A.P)** is taken where the aft side of the sternpost meets the summer load line, or, if there is no sternpost, at the center of the rudder post. These positions correspond with those required by the Rules for the determination of scantlings and make the Length Between Perpendiculars **(L.B.P.)** [5].

Block Coefficient (C_B):

It is the ratio of the volume of displacement to a given waterline and the volume of the circumscribing block of constant rectangular section having the same length, breadth and draught as the ship [10].

Prismatic Coefficient:

The ratio of the immersed volume to the area of the Midship section multiplied by the water line length. That is $C_p = \nabla \div L \times A_m$ where A_m is the Midship section area [5].

Tons Per Inch:

The additional displacement in tons for one inch additional immersion [5].

Trim:

The difference between the draughts of water forward and aft [5].

Change of Trim:

The alteration of trim due to the addition, removal or movements of loads or from other causes is called the change of trim.

Centre of Floatation (CF):

It is the centroid of the waterplane area. For small angles of trim consecutive waterlines pass through the CF [10].

Centre of Buoyancy (B):

It is the centroid of the underwater volume of the ship and is the point through which the total force of buoyancy can be assumed to act. Its position is defined thus:

a. KB= the vertical distance above base.

b. LCB = the longitudinal distance from amidships [10].

Centre of Gravity (G):

It is the point through which the total mass of the ship may be assumed to act. The position is defined thus:

a. KG= the vertical distance above base.

b. LCG = the longitudinal distance from amidships [10].

Hydrostatic Curves:

For various purposes during the completion of a ship and for future design purpose it is essential to plot the results of the displacement and other calculations in relation to the draught. Such curves are called the hydrostatic curves and the most important are:

a. Displacement in tones (Δ)
b. Vertical Center of buoyancy (KB or VCB).
c. Longitudinal center of buoyancy (LCB).
d. Tons per inch (TPI)
e. Transverse metacentre (BM_T)
f. Longitudinal Metacentre (BM_L)
g. Longitudinal Centre of Floatation (L.C.F):
h. Moment to change trim 1 inch (MCT1):
i. Form Coefficients: Block, Prismatic, Midship Area, Water plane area [9].

Lightweight:

This generally defined as the weight of the ship complete and ready for sea but with no fuel, feed water, fresh-water, stores, provisions, ballast-other than permanent ballast-passengers and baggage or cargo on board [9].

Deadweight:

The total deadweight of a ship is the difference between the load displacement and the lightweight. The latter comprises the net steel, wood and outfitting and propelling machinery. Consequently the total deadweight includes:

a. Cargo.
b. Fuel.
c. Feed and Fresh water.
d. Stores and provisions.
e. Passenger and Baggage.

Thus,

Displacement = Lightweight + Deadweight.

Sometimes the crew and effects are included in the deadweight [9].

Waterplanes:

These are planes at right angles to the middle line plane; they are symmetrical about the middle line plane. Waterplanes looked at edge on in the profile are called waterlines [10].

Freeboard:

The vertical distance between the actual or permissible waterline and the upper surface at side of the deck to which it is to be measured [10].

Scantlings:

The dimensions and thickness of rolled sections and the breadth and thickness of plates which together compose the ship's structure or part of same [10].

SI units:

SI is the accepted abbreviation for the International System of Units agreed at he General Conference of Weights and Measures in 1960. The system is an extension and refinement of the traditional metric system.

Quantity	Unit	Unit symbol
Length	Metre	m
Mass	Kilogramme	kg
Time	Second	s
Force	Newton	$N = kg\ m/s^2$
Work	Joule	$J = N\ m$
Power	Watt	$W = J/\ s$

Resistance:

A ship in motion encounters two fluids, water and air, both of which offer resistance to the motion. The resistance exerted by the water is very much greater than that exerted by the air. The study of resistance, in naval architecture, has been based on experience, experiment and theory.

The principal elements contributing to the resistance to motion of a ship in smooth water are:

a. Skin friction drag due to the friction of the water upon the surface of the ship.
b. Wave-making resistance, representing the energy applied by the ship to the wave system generated on the water surface.
c. Eddy resistance due to the energy carried away by eddies formed around stern fittings, bossings and sudden changes in hull section.
d. Air resistance experienced by the above-water structure advancing through the water [9].

Power:

Power is the rate of doing work and the unit of power is a horse power which is exerted when work is done at 550ft-lb/sec or 33000 ft-lb/min.

The unit of speed for a ship is the knot which is one nautical mile 6080 ft/hr. Thus V knots= $V \times 6080/60 = V \times 101.3$ ft/ min.

When the total resistance R_t necessary to maintain the given speed V is known, the power expended in overcoming this resistance will be R_tV [9].

Statutory Requirements:

All inland ships which have over all length of more than 20 meter and a propulsion unit of more than 12 kilowatt and are built by steel have to follow few specific rules and regulations under the title "Inland Shipping Ordinance 1976". These laws and rules have been modified up to March. 2005. The headings of these rules are:

1. Inland Ship construction Rules-2001.
2. Inland Ship (Passenger) Rules-2001.
3. Inland Ship (Freeboard) Rules-2001.
4. Inland Ship (Stability) Rules-2001.
5. Inland Ship (Life Saving) Rules-2001.
6. Inland Ship (Fire Fighting) Rules-2001.
7. Inland Ship (Navigation) Rules-2001.
8. Inland Ship (Dangerous Goods) Rules-2001..
9. Inland Ship (tonnage) Rules-2001 and few more.[11]

3.2 ECONOMIC CRITERIA

There are a number of different economic criteria which may be used to assess the likely success of a shipping investment or to compare the profitability of alternatives. These criteria should take account of:

-the time value money.

-the full life of the investment,

-changes in items of income and expenditure which can be expected over the life,

-the economic facts of life such as interest rates, taxes, loans and investment grants.

The time value of money represents the facts that a sum of money available now is of much more value than the same sum not available for a number of years.

Interest (or discount rate) in fundamental to the calculations whether there is a need to borrow or not. This takes account of the fact that if available cash is used the interest it might have earned is being foregone [11].

Interest:

This may be simple or compound and the following relationships apply:

-Simple interest

Total repayments after N years: $F = P\ (1+N.i)$ ……………… *(3.1)*

-Compound Interest

Total repayments after N years: $F = P\ (1+i)^N$ ……………………… *(3.2)*

$(1+i)^N$= Compound amount factor *(CA)*

P = Original Investment

Present Worth:

The reciprocal of *CA* is called the present worth *(PW)* factor.

$PW = 1/(CA) = (1+i)^{-N}$ …………… *(3.3)*

$P = (PW)\ F$ ……………………………… *(3.4)*

Repayment of Principal:

If the loan is repaid by annual installments of principal plus interest, this may take two forms:

a. principal repaid in equal installments with interest being paid on the reducing balance; or

b. Equal annual payments with interest predominating in the early years and capital repayments in the later years.

The concept of equal annual payments enables a present sum of money to be converted into an annual repayment sum spread over a number of years with the annual sum A being linked to the sum invested—the *"present sum P"* by the capital recovery factor *(CR)*

$$A = (CR)\,P \quad \text{and} \quad CR = \frac{i(1+i)^N}{(1+i)^N - 1} \qquad \ldots\ldots\ldots\ldots\ldots\ (3.5)$$

Net Present Value:

In this type of calculation the net present values (NPV) of income and expenditure are calculated over the assumed life of the ship (N) years. The final sum should be positive for the investment to be profitable at the assumed discount rate—or where alternatives are being compared it should be the larger sum.

NPV = $\sum$ [PW (passenger capacity× fare rate) - PW (operating cost) - PW (ship acquisition cost)] from 1 to N years. .... *(3.6)*

Required Fare Rate:

The required fare (RFR) is that which will produce a Zero NPV, i.e. the break-even rate. Transposing the equation above gives:

$$RFR = \sum_{1}^{N} \frac{PW\left[(operating\ cost) + PW\ (ship\ acquisition\ cost)\right]}{Passenger\ Capacity}$$

.... *(3.7)*

3.3 INPUT DATA

a. Description of the Model Ship

Principal Particulars :

Length O.A	:	73.64	m
Length LWI	:	68.07	m
Breadth (MLD)	:	11	m
Depth (MLD)	:	2.335	m
Draught (LOADED):		1.4	m

Table 3.1: Offset Table of Lines Plan

Half Breadth				
Station. No	**WL-1**	**WL-2**	**WL-3**	**WL-4**
0	0	0	0	0
0.5	0	0	3027	4930
1	0	3711	4962	5395
1.5	3913	5063	5352	5465
2	4954	5358	5483	5500
3	5313	5483	5500	5500
4	5313	5483	5500	5500
5	5313	5483	5500	5500
6	5313	5483	5500	5500
7	5313	5483	5500	5500
8	5096	5285	5359	5419
8.5	4448	4826	5051	5203
9	2527	3628	4167	4549
9.5	695	1576	2350	2991
10	0	0	0	0

Table 3.2: Hydrostatic Properties of the Vessel

Draft (M)	Displacement (Tonne)	KB (M)	C_B	TPC (Tonne)	BM_L (M)
0.350	110.1008	0.2936	0.4810	5.4785	1139.866
0.700	326.5903	0.4260	0.6715	6.0794	491.6416
1.050	541.4292	0.6164	0.7119	6.5781	373.6700
1.400	784.7065	0.7944	0.7485	6.8753	290.2724

Draft (M)	LCF (M)	MCT1cm	AWP	LCB	BM_T
0.350	-1.170	21.10984	547.853	-0.589247	42.497
0.700	-0.6029	25.4224	607.935	-0.4292	17.0479
1.050	0.5606	30.7242	657.812	0.3435	11.1209
1.400	1.0349	33.4614	687.529	0.6940	8.2945

b. Service Speed of 9 knots to 20 knots.

c. Total Number of Passengers on board = 725 persons.

d. Light Ship Weight = 654.43 tones

V.C.G. = 3.05 meter above from Base.

e. Number of Voyage in a year: Case-1: 330 times.

Case-2: 660 times.

f. Specific Fuel Consumption of Engine = 198gm/kW.hr

g. Specific Lube oil Consumption of Engine = 0.9gm/kW.hr.

h. Diesel Price = Tk.44/liter

i. Lubricant Oil Price = Tk.140/liter.

j. Distance: Dhaka to Barisal

by waterways : 174 kilometer [1].

by road : 249 kilometer [3].

k. Road fare: by Bus:

Passenger Capacity: 42 persons

Fare: Tk.300/ person.

3.4 DESCRIPTION OF METHODOLOGY

3.4.1 Basis of Selecting the Model Ship:

In order to find out the speed-cost relationship, design of a practical passenger vessel that is plying on the rivers presently on Dhaka to Barishal route has been picked up. It has been considered as the model ship for all calculation and to compare with. The reason behind this is to keep the comparison realistic and also to determine the incremental cost of our conventional passenger vessel with enhanced speed. This model ship is considerably large in size that can accommodate quite a big number of passengers which reduces the cost per passenger in comparing with relatively small vessels. In addition to that, facts about the recent accidents on waterways showed that smaller vessels are more vulnerable to capsize. That's why people are willing to travel by a large size vessel.

3.4.2 Selection of Drawings:

Many drawings are produced to construct a ship. Of them, the General Arrangement Plan and Lines Plan of the ship has been collected to start with.

Lines plan is used to calculate hydrostatic properties of the ship. General Arrangement Plan (GA) is used to find the distribution and capacity of passengers and cargo on board.

3.4.3 Hydrostatic Calculations:

First of all, at calculation stage, it's needed to determine the hydrostatic properties of the selected model ship that will be required as input data in later stage of other calculations. It is customary to prepare hydrostatic chart from gathering all that hydrostatic properties to be available on board for master or mariners. Theoretical procedures of Naval Architecture have been followed to determine the Hydrostatic characteristics of the vessel at various designed number of water lines. The formulas used here are given bellow:

Displacement Calculation:

The calculations for displacement, centre of buoyancy and of floatation, transverse metacentre, etc. are conveniently set out in a standard tabular form termed a displacement sheet. Such a sheet is based on the integration rules:

a. Simpson's First Rule

The area under a curve, $A = S/3.(y_1 + 4y_2 + 2y_3 + 4y_4 + \ldots\ldots\ldots y_{n-1} + y_n)$

y_1, y_2, y_3 etc are length of the ordinate.

b. Simpson's Second Rule

The area under a curve $=(3/8).S.(y_1 + 3y_2 + 3y_3 + 2y_4 + \ldots\ldots\ldots 3y_{n-1} + y_n)$

y_1, y_2, y_3 etc are length of the ordinate.

c. "5+8-1" Rule etc

The area under a curve. $A = (S/12)(5y_1 + 8y_2 - y_3)$

As shown in appendix f, the offset table of lines plan drawing has been rearranged in a tabular form to start the calculation.

Tones per Centimeter (TPC):

T.P.C. = Area of waterplane / 100.

Transverse BM (BM_T):

$BM_T = I/V$ where I= moment of inertia of waterplane about middle line and

V = volume of displacement

Moment to change trim 1cm:

$MCT1cm = (W \times GM_L)/100L$

W = displacement

L= length of waterline up to that displacement.

GM_L = Longitudinal Metacentre

Block Co-efficient (C_B):

C_B = immersed volume / (L×B×D)

L= length of circumscribing rectangle

B= breadth of circumscribing rectangle

D= depth of circumscribing rectangle

Prismatic coefficient (C_p):

C_p = immersed volume/ (length × midship area)

Midship Area coefficient (C_m):

C_m = midship area/ (B ×D)

Water plane area coefficient (C_w):

C_w = area of waterplane/ (L × B)

3.4.4 Estimation of Construction Cost:

The cost of a ship is the sum needed to pay for all the materials and labor involved in its construction plus the overhead cost incurred. The material and labor costs attributable to a particular construction are easily identifiable, but making a correct and equitable allocation of overheads is not a easy matter depending as it does not only on the ship being costed but on the general level of activity in the shipyard at the time.

Cost can be divided in two categories—estimated and actual. The estimated cost is that calculated when a shipyard is tendering; the actual cost is that calculated when the shipyard is tendering; the actual cost is that ascertained to have been incurred at the end of the Contact.

For the model ship of this project, cost incurring items have been identified and their present market price has been incorporated. Hundreds of items are required in constructing a ship. Almost all the names have been tried to accumulate in order to get the actual cost. These have been shown in a tabular form under cost estimation section.

It is worthy of noting that the local shipyards of our country don't maintain a book of records of materials needed. Usually the owner supplies the materials. So its not an easy task to have proper record of costing of our costing. But the owner of this model ship and many other learned personnel relating to this sector has been interviewed; they provided useful information for estimation of cost.

3.4.5 Determination of Speed-Cost Relationship:

In order to find the nature of this relationship, all the items of costing have been sorted out and monetary values of them have also been calculated. Estimation of the construction cost is summarized in a separate table as shown later. Annually recovered amount on investment and return rate at 10% has been calculated using the formula

$$CR = \frac{i(1+i)^N}{(1+i)^N - 1}$$, (CR being Capital Recovery Factor) *(eq^n no. 3.5)*

When a vessel moves forward into the water it has to work against a resistance force generated by water and air. This resistance force is the most important criteria for predicting the power the ship will need to achieve an approximate speed. Power estimation is a difficult process in conventional method. An authentic and internationally renowned Ship Design Software "Hullspeed of Maxsurf suit" has been used to predict the power against various speed of the vessel.

Greater portion of cost due to higher speed are the cost of consumption of diesel oil and lubricating oil. Specific fuel consumptions of these two items have been found to be 198gm/KW/hour and 0.9gm/KW/hour consecutively. Then total consumption and cost have been calculated against various speeds.

All the costs have been figured out on annual basis, and then the RFR has been calculated considering two cases:

Case-1: 1(one) no. of voyage in 24 hours.

Case-2: 2(two) no. of voyages in 24 hours.

CHAPTER 4

DETAILS OF ESTIMATION

4.1 COST ESTIMATION

In this stage, it's needed to estimate the total cost of the model ship: from design preparation to Operation. Components of cost and associated value in Taka are shown bellow:

1. Construction Cost : **44,791,121.75**

2. Operating Cost :

Fixed Cost : Annually

a.	Office maintenance and management cost	600,000.00
b.	Crew Cost	1,161,600.00
c.	Berthing Charge	330,000.00
d.	Conservancy Charge	11,613.87
e.	VAT	326,250.00
f.	Tax	47,125.00
g.	Welfare Fund of Passenger @ Tk:20/passenger	14,500.00
	Total Fixed Cost for One year :	**2,491,088.87**

Variable Cost :

a.	Fuel Cost :	
	Diesel	Depends on speed
	Lubricant Oil	Do
c.	Miscellaneous expenses	**1,200,000.00**

3. Maintenance Cost :

Yearly :	Paint Survey Fitness	**1,000,000.00**
Periodic :	Docking Undocking Engine Overhauling	

4. Depreciation :

30 years @ 2.5%
25% scrap value at NPV **641,728.60**

So, total Cost of the Ship is reduced to: **44,149,393.15**

Complete break down of this estimation has been shown in Appendix A.

4.2 CAPITAL AMORTIZATION

Capital amortization is made on the assumption of a 30 year life, Rate of Return of 10 % on investment and on the basis of equal annual payments based on the formula:

$$CR = \frac{i(1+i)^N}{(1+i)^N - 1}$$

Where, i = Rate of Return

N = Ship Life

CR = Capital Recovery Factor

So, the annual Payments will be,

$$= 44149393.15 \times \frac{0.1(1.1)^{30}}{(1.1)^{30} - 1}$$

$= 4,414,938.32$

4.3 ANNUAL OPERATING BUDGET

Capital Charges:		
Capital amortization	4,414,938.32	
Operating Cost:		
Fixed Cost	2,491,088.87	
Variable Cost:		
Diesel		----
Lube Oil		-----
Miscellaneous expenses (Excluding fuel cost)		1,200,000.00
Maintenance cost:	1.000.000.00	
	Total: **9,106,027.18**	

Here, for simplicity, it is assumed that no escalation will occur and the cash flow will be uniform. Also, total cost will be born by the owner i.e.: no Loans and no tax allowance have been included.

Now, in order to find the diesel and lubricant oil consumption and thus cost thereof, it is needed to know the resistance that the vessel needs to work against. A vessel moving forward in water faces different resistance at different speed. Brake horse power (B.H.P.) of the prime mover (engine) should be equal to that resistance at different speed of advancement. For this purpose, an estimation or prediction of required power of the engine is possible. 'Hullspeed' of Maxsurf suit has been used to get the required power of engine in kilowatt against a speed range of 9 to 20 knots. The result is presented below in a tabular format:

Table 4.1: Resistance Vs Power

Speed (Knots)	Resistance (KN)	Power (kW)
9.28	61.05	469.82
9.83	74.84	610.08
10.1	88.24	739.49
10.93	89.79	813.92
11.2	106.04	985.45
11.75	154.68	1508.01
12.3	164.74	1681.31
12.58	161.41	1684.16
13.4	160.04	1779.43
13.95	199.58	2310.14
14.23	222.33	2624.25
14.78	273.67	3355.13
15.6	321.84	4165.94
15.87	327.95	4319.91
16.43	331.06	4511.83
16.97	324.04	4564.16
17.25	322.81	4620.50
17.8	319.55	4719.61
18.63	319.37	4935.55
18.9	328.33	5149.00
19.17	338.53	5386.19
19.73	345.89	5661.10
20	354.4	5881.22

Once the power required out of engine is known then total diesel and lubricant oil consumption can also be estimated if their specific consumption is known. From the brochures of the engines mostly used in our inland vessels, it is known that specific fuel consumption and specific lube oil consumption are 198g/kW.h and 0.9g/kW.h respectively.

As the Dhaka to Barisal route has been taken for the model ship. the distance of the two destination point is 94 nautical miles (converted from kilometer) [2] and hence the journey time needed can be obtained.

From these above data given so far, the calculated results are presented below in the table:

Table 4.2: Estimation of Diesel Consumption & Cost: For Each voyage

Speed (knot)	Power (kW)	Time of Journey (hr)	Total Diesel Consumption (Kg)	Volume (Liter)	Cost (Taka)
9.28	469.82	10.13	942.27	1121.753	49,357.14
9.83	610.08	9.56	1155.12	1375.140	60,506.18
10.10	739.49	9.31	1362.71	1622.276	71,380.14
10.93	813.92	8.60	1385.97	1649.967	72,598.56
11.20	985.45	8.39	1637.61	1949.532	85,779.40
11.75	1508.01	8.00	2388.69	2843.676	125,121.74
12.30	1681.31	7.64	2544.11	3028.701	133,262.86
12.58	1684.16	7.47	2491.70	2966.310	130,517.62
13.40	1779.43	7.01	2471.55	2942.320	129,462.07
13.95	2310.14	6.74	3082.17	3669.255	161,447.20
14.23	2624.25	6.61	3432.36	4086.148	179,790.50
14.78	3355.13	6.36	4225.01	5029.776	221,310.16
15.60	4165.94	6.03	4970.29	5917.008	260,348.36
15.87	4319.91	5.92	5066.30	6031.308	265,377.57
16.43	4511.83	5.72	5111.03	6084.556	267,720.48
16.97	4564.16	5.54	5005.78	5959.266	262,207.71
17.25	4620.50	5.45	4985.32	5934.903	261,135.74
17.80	4719.61	5.28	4934.91	5874.892	258,495.24
18.63	4935.55	5.05	4930.78	5869.978	258,279.02
18.90	5149.00	4.97	5070.54	6036.356	265,599.66
19.17	5386.19	4.90	5229.41	6225.487	273,921.42
19.73	5661.10	4.76	5340.31	6357.517	279,730.73
20.00	5881.22	4.70	5473.06	6515.552	286,684.27

Diesel Price: Taka 44 /liter (market price) *Specific Gravity : 0.84 kg/litter*

Total Distance to Travel : 94 Nautical Mile

Table 4.3: Estimation of Lubrication Oil Consumption & Cost: For Each voyage

Speed (knot)	Power (kW)	Time of Journey (hr)	Total Lube Oil Consumption (Kg)	Volume (Liter)	Cost (Taka)
9.28	469.82	10.13	4.28	4.66	651.770
9.83	610.08	9.56	5.25	5.71	798.995
10.1	739.49	9.31	6.19	6.73	942.587
10.93	813.92	8.60	6.30	6.85	958.677
11.2	985.45	8.39	7.44	8.09	1132.732
11.75	1508.01	8.00	10.86	11.80	1652.254
12.3	1681.31	7.64	11.56	12.57	1759.759
12.58	1684.16	7.47	11.33	12.31	1723.508
13.4	1779.43	7.01	11.23	12.21	1709.569
13.95	2310.14	6.74	14.01	15.23	2131.938
14.23	2624.25	6.61	15.60	16.96	2374.165
14.78	3355.13	6.36	19.20	20.87	2922.439
15.6	4165.94	6.03	22.59	24.56	3437.945
15.87	4319.91	5.92	23.03	25.03	3504.357
16.43	4511.83	5.72	23.23	25.25	3535.296
16.97	4564.16	5.54	22.75	24.73	3462.498
17.25	4620.50	5.45	22.66	24.63	3448.343
17.8	4719.61	5.28	22.43	24.38	3413.475
18.63	4935.55	5.05	22.41	24.36	3410.620
18.9	5149.00	4.97	23.05	25.05	3507.290
19.17	5386.19	4.90	23.77	25.84	3617.180
19.73	5661.10	4.76	24.27	26.38	3693.893
20	5881.22	4.70	24.88	27.04	3785.716

Lube Oil Price: Taka 140 /liter (market price) *Specific Gravity : 0.92 kg/litter*

Total Distance to Travel: 94 Nautical Mile

In this stage, it is possible to prepare a complete annual operating budget once the total diesel and lubricating oil consumption and cost are determined against various cruising speed for each voyage. Then the annual consumption and cost are easily identifiable if the total number of voyage in a year is known.

One important factor needs to be considered here that, at present days, the vessel that are plying in that specific route usually serve one trip in twenty four hours at night. And this trip usually takes 9 to 10 hours. It reveals that the average speed of a vessel is somewhere between 9.4 knots to 10.4 knots. If she would travel with a higher speed, then the journey time would be less proportionately.

If it is possible to reduce this journey time considerably, then it might be possible to give two trips in twenty four hours. So, two cases can be analyzed at this point: case-1; with one number of trip in twenty four hours and case-2; with two numbers of trips in the same time, one trip during day time and the other at night time. The advantage of case-2 will be that having two numbers of trips in twenty four hours, cash flow will also go up and it will expedite the capital recovery time if the fare rate is kept the same as case-1. However, if the fare rate is such that just to recover the total cost of a year which is higher than case-1 due to higher rate of diesel and lubricating oil consumption, then the fare rate will be less in case-2 than in case-1 due to one extra trip in 24 hours. The reason behind this less fare rate is that one extra trip will increase the total passenger.km which eventually reduces the cost per person due to higher number of passenger carried.

It can be assumed that a vessel is in service for 330 days in a year and the rest of days she expends for its docking, engine overhauling and other maintenance purposes. So, total number of voyages for case-1 and for case-2 is 330 and 660 times respectively. Total diesel and lubrication oil consumption and cost, thus, can be found multiplying above mentioned cost by 330 and 660 for case-1 and for case-2 respectively.

For both the cases, total cost can be estimated and presented in a tabular format as given in the next two pages:

4.4 DETERMINATION OF TOTAL ANNUAL COST WITH DIFFERENT POWER OF ENGINE OUTPUT

Table 4.4: Case-I: One trip in 24 hours

Speed (knot)	Power (kW)	Time of Journey (hr)	Annual Operating Cost	Total Diesel Cost	Total Lube Oil Cost	Total Cost (Taka)
9 28	469 82	10.13	9,106.027.18	16,287.855.15	215,083 97	25,608,966.30
9.83	610.08	9.56	9,106.027 18	19,967.037.99	263.668.22	29.336,733.39
10.10	739.49	9.31	9.106.027 18	23,555.444.60	311,053.75	32.972,525.54
10.93	813.92	8.60	9.106.027 18	23,957,524.03	316,363.28	33.379,914.50
11.20	985.45	8.39	9.106.027.18	28,307,202.08	373,801.54	37,787,030.80
11.75	1508.01	8.00	9,106.027.18	41,290,175.52	545,243.96	50,941,446.67
12.30	1681.31	7.64	9,106.027.18	43,976,742.72	580,720.55	53,663,490.45
12.58	1684.16	7.47	9.106.027 18	43.070.814.18	568,757.61	52,745.598.97
13.40	1779.43	7.01	9.106.027 18	42,722.482.84	564,157.83	52,392.667.85
13.95	2310.14	6.74	9,106.027 18	53,277.577.14	703,539.69	63,087,144.01
14.23	2624.25	6.61	9,106,027.18	59,330,864 98	783.474.41	69.220,366.58
14.78	3355.13	6.36	9,106,027.18	73,032,352 86	964,404.95	83.102,784.99
15.60	4165.94	6.03	9,106,027 18	85,914,958 87	1.134,522.00	96,155,508.06
15.87	4319.91	5 92	9,106.027 18	87,574,596.77	1.156,437.81	97,837,061.77
16.43	4511.83	5 72	9,106.027.18	88,347,759.11	1.166,647.56	98,620.433.85
16.97	4564.16	5 54	9,106.027.18	86,528,543.28	1.142,624.49	96,777,194.96
17.25	4620.50	5.45	9,106,027 18	86,174,793.09	1.137,953.16	96,418,773.44
17.80	4719.61	5 28	9,106,027 18	85,303,428.09	1.126,446.63	95,535.901.90
18.63	4935.55	5 05	9,106.027 18	85,232,077.67	1,125,504.44	95,463.609.29
18.90	5149.00	4 97	9.106.027.18	87,647,889.25	1,157,405.65	97,911.322.09
19.17	5386 19	4 90	9,106,027.18	90,394,067.83	1,193,669.42	100.693,764 43
19.73	5661 10	4.76	9,106,027.18	92,311,140.23	1,218,984 69	102,636.152 11
20 00	5881 22	4.70	9,106,027.18	94,605,809 02	1.249.286 20	104,961,122 40

Table 4.5: Case-2: Two trip in 24 hours

Speed (knot)	Power (kW)	Time of Journey (hr)	Annual Operating Cost	Total Diesel Cost	Total Lube Oil Cost	Total Cost (Taka)
9.28	469.82	10.13	9,106,027.18	32,575,710.30	430,167.93	42,111,905.42
9.83	610.08	9.56	9,106,027.18	39,934,075.98	527,336.43	49,567,439.60
10.10	739.49	9.31	9,106,027.18	47,110,889.21	622,107.50	56,839,023.89
10.93	813.92	8.60	9,106,027.18	47,915,048.07	632,726.56	57,653,801.81
11.20	985.45	8.39	9,106,027.18	56,614,404.17	747,603.07	66,468,034.42
11.75	1508.01	8.00	9,106,027.18	82,580,351.04	1,090,487.93	92,776,866.15
12.30	1681.31	7.64	9,106,027.18	87,953,485.44	1,161,441.10	98,220,953.72
12.58	1684.16	7.47	9,106,027.18	86,141,628.35	1,137,515.21	96,385,170.75
13.40	1779.43	7.01	9,106,027.18	85,444,965.68	1,128,315.66	95,679,308.52
13.95	2310.14	6.74	9,106,027.18	106,555,154.27	1,407,079.38	117,068,260.84
14.23	2624.25	6.61	9,106,027.18	118,661,729.97	1,566,948.82	129,334,705.97
14.78	3355.13	6.36	9,106,027.18	146,064,705.72	1,928,809.89	157,099,542.79
15.60	4165.94	6.03	9,106,027.18	171,829,917.75	2,269,014.01	183,204,988.94
15.87	4319.91	5.92	9,106,027.18	175,149,193.54	2,312,875.62	186,568,096.35
16.43	4511.83	5.72	9,106,027.18	176,695,518.22	2,333,295.11	188,134,840.51
16.97	4564.16	5.54	9,106,027.18	173,057,086.56	2,285,248.99	184,448,362.73
17.25	4620.50	5.45	9,106,027.18	172,349,586.19	2,275,906.32	183,731,519.69
17.80	4719.61	5.28	9,106,027.18	170,606,856.18	2,252,893.27	181,965,776.63
18.63	4935.55	5.05	9,106,027.18	170,464,155.33	2,251,008.88	181,821,191.40
18.90	5149.00	4.97	9,106,027.18	175,295,778.50	2,314,811.30	186,716,616.99
19.17	5386.19	4.90	9,106,027.18	180,788,135.66	2,387,338.84	192,281,501.68
19.73	5661.10	4.76	9,106,027.18	184,622,280.46	2,437,969.39	196,166,277.03
20.00	5881.22	4.70	9,106,027.18	189,211,618.05	2,498,572.39	200,816,217.62

In case-2, there should be other various cost items associated with the extra number of trip in a day. Due to total extra numbers of trips in a year. the wear and tear of the ship will also be increased which requires more money to be expended for its extra amount of maintenance and overhauling and other resources consumption, possibly with an addition to crew salary for extra number of personnel on board. Cruising speed will also be reduced gradually over the life of the ship. But this matter has not been dealt with here to avoid much complexity in the estimation. Main focus is on the speed-cost analysis based on fuel and lubrication oil consumption.

4.5 DETERMINATION OF MINIMUM REQUIRED FARE RATE (RFR)

Now it is possible to determine the minimum required fare rate (RFR) for both the cases as total operating cost is known. Minimum Required Fare Rate (RFR) is that amount in money value at which it will give a Zero NPV; that is the RFR required at which the income equals the total expenditure.

Total Number Of passenger on board: 725 persons

Case-1:

Number of Voyage in a year: 330 times

So. Total number of passenger carried in a year:

= 239,250 persons

Distance to travel of the said Route = 94.00 Nautical Mile

or, 108.19 Mile

or, 174.19 Km

Total Number of Passenger.Km = 41,675,517

Case-2:

If we consider two trips in a day:

Number of Voyage a year = 660 times

So, Total number of passenger carried in a year:

= 478,500 persons

Total Number of Passenger.Km = 83,351,035

One of the primary parameters for comparison with road transport is to compare the RFR/km in both transport systems. So, for waterways, the RFR/Km has been calculated in next step and presented in tabular form again for both the cases.

It is to be noticed here that these RFR/km has been calculated on the basis of first year's capital recovery amount plus the yearly operation and maintenance cost. It is also possible to calculate the NPV of total cost of each year of the ship life and then find out the RFR/km. But, to have an idea about RFR/km, considering only the first year's cost will serve the purpose as it can be said that RFR/km will gradually go up over the ship life.

Table 4.6: RFR Vs Speed; Case-1: One trip in 24 hours

Speed (knot)	Power (kW)	Time of Journey (hr)	Total Cost	Total Number of Passenger	RFR (Taka)	RFR/KM (Taka/km)
9.28	469.82	10.13	25,608,966.30	239,250	107.04	0.614
9.83	610.08	9.56	29,336,733.39	239,250	122.62	0.704
10.10	739.49	9.31	32,972,525.54	239,250	137.82	0.791
10.93	813.92	8.60	33,379,914.50	239,250	139.52	0.801
11.20	985.45	8.39	37,787,030.80	239,250	157.94	0.907
11.75	1508.01	8.00	50,941,446.67	239,250	212.92	1.222
12.30	1681.31	7.64	53,663,490.45	239,250	224.30	1.288
12.58	1684.16	7.47	52,745,598.97	239,250	220.46	1.266
13.40	1779.43	7.01	52,392,667.85	239,250	218.99	1.257
13.95	2310.14	6.74	63,087,144.01	239,250	263.69	1.514
14.23	2624.25	6.61	69,220,366.58	239,250	289.32	1.661
14.78	3355.13	6.36	83,102,784.99	239,250	347.35	1.994
15.60	4165.94	6.03	96,155,508.06	239,250	401.90	2.307
15.87	4319.91	5.92	97,837,061.77	239,250	408.93	2.348
16.43	4511.83	5.72	98,620,433.85	239,250	412.21	2.366
16.97	4564.16	5.54	96,777,194.96	239,250	404.50	2.322
17.25	4620.50	5.45	96,418,773.44	239,250	403.00	2.314
17.80	4719.61	5.28	95,535,901.90	239,250	399.31	2.292
18.63	4935.55	5.05	95,463,609.29	239,250	399.01	2.291
18.90	5149.00	4.97	97,911,322.09	239,250	409.24	2.349
19.17	5386.19	4.90	100,693,764.43	239,250	420.87	2.416
19.73	5661.10	4.76	102,636,152.11	239,250	428.99	2.463
20.00	5881.22	4.70	104,961,122.40	239,250	438.71	2.519

Considering one voyage in 24 hours.

Table 4.7: RFR Vs Speed; Case-2: Two trip in 24 hours

Speed (knot)	Power (kW)	Time of Journey (hr)	Total Cost	Total Number of Passenger	RFR (Taka)	RFR/KM (Taka/km)
9.28	469.82	10.13	42,111,905.42	478,500	88.01	0.505
9.83	610.08	9.56	49,567,439.60	478.500	103.59	0.595
10.10	739.49	9.31	56,839,023.89	478,500	118.79	0.682
10.93	813.92	8.60	57,653,801.81	478,500	120.49	0.692
11.20	985.45	8.39	66,468,034.42	478,500	138.91	0.797
11.75	1508.01	8.00	92,776,866.15	478,500	193.89	1.113
12.30	1681.31	7.64	98,220,953.72	478,500	205.27	1.178
12.58	1684.16	7.47	96,385,170.75	478,500	201.43	1.156
13.40	1779.43	7.01	95,679,308.52	478,500	199.96	1.148
13.95	2310.14	6.74	117,068,260.84	478,500	244.66	1.405
14.23	2624.25	6.61	129,334,705.97	478,500	270.29	1.552
14.78	3355.13	6.36	157,099,542.79	478,500	328.32	1.885
15.60	4165.94	6.03	183,204,988.94	478,500	382.87	2.198
15.87	4319.91	5.92	186,568,096.35	478,500	389.90	2.238
16.43	4511.83	5.72	188,134,840.51	478,500	393.18	2.257
16.97	4564.16	5.54	184,448,362.73	478,500	385.47	2.213
17.25	4620.50	5.45	183,731,519.69	478.500	383.97	2.204
17.80	4719.61	5.28	181,965,776.63	478,500	380.28	2.183
18.63	4935.55	5.05	181,821,191.40	478,500	379.98	2.181
18.90	5149.00	4.97	186,716,616.99	478.500	390.21	2.240
19.17	5386.19	4.90	192,281,501.68	478,500	401.84	2.307
19.73	5661.10	4.76	196,166,277.03	478,500	409.96	2.353
20.00	5881.22	4.70	200,816,217.62	478,500	419.68	2.409

Considering Two voyage in 24 hours

Now, the RFRs can be presented graphically plotted as Speed Vs RFR for both the cases so that the behavior of RFR with growing speed can be clearly understood. Also the Time Vs RFR figures can be plotted for both the cases. From the second figure it can be estimated what amount a passenger needs to pay for each kilometer distance traveled according to a specific duration of journey. These figures are given next.

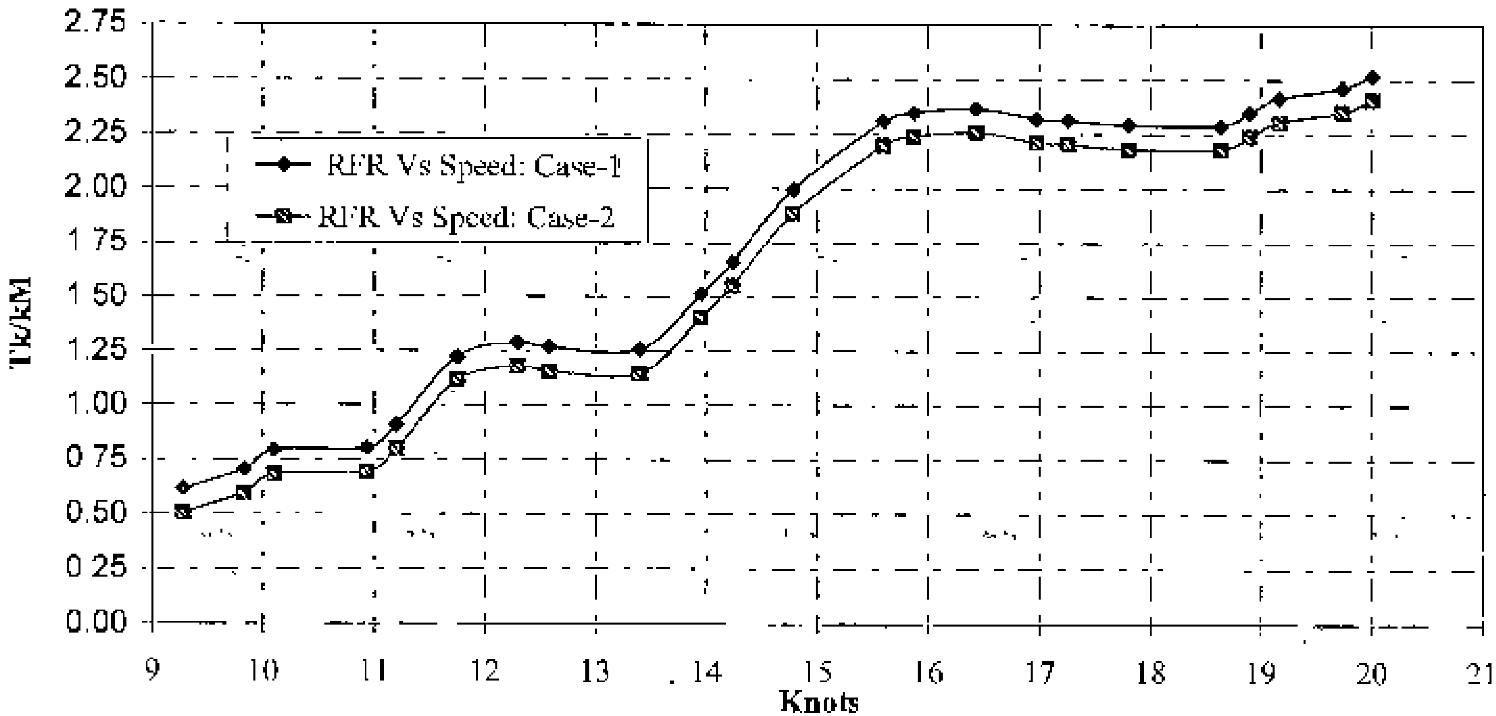

Figure 2: Required Fare Rate(RFR) Vs Speed. Case-1: One trip in 24 hours. Case-2: two trips in 24 hours

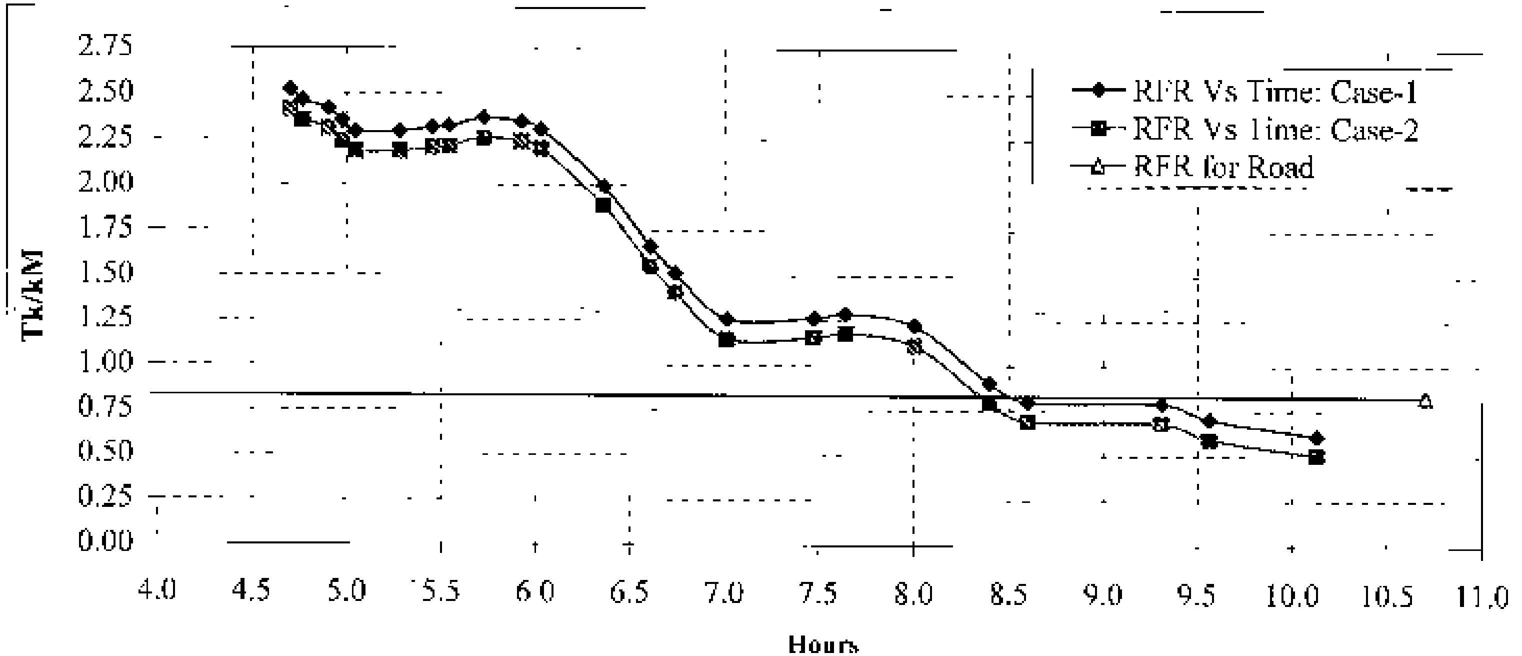

Figure 3: Required Fare Rate(RFR) Vs Time. Case-1: One trip in 24 hours. Case-2: two trips in 24 hours; horizontal line at Tk.0.83 represinting Fare rate for Bus transport showing journey time needed in both cases.

4.6 COMPARISON WITH ROAD TRANSPORT

In this project, a specific route such as Dhaka to Barisal has been taken in an effort to find out the minimum RFR for traveling on waterways. Now it is required to compare this RFR with that of the roadway for the same destination places Typical interview of the concerned persons regarding road journey reveals the following:

Distance- Dhaka to Barisal:	249	k.m.	(on road) [3]

Considering a passenger accommodation for a standard bus on that route:

Number of Passenger:	42	people
Time of Journey:	6	hrs
Average Speed (in knots)	22.39	knots
Average fare per passenger:	300	taka
Fare rate	0.83	taka/passenger.km.

For this same amount of fare rate, the time of journey on water was found to be:

Considering:

Case-1:	1 No voyage in 24 hours:	8.54	hrs
Case-2:	2 Nos voyage in 24 hours:	8.35	hrs

Hence, it's found that with the same amount of RFR, time of journey on road takes lesser time than that of water. In order to defeat the road regarding journey time, it's needed to increase the speed of water vessel for which the cost and RFR will go up also.

Minimum RFR required for water vessels to equal to the journey time on road, i.e. 6 hours:

Considering:

Case-1:	1no Voyage in 24 hours:	2.30 taka/passenger.km.
Case-2:	2 nos. voyage in 24 hours:	2.19 taka/passenger.km.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

Bangladesh is a land of river and her rivers are the lifeline of the nation providing the cheapest means of transportation. But recently, other mode of passenger transport such as road is playing a significant role in this area. The reason of this growth may be attributed to lesser time taken by vehicles on road in comparison with water vessels though the Required Fare Rate (RFR) is higher than that of water transport. The main objective of this study is to find the optimum speed of a specific passenger vessel based on fuel consumption, as it increases the fuel cost. and other operating expenses in comparison to road transport.

A model passenger vessel was picked up as the basis ship for comparing to the road transport with water transport. Then the RFR of the vessel has been calculated on the basis of first years' operating cost.

Considering the RFR and time of journey for water and Road transport, apparently the scope of road transport is found to be better than water transport. It can be seen that the RFR on waterways is much higher than that of roadways in both the cases. Raising the number of trip is not favoring that much for dropping the minimum RFR. But it must be noted that a vessel has an optimum speed for that specific design of the vessel. This optimum speed is that speed up to which the operating costs remain to be economical. Beyond this optimum speed, the associated operating costs tend to increase at a higher rate. So, it's needed to design a vessel of which optimum speed can provide an acceptable journey time with the operating costs being favorable to the economic condition.

5.2 RECOMMENDATIONS

Most of the factors influencing speed of passenger vessels have been discussed in this thesis work. Surely there are some sorts of solution to each and every kind of problems that have been found out during this work. But suggesting the solution is beyond the scope of this current project work. This project work can be carried on step by step towards a complete solution comprising all the obstacles, even to a design of a new ship that will be suitable for Bangladesh in every aspect. But that requires a great deal of effort and work.

During the analysis of Speed-cost relationship, it has been assumed that extra amount of cost due to enhanced speed is only due to extra amount of fuel and lubrication oil consumption. But in real practice, that extra amount of cost involves so many other items that should not be overlooked. Also, the nature and behavior of a ship get changed along with its lifetime that comprehensively affect its performance and thus cost. These are some complex subjects to deal with separately. A simple approach has been followed here to find a minimum amount of cost that is involved with speed.

Following recommendations might be placed for further development of this work:

- Determination of future demand of water transport of Bangladesh.
- Study on alternative and innovative technology and idea for water transport system.

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APPENDICES

APPENDIX A

ESTIMATION OF CONSTRUCTION COST OF PASSENGER VESSEL:

SL No.	Items	Quantity	Unit	Unit Price (TK)	Total Price (TK)
1.	Steel Plate	400	M. Ton	48,000.00	19,200,000.00
2.	Contractor charge (MS Plate+MS Angle+MS Tee+Fabrication)	400	ton	10,000.00	4,000,000.00
3.	welding Rod	4000	Pack	550.00	2,200,000.00
4.	Dock Charge	12	Month	30,000.00	360,000.00
5.	Main Engines: with suitable reduction gear box of suitable gear ratio. Make- China	2	Nos	2,850,000.00	5,700.000.00
6.	Propeller, Propeller Shaft. Stern tube. Bushes. Sealing System, Rudder etc.	2	No	850,000.00	1,700,000.00
7.	Generating sets: 30 KVA, 1500 rpm. 3 Phase 4 wire system 380/220 Volts, 50Hz. Marine Gen set. Make-China	2	Sets	700,000.00	1.400,000.00
8.	**Anchor :**				
	Stockless Anchor (750 kg each fitted & 1 spare)	1500	kg	120.00	180,000.00

Anchor chain (stud link/15. mm dia & to be fitted by necessary nos of joining shackles, swivel, clits etc.	6	Shackles	150,000.00	900.000.00
Anchor windlass (Electric motor driven anchor windlass & have Gypsy, Break shoe, Winch drum, Chain stopper etc.	1	Set.	300,000.00	300,000.00

9. **Pump sets with pipes & fittings :**

i. GS Pump	1	No	800,000.00
ii. Bilge pump-	1	No	
iii. Fire Pump-	1	No	
iv. Sanitary Pump	2	No	
v. Semi Rotary Hand Pump	1	No	

10. **Electric Equipment, Cables, Galley & Fittings :**

Electric Galley	1	Set	1,200,000.00
Wiring system	As per requirements	Meter	
Distribution Box	1	Set	
Navigation Panel	1	Set	
Main panel board	1	Set	
CKT breaker	As per requirements	No	
Emergency ckt breaker switch	As per requirements	Nos	
Emergency panel Board	1	Set	
Ceiling Mounted Fan	As per requirements	Nos	
Wall mounted Fan	As per requirements	Nos	

	Tube light	As per requirements	Sets		
	Electric cable	As per requirements	Meter		
	Light shade & Light (Heavy & Marine quality)	As per requirements	No		
	Lighting transformer	1	No		
11.	**Navigational equipments :**				
	Hydro-Electric & Manual steering gear system shall be installed with necessary fitting and rudder indicator.	1	Set	LS	700,000.00
	Telegraph/Bridge control system (Bridge Engine room).	1	Set	20,000.00	20,000.00
	Liquid Magnetic Compass (fitted with a binnacle and have dimmer system).	1	Set	170.000.00	170,000.00
	Horn/Siren(fitted & connected with necessary power or air supply).	1	Set	15,000.00	15,000.00
	Voice pipe (Wheel house to Engine room).	1	Set	10,000.00	10,000.00
	GPS with DGPS facilities.	1	No.	50,000.00	50.000.00
	Internal communication & public address system (Wheel house, Engine room. staff accommodation, passenger's accommodation.	1	Set.	100,000.00	100,000.00

Search Light (with one spare bulb) to be fitted on the wheelhouse with an operating handle and a separate switch in the Bridge	1	Set.	25,000.00	25.000.00
Hand Mike (With one set spare batteries).	1	No.	7,000.00	7,000.00
Binocular (7/50 rubber coated).	1	Pair	7,500.00	7,500.00
Navigation lights	4	Nos.	4.000.00	16,000.00
Anchor Light	1	No.	4.000.00	4,000.00
Not under command lights	2	Nos.	4,000.00	8,000.00
Line throwing apparatus	1	Set	8,000.00	8.000.00

12. **Deck Equipment & Mooring :**

Capstan (fitted in the after part & supply necessary no of capstan bars).	1	No.	100.000.00	100.000.00
Double Bollard (fitted with supporting deck plate & reinforcement nuts. bolts etc.	10	Pairs	10,000.00	100.000.00
FS wire rope (2" size)	300	ft	40.00	12,000.00
P.P rope (4" size).	300	ft	30.00	9,000.00
Heaving line (1" PP rope)	2	Coils	1,000.00	2,000.00
Wooden pin	4	Nos.	500.00	2.000.00
Wooden hammer	2	Nos.	700.00	1,400.00
Fender (rubber or wooden, fitted around the side hull with necessary arrangements.)	1	No.	100.000.00	100.000.00
Hand lead line (with one spare lead.)	1	No.	2,500.00	2,500.00

	Three celled torch light (with one set spare battery and a bulb).	1	No.	500.00	500.00
	Fire Bell.	1	No.	3,500.00	3,500.00
	Manual operated foghorn	1	No.	4,000.00	4,000.00
	Accommodation. Internal finishing including paneling, insulation.	As per requirement	M2	LS	775.000.00
13.	Furniture & Fittings including crew accommodation. (Passenger bench, Doors. Chair, Table, Bunk, Almira etc.)	As per requirement	Nos.	LS	475,000.00
14.	**Life Saving Equipments :**				
	Life jacket	760	Nos.	500.00	380,000.00
	Life Buoy (Two for W.house fitted with 30m, buoyant life line and self igniting light). plastic	126	Nos.	800.00	100,800.00
	Self igniting light	2	Nos	1,300.00	2,600.00
	Parachute rocket signal	3	Nos	450.00	1,350.00
	Red hand flare	2	Nos.	500.00	1.000.00
	Transistor Radio (having MW, SW. FM band)	1	No.	2,000.00	2,000.00
15.	**Fire Fighting Equipments:**				
	Fire Alarming system.	1	Set.	100,000.00	100,000.00

Fire pump (fitted with pipe lines, hydrants etc)	1	No.	25,000.00	25,000.00
Hose pipe (15 m long each)with standard coupling & hose box to be fitted.	4	Nos.	5,000.00	20.000.00
Nozzles (spray-jet type)	4	Nos.	1,200.00	4,800.00
Fire buckets (fitted with lanyard).	6	Nos.	150.00	900.00
9 litres BE type fire extinguisher (for E.room)	4	Nos.	1.500.00	6,000.00
9 litres BE type fire extinguisher (for accommodation deck).	6	Nos.	1,500.00	9,000.00
9 litres BE type fire extinguisher (for wheel house.)	1	No.	1,500.00	1,500 00
9 litres ABE type fire extingui-sher (for galley)	4	Nos.	1,500.00	6,000.00
Breathing apparatus (self containing system)	1	Set.	12,000.00	12,000.00
Fire man kit	1	Set	10,500.00	10,500.00
Fireman Axe	1	No.	1,500.00	1.500.00
Safety lamp.	1	No.	2,500.00	2,500.00
Hand/Rotary pump/Bilge pump	1	No.	LS	
Sand box 50 kg capacity with a scrap for EPROM.	1	No	800.00	800.00
Fire drill machine	1	No	5.000.00	5,000.00

16. **Any other marine equipments :**

Oscillating wall mounted fan (Two for Wheel house)	20	Nos.	1.500.00	30,000.00
Anchor ball	3	Nos.	1.000.00	3,000.00
Crow bar	1	No.	600.00	600.00
Chipping hammer	6	Nos.	200.00	1,200.00
Scraper	6	Nos.	150.00	900.00
Marline spike	3	Nos.	100.00	300.00
Hand saw	1	No.	200.00	200.00
Chipping gaggles	3	Sets.	300.00	900.00
Chain block (5 tons lifting capacity)	1	Set.	15,000.00	15,000.00
Pliers with rubber handle	1	No.	200.00	200.00
Screw driver (21o mm)	2	Nos	50.00	100.00
Deck brushes	2	Nos	50.00	100.00
Paint brushes (various sizes/ /two with long handle)	8	Nos.	-----	5,000.00
Iron hammer	1	No.	200.00	200.00
Monkey spanner (250 mm)	1	No.	600.00	600.00
Wire brush	3	Nos.	50.00	150.00
Plastic bucket	2	Nos	100.00	200.00
Waste basket	2	Nos.	100.00	200.00
Wooden plank (standard size)	1	No.	7,500.00	7,500.00
Pilot ladder	1	No.	20,000.00	20,000.00
Iron ladder	1	No.	2,000.00	2,000.00
Broom	20	kg.	35.00	700.00
Rubbish collector	5	No.	100.00	500.00
Bowl	20	Nos.	---	1.000.00
Kettle	10	No.	250.00	2,500.00

Cup	250	Nos.	50.00	12,500.00
Plates	250 .	Nos	60.00	15,000.00
Jugs	160	Nos.	200.00	32.000.00
Drinking glass	300	Nos.	35.00	10,500.00
Spoons (various sizes)	100	Nos.	---	2,000.00
Cup board/Rack/Self	1	No.	----	3,500.00
Canvas cover (all machineries and equipments are to be safely covered by canvas cover).	3	Nos.	---	4,500.00
Reels (FS wire ropes & PP ropes to be reeled)	3	Nos.	1,500.00	4,500.00
Bed sheet	150	Nos.	125.00	18,750.00
Pillows with cover	150	Nos.	180.00	27.000.00
Bed mattress	150	Nos	500.00	75.000.00
1st Aid box with medicines	5	No.	2,200.00	11,000.00
Boat hook	1	No.	1,000.00	1,000.00

17. **Bridge settings & Equipments :**

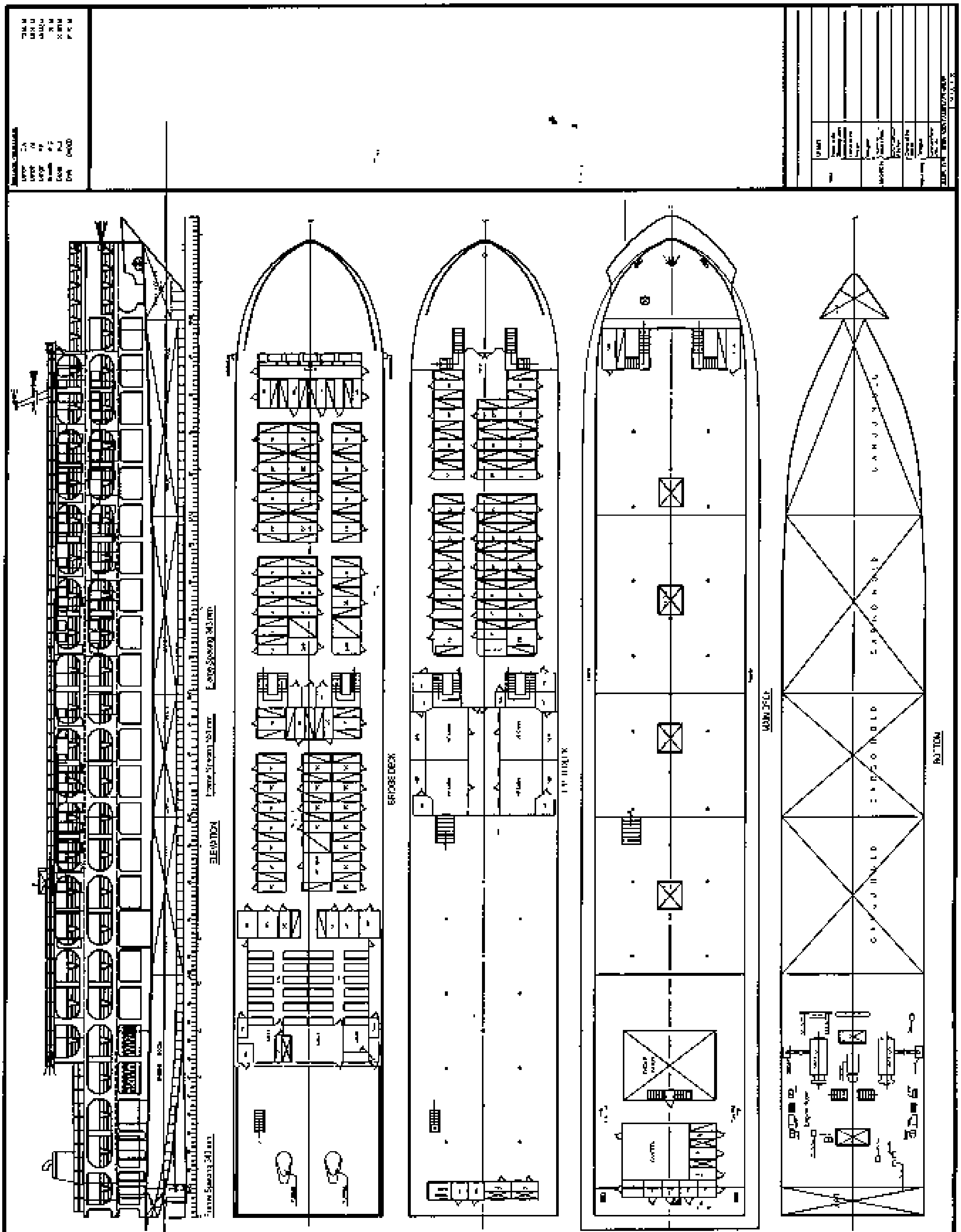
Marine clock (one in wheel house)	3	Nos	2,000.00	6,000.00
Aneroid barometer (Wheel house).	1	No.	15,000.00	15,000.00
Inclinometer (pendulum type)	1	No.	20,000.00	20.000.00
Anemometer (wind speed indi- cator)	1	No.	20,000.00	20,000.00
Thermometer (fixed type)	1	No.	500.00	500.00
Clear view screen (CVS/fitted)	1	No.	20,000.00	20.000.00

	Window wipers	2	Nos.	5,000.00	10,000.00
	VHF (Marine international frequency)	1	Set.	65.000.00	65,000.00
	Map of Bangladesh (fitted in a frame board)	2	No.	450.00	900.00
	GA plan (fitted in a frame board)	1	No.	450.00	450.00
	Table (stage type/with sufficient drawers & boxes for securing small items)	1	No.	5,000.00	5,000.00
	Sits (2 chairs and 1 tool)	1	Set.	4,000.00	4,000.00
	Wheel man's standing platform	1	No.	1,500.00	1,500.00
18.	Paint: (3 coats epoxy / antifouling included)	As per requirement	Unit	LS	750,000.00
19.	Zinc anode (Hull and Rudder Blades)	100	Pcs	500.00	50.000.00
20.	Intercom system-(Digital PABX)	1	Units	50,000.00	50,000.00
21.	Drawings and Stability booklet (with approval), As per POMMD / DOS Bangladesh rules.	1	Sets	600.000.00	600,000.00
22.	Cost of owners inspection				100,000.00
23.	HSD Lube oil ,Hydraulic oil etc for trial (Min 10 hrs)	1	Time	25,000.00	25.000.00
				Sub Total =	**43,414,300.00**

24.	Contingency & Miscellaneous	400,000.00
25.	Survey supervision fees 2.25% on Labor cost only (excluding VAT, TAX & cost of spares & other materials)	976,821.75
	Total Ship Acquisition/Construction Cost =	**44,791,121.75**

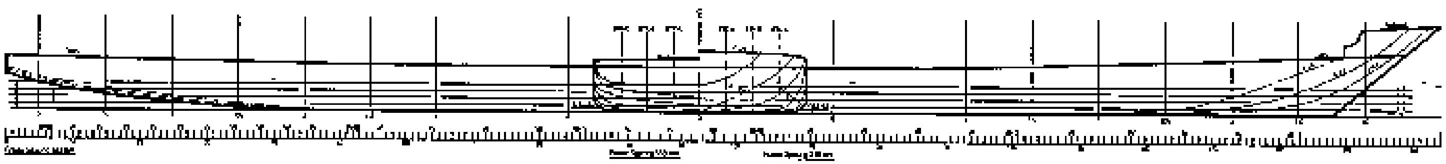
APPENDIX B

GENERAL ARRANGEMENT AND LINES PLAN OF THE MODEL PASSENGER VESSEL

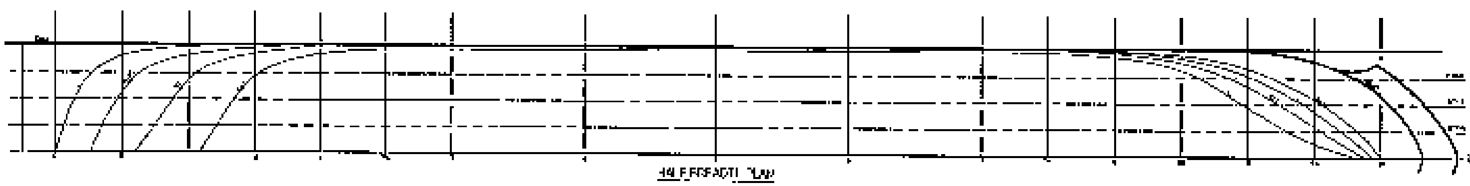

ELEVATION
BRIDGE DECK
MAIN DECK
BOTTOM

OFFSET TABLE

STATION	HALF BREADTH WL 1	WL 2	WL 3	WL 4	Deck at Side	HEIGHT ABOVE BASELINE KEEL	BTK A	BTK B	BTK C	DECK
0	—	—	—	—	5500	[illegible]	[illegible]	[illegible]	1500	[illegible]
½	—	—	[illegible]	[illegible]	5500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1	—	[illegible]	[illegible]	[illegible]	5500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1½	[illegible]	[illegible]	[illegible]	[illegible]	5500	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible]	[illegible]	5500	—	[illegible]	[illegible]	[illegible]	[illegible]
2½	[illegible]	[illegible]	[illegible]	[illegible]	5500	—	[illegible]	[illegible]	[illegible]	[illegible]
3	[illegible]	[illegible]	[illegible]	5500	5500	—	[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]	[illegible]	5500	—	[illegible]	[illegible]	[illegible]	[illegible]
5	[illegible]	[illegible]	[illegible]	[illegible]	5500	—	[illegible]	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	[illegible]	[illegible]	5500	—	[illegible]	[illegible]	[illegible]	[illegible]
7	[illegible]	[illegible]	[illegible]	[illegible]	5500	—	[illegible]	[illegible]	[illegible]	[illegible]
7½	[illegible]	[illegible]	[illegible]	[illegible]	5500	—	[illegible]	[illegible]	[illegible]	[illegible]
8	[illegible]	[illegible]	[illegible]	5415	[illegible]	[illegible]	6	[illegible]	[illegible]	[illegible]
8½	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]
9½	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]
10	—	—	—	—	[illegible]	1430	[illegible]	[illegible]	—	[illegible]



PROFILE WITH BODY PLAN



HALF BREADTH PLAN

LINES PLAN & OFFSET TABLE

Appendix C: Hydrostatic Curves