Techno-Economic and Environmental Impact Study of Passenger Water Transport Services in and around Dhaka City

A Thesis

By

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Department of Naval Architecture & Marine Engineering

BANGLADESH UNIVERSITY OF ENGINEERING & TECHNOLOGY (BUET)

Dhaka- 1000

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CERTIFICATE OF APPROVAL

The thesis titled 'Techno-Economic and Environmental Impact Study of Passenger Water Transport Services in and around Dhaka City', submitted by Md. Akram Ali, Student No.: 9612001F, Session:1995-96-97, has been accepted as satisfactory in partial fulfillment of the requirement for the degree of Master of Science in Naval Architecture and Marine Engineering on March 31, 2019.

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I hereby declare that the work done in this thesis is the result of original research performed by me and has not been submitted for any degree to any other University or Institution.

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MD AKRAM ALI

ABSTRACT

Dhaka, the capital city of Bangladesh is surrounded by the rivers Buriganga, Sitalakhya, Balu, Tongi and Turag. The encompass of the area is from Tongi in the north to Narayanganj in the south and Jinjira in the west to Demra in the east, an area of about 280 sq. km with a population of about 20 millions. With the growth of population, economic and commercial activities are rapidly increasing and so is the problem with traffic, especially congestion. Many projects have been taken up to mitigate the problem with transportation system but the focus has been on the development of the road transport network. Although surrounded by river system, there is very limited role of water transport in the transport system of the city. Although some projects have been taken up to develop water transport system, but due to some limitations its contribution to the passenger transportation system of the city insignificant until very recently. This thesis work presents the techno economic study and planning of the passenger water transportation system in the circular water channel around the Dhaka city. Six alternative vessels (three mono hull and three catamarans) have been considered with different dimensions and speed. The passenger fare rate has been taken comparable to that of road. The results of the study show that such services can be a very effective alternative to road transport system to many passengers and also are viable for most of the vessels considered.

Nowadays environmental issues related to any transportation system are getting more and more importance and hence this thesis also presents a comparison of environmental impacts created by alternative passenger transportation vehicles (three mono hull and three catamarans) in the circular water channel around Dhaka city. Twelve different compounds and substances consumed or released during the production and use of the transports were considered. The impacts of these substances in six different impact categories were estimated using relevant characterization factor. The results are shown by some indices that assessed the ability of each vessel in damaging the environment. These indices are intended for rating vessels with respect to environmental friendliness. The results presented in the thesis show that the smallest conventional monohull vessel would be the best option as regards environmental consideration for the purpose of passenger transportation in the intended route.

This thesis also tries to identify the inherent problems of the circular waterways that are currently being used in a limited scale. On the basis of the study, some recommendations have been put forward so that policy makers can take appropriate action to utilize it properly.

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March,2019

MD AKRAM ALI

DEDICATION

To

My Father Md Ayub Ali

My Mother Mrs Sofura Begum

&

My son Tanjim Akram

My son Wasim Akram

List of Contents

Chapter I

1 INTRODUCTION

1.1 Background and Present State of the Problem:

An estimated half a million people move in or out of the city daily with approximate 50 million passenger-km movement[1]. The problem has been worsened due to the extremely scare road and parking space available in the city. This has accelerated the demands for expanded infrastructure including transport[2]. Recognizing the need for an integrated planned development of the transport system of Greater Dhaka, Government of Bangladesh (GOB) with assistance of UNDP initiated a study through Planning Commission in 1994, known as Greater Dhaka Metropolitan Area Integrated Transport Study (DITS) [3]. Although in and around of Dhaka city is blessed with unique river network, but the study found that the role of water transport in the city area was not significant, particularly in case of passenger movement.

As a follow up of the DITS report, the government of Bangladesh adopted, in principle, the concept of introduction of water transport system including water taxi for passenger transportation. Such a system is expected to have several benefits such as ease in traffic congestion in the roads of Dhaka city, improving environment, drainage and flood control etc. As a follow up of the same, the Bangladesh Inland Water Transport Authority (BIWTA) submitted to the government a Technical Assistance Project Proposal [4] entitled "Feasibility study For Development of water Transport System in and around Greater Dhaka Area". The proposal elaborately dealt with the various infra-structural developments necessary for introduction of the transport system including river training necessary for maintaining the navigability of the waterways. The end product of the development was the introduction of the passenger transport service in limited scale and this was largely dependent on feasibility of the various alternative services and the financial as well as economic viability of the alternatives. In addition to the direct and accountable economic benefits, enormous benefits in terms of positive environmental effects are also expected to be derived from the proposed water transport service which was not assessed in that study.

On the other hand, in the past two decades environmental issues have caused greater public concern. People all over the world have become more aware of their consumption of goods and services and their impact on natural resources and the quality of environment. The gradually increasing devastating effects of climate change are imposing more and more pressure on people to think about the environment of this planet. Frequent natural Calamities such as long-lasting floods in various parts of the world, including Bangladesh, frequent cyclones and hurricanes, and coral bleaching [5] in Pacific Ocean as well as Indian Ocean and Caribbean Seas are some of the devastating effects of climate change. Scientists believe that global warming is the main reason behind the increasing frequency and strength of all these disasters. Since the industrial revolution, the global mean temperature has risen by 0.3^0C to 0.6^0 C. This is believed to be the effect of increased atmospheric concentrations of the greenhouse gases and motor vehicles are responsible for a considerable portion of the emissions to the atmosphere [6].

It is not only the increased emission that is causing the damage but also the fact that most of these emission are taking place in relatively small geographical regions, cities and industrial belts. Massive urbanization has taken place in almost all developing countries. Since independence of Bangladesh, Dhaka as the capital of the country grew rapidly as a metropolis that has an estimated population of about 20 millions. The increasing number of motorized vehicles and resulting emission has caused massive environmental pollution situation in the city [7].

As no such detailed study of the transport service encompassing development of the passenger water transport service in terms of speed, safety, fare, comfort, frequency, ghat facility etc. have been carried out which largely determine the ultimate viability of the concept and the extent of environmental benefits, this present thesis work has been planned considering this background. The techno-economic component of the study has been carried out considering the matters related to the design, construction and operation of the service and the response of the passengers that are to be understood from the survey results. On the environmental side, the study will evaluate the various environmental benefits that may be derived from the proposed passenger water transport services.

1.2 Objective with specific aims and possible outcomes:

The objective of the thesis work is to investigate and evaluate the technical and economic feasibility of a passenger water transport service in and around Dhaka city and also to evaluate the potential of environmental benefits from such a service. The study has been taken into consideration the various governing factors such as draft, ghat /berthing facilities, maneuvering restrictions etc. and functional requirement such as traffic load, frequency of service, speed requirement, safety, comfort etc. The specific aims of the study are as follows:

1) Evaluation of economic prospect and viability of the passenger transport services in the proposed routes using the alternative and suitable vessels of appropriate type and size.
2) Environmental impact assessment of the proposed water transport service including the benefits of modal shift.

The study is expected to draw a scenario of the techno-economic aspect of the operation vis-à-vis the expected response of the users towards the proposed service. The results obtained in this research work can also work as a guideline regarding the appropriate size, capacity and speed of the vessel, the investment required, frequency of service and other particulars regarding the same. The study also gives an indication of the expected amount of traffic load that the water transport services take off from the road transport network of the Dhaka city.

The environmental evaluation includes the expected reduction in the engine emission level, its geographical dispersion, reduction in noise level, fuel saving etc. The environmental evaluation will also incorporate the scope of modal shift from road transport to water transport in the proposed routes. Life cycle impact assessment [8], a very useful tool for quantitatively evaluating the environmental influence of a product, has been used to compare the environmental burden imposed by these transportations.

1.3 Organization of the Thesis:

This thesis work has few chapters. Chapter I describes introduction and objectives of the thesis, Chapter II describes transport scenario of Bangladesh, Chapter III describes the methodology of this study, Chapter IV describes water transport system and demand, Chapter V describes economic analysis of alternative water craft, Chapter VI describes environmental impact analysis, chapter VII describes existing condition of water transport routes in and around Dhaka, Chapter VIII describes conclusions and recommendations.

Chapter II

2 TRANSPORT SCENARIO

2.1 Comprehensive Picture of Existing Problems

Dhaka has been a city in transformation as it had to develop from a subservient regional center during the British Raj to the Capital of East Pakistan and consequent to the Capital of a new nation. Dhaka had just over 1.0 million inhabitants in 1958. This has expanded to 7.3 million in 1991 and is estimated to be over 20.0 million in 2019. Although the overall growth rate is falling slightly it is nonetheless assumed that Dhaka joined the mega-cities at the year 2000 and the projections are that Dhaka will have 24.6 million in 2025 and over 28 million in 2030.

Due to absence of land suitable (flood free) for development and lack of resources to create such land in a cost effective way, the above urbanization has taken place in the form of densification of the existing urban area and gradual occupation of Dhaka's fringe. This process of urban growth has largely gone autonomous without reference or taking heed of any planning, town outlays or infrastructure reservations.

As in the same time also the required large scale investment in development supporting infrastructure and facilities has not come forward and only minimal investments were made to keep the existing networks going, one cannot expect otherwise then that after years of neglect the whole system is on the verge of collapse.

The transport and transportation sector has been among the most deprived sectors when funds for operation, maintenance and especially new developments had to be secured. As a result the present network is increasingly unable to manage the traffic. This aggravated by the absence of a number of (especially east west) link roads (the missing links).

Poverty of a large part of the population has proven to be a benefit is disguise for the traffic management of Dhaka as 60% of all movements is still pedestrians and these pedestrians do claim but little of the available road space.

DITS surveys revealed the following movement picture:

❖ Walking	60.0%
❖ bus	9.5
❖ rickshaw	19.2
❖ auto rickshaw/tempo	2.2
❖ car	3.1
❖ motorcycle	1.5
❖ water transport	3.3
❖ others	1.2
TOTAL	100.0

The lowest income groups (60%) largely walk (80% of their movements) to reach their destination. They have only a marginal impact on the flow of traffic. They need however, protection and especially safe passage at the main intersections.

The financial constraints among most of Dhaka's population also have resulted in a poorly developed public bus system. Some 1400 buses, a large part of them in a very poor (technical and comfort) state are plying Dhaka's streets. To meet the demand DITS estimated that at least 4000 buses were required. Still with its 9.5% of all movements or 22% of the vehicular trips the bus is a serious actor in the transport field.

During the last few years, an improved economy has resulted in a developing financial capability for the low, moderate and higher income groups to spend transport. To rickshaw stationed at their doorsteps and available for short and medium length distances takes with 47% of the vehicular trips, the major share. However, auto rickshaw/tempos are increasingly preferred for the medium to longer distance trips. However, with their two stroke engine emitting half burned exhaust fumes these new traffic modes may contribute significantly to the increasing air pollution.

The number of office and private cars is still very limited, reaching less than 8% of the vehicular trips in general. However, almost 40% of the highest income group's (3% of population) vehicular trips are made in a car.

The high level of pedestrian movement coupled with the low rate of car users has meant that Dhaka is only recently beginning to suffer congestion that cities such as Bangkok are now experiencing.

A number of intersections are becoming notorious because of the daily traffic jams. In part this is caused by the sheer number of traffic users, but also because they are not designed for the numbers they have to accommodate. The major problem is however the lack of discipline (and understanding) of the various users of the public road space the inability of the Dhaka traffic police to enforce improved rules and regulations and absence or outdated traffic ,management and control equipment.

The situation at some intersections is further aggravated if one of the approaches is crossing a railway, or more than two major arteries are coming together. In these cases the only way out may be to study traffic segregation at grades.

Though a number of traffic management measures, promotion of public transport by buses, adjustment of intersections and construction of flyovers the lifetime of the present traffic circulation system may be extended and may cater even for the increasing numbers in the next couple of years. However, in the medium and longer term more drastic traffic management measures will be required to cater for the greater mobility due to economic growth and for the sheer increase of numbers due to population growth. It is under stander stood that under DUTP- III these medium and longer strategies will be studied.

2.2 Current Situation and Expected Developments of Public transport services

The baseline survey executed under DITS concluded that some 60% of all movements were pedestrian, largely made by the poor and low income groups, Among the remaining 40% vehicular trips public transport services amounted to almost 35%, or 87.5% of all vehicular trips.

DITS baseline survey was done in 1992, but its findings are considered still relevant, because, for the demographic growth, the economic circumstances have not altered.

The demographic growth has resulted in the Dhaka population growing from 7.363 million in 1991 to over 9.0 million in 1996 and a projected population of 24.6 million in 2025 and 28 million in 2030.

The fact that 60% of all movements are pedestrian is largely a resultant from inability of the lowest income groups to afford vehicular transport. This in itself is unique for a town like Dhaka. It is also a benefit in disguise as pedestrians absorb very little road space. As such the Dhaka arteries with their limited length and road space have been able to cope with the growing traffic demand up till now. The sheer numbers and the gradual increasing economic capability of the emerging moderate and the higher income groups (who can afford vehicular transport) have resulted in Dhaka starting to experience traffic jams at some junctions of its road network. These are, however, a far cry from the conditions experienced in other metropolitan cities as e.g. Bangkok.

In part this is because most vehicular transport in Dhaka is provided by public services and among these the bus (22%) is an effective road user. The number of auto-rickshaws/tempos (6%) is rapidly growing and these traffic modes are also efficient in their road use. However, the half burned exhaust fumes of their two stroke engines contribute heavily to Dhaka s emerging air pollution. Given the negative effect of the pollution on the urban environment this segment of the public transport market will have to invest in less and nonpolluting propulsion alternatives. As long as the alternatives are not yet available further development of the auto rickshaw/tempo fleet should be banned and the existing fleet licensed at reduced level until they are phased out totally.

Neither large scale widening of the space, especially at the intersections to cope with the increasing intensities, nor substantial grade separation is to be expected in the coming years. The only way to forestall that traffic gets totally choked at the intersections and various junctions will be by introducing or expanding traffic mode segregation and introducing additional traffic rules and regulations (e.g. preferential treatment for buses at intersections) and seeing to it that these and the regular rules are strictly enforced.

On top of these actions measures will be introduced to promote improved bus services, as buses are the most effective vehicular transport means. Given full implementation of these strategies it is expected that:

1. Auto rickshaw and Tempo’s gradually phase out and may be replaced by taxis or by less polluting small motorized multi passengers transport means;
2. Rickshaw and NMT (together with pedestrians) will receive protection from MT by specific measures at crossings and intersections and provision of a NMT only or main route network As these measures will put a number of restrictions on their operations

the rickshaws will become less popular for longer trips and a more short trip transport facility within its own neighborhood. As a result it is expected that the number of rickshaws will remain constant or even reduce somewhat. To enforce improved traffic discipline by the rickshaw pullers, licensing will be reintroduced, to be withdrawn in case of reoccurring traffic offenses.

This however only may happen if the expected promotion of buses takes off and absorbs the shaded demand from auto rickshaw, tempo and rickshaw while catering for the new demand from the additional and luring some car users into premium bus services.

2.3 Existing and Future Demand, inclusive Affordability

When extrapolating the DITS baseline survey data for the whole Dhaka Metropolitan Area population it may be calculated that on a daily basis the approximate 1400 buses transport almost 1.0 million (973.495) passengers. Similarly the estimated 250,000 licensed and non-licensed rickshaws move almost 1.6 million (973.495) passengers. And the 10.000 auto rickshaws tempos almost 150,000 (143.100) passengers.

Under the present conditions, accounting only for the demographic growth these totals could increase to just over 2.0 million (2,038,050) bus passengers, 3.3 million (3,272,650) rickshaw passengers and 0.3 million (299,300) auto rickshaw/tempo passengers in the year 2006.

As stated in the previous chapter the proposed public transport strategy is to gradually phase out the polluting auto rickshaws/tempos, to consolidate or reduce the rickshaws and to promote the buses. With all promoting measures in place it is expected that the buses may increase their coverage to just over 3.5 million (3.576, 150) passengers. The additional 1.5 million is bow ever not sufficient to meet the growth of 1.7 million extra rickshaw trips nor the 0.3 million auto rickshaw/tempo passengers. It also in not sufficient to draw car owners in large numbers into the buses, Nonetheless it will be a major achievement if this shift may be realized.

If as hoped for the economic growth will improve the affordability of the lower and slowest income groups and they will be able to share in the vehicular transport, the bus promoting efforts have to be expanded further or alternative forms of public transport (mass transit) have to be introduced to support the bus operations.

The base line survey of DITS indicated that the lowest income group spends up to 16.5% of the household income on bus fares. As these only amounts to Tk. 169 it is not sufficient for even the daily work trip to and from wok of the main income earner, it is therefore indicative of the fact that the lower income groups can ill afford even the low bus fare and do so only in emergency cases. They generally walk to their daily destination and this accounts for almost 40% of Dhaka's population with a household income of less that Tk. 3,000 per month (1992 DITS survey). Provision of a denser network with frequent schedules and maintaining basic bus services at present fares may help to increase the bus share among the (emergency) vehicular grips of these income groups.

The next income group (40-60 percentiles) is considered low income. They spend almost Tk. 500 per month probably for daily transport of the main income earner. As this amounts to more than 10% of their income it may not be expected that they would be able to afford higher bus fares than the present tariffs.

The 60 to 85 percentile group of moderate income households spends some Tk.1000 per month on transport again being almost 10% of the household income this allows two household members daily bus trips, or somewhat longer trips for the main income earner. IN the latter case the household may have moved to the less expensive urban outskirts and pays the difference in commuting money.

The last 3 percent highest income group households (160000 HH in 1996) spends up to Tk.2000 per month per household on transport. They may be the prime candidate for the more expensive premium bus services.

The last 3 percent highest income group spends in average some 4000 taka on transport, but with 40% of their trips made by car the major share will go into the car operation costs.

The affordability analysis is based upon DITS base line survey of 1992 and is not very supportive to a strong increase in bus fares if the objective is to lure more passengers to the buses. The emphasis has to be on improved efficiency and better services as the tools to increase the number of passengers of the moderate medium and higher income groups.

If as hoped for, the economy improves and herewith the buying capacity of the Dhaka population then more households may enter into the more affluent groups that can afford basic and even premium bus services. However, this only if bus fares are kept as they are.

Expectations of economic growth are however, modest and generally are slow to reach down to the lower income groups. It is therefore prudent to work in the assessments of bus demand with the conditions found in the DITS baseline survey and to treat a better performing economy as a welcome gift.

2.4 Non-Motorized Transport (incl. rickshaws) and Pedestrian Movement

Current Situation and Expected Development

DITS found that 60% of all move3ments are-pedestrian and 47% of the remaining vehicular trips are made by rickshaw. When bicycles and other NMT vehicles are included the total accounts for over 80% of all movements.

Poor understanding of urban traffic and its rules and regulations, coupled with reckless driving and indiscipline behavior of the motorized/vehicular traffic participants, combined with severe shortage of pedestrian facilities as sidewalks and protected crossings are the ingredients for the alarming fact that pedestrians are involved in 50% of all road accidents and account for 2/3 of all road facilities.

Walking is a must for the low income groups but even the moderate and higher income groups walk to a large extent as shown by the findings of DITS in Table -1.

Table-2.1: Walk Trips by Income Levels

HH Income in Tk.	% Population	Number of trips	% of total
<1500	10%	3177	80.8
1500-1999	10%	4758	79.9
200-2999	20%	11523	77.2
3000-4999	20%	11874	69.4
5000-9999	25%	10567	55.2
10000-29999	12%	4644	39.9
>30000	3%	932	22.3

DITS furthermore confirms that children largely (85%) walk, followed by the elderly over 59 years (65%) Only women between 15 and 59 years walk for less than half of their trips.

With the further growth of Dhaka the distances will tend to increase forcing more people to move to vehicular transport. The first affordable mode would be the bicycle, especially as Dhaka is largely that. The bicycle accounts however only for 2% of the trips, contrary to Indian cities, including Delhi, where bicycle trips account for 18-35% of all trips and China where in cities bicycles typically account for 50-90% of all vehicle trips. Also in developed countries as Japan cycle use is substantial while in the Netherlands, densely populated and flats like Bangladesh the bicycle accounts for almost 29% of all journeys. Efforts should be made under the DUTP III strategic studies how the use of bicycles in Dhaka may be promoted and the cultural disregard for bicycles may be overcome.

The main vehicular mode in Dhaka is however the Rickshaw with 47% of all vehicular trips and moving some 1.6 million passenger per day. There are some 100,000 licensed and 150,000 to 200,000 unlicensed rickshaws pulling these passengers, providing work to some 350,400,000 rickshaw pullers or 20% of the Dhaka workforce.

The rickshaw is not only traffic mode for movement of passenger but also movement of goods, and the combination of both. They together with a fleet of rickshaw vans and pushcarts (thelagari) assure the distribution of goods from the wholesale markets to the retail markets and shops, or from the gnats, container depots and bulk transfer stations to the factories and workshops.

It is expected that with a gradual reorganization of the goods movement sector and introduction of smaller trucks for intercity transport of goods the number of these NMT transport means will not increase further and eventually even may fade out.

2.5 Existing and Required Facilities (pedestrian walkways, NMT/ pedestrian underpasses bridges)

DITS surveyed approximately 460 km of the Dhaka registered road network of 2000 km. Of these, 167 km roads had pedestrian walkways constructed in concrete. 20% of the walkways were occupied by hawkers, especially near the main attraction points, where the pedestrian intense 9 ties were also highest

DUTP-I surveyed all major roads identified under DITS as lacking pedestrian walkways, and recommends almost 40 km of road to be upgraded with pedestrian walkways (see working paper III. 7 Pedestrian Facilities).

Apart from the six bridges found by DITS a program has been under implementation to construct some 41 foot bridges and 5 underpasses throughout Dhaka DUTP-1 has identified 17 locations where these have been constructed or are being built and recommends some 18 more locations (12 with first and 6 with second priority): see Appendix E of working paper III Pedestrian Facilities).

Hardly any facilities exist specifically for the NMT in general and the rickshaw especially. Although being in numbers the most important group of the vehicular traffic, instead of being well served it is looked upon by most and especially the upper income groups as the single biggest contributor to the Dhaka traffic jams. In some way this is correct because of the sheer numbers (300,000 versus the 140,000 other vehicles) and the indiscipline (Largely ignorance) of the rickshaw pullers.

But if they would be replaced by cars, who have a worse road-space utilization rate and whose drivers are less illiterate but as indiscipline, the situation world be far worse than at present.

The problem is there, however, and the NMT/rickshaws, being with the pedestrians, the weaker partners, vying for public space, need to be protected. This should be done considering the importance of the roads for inner quarter traffic, for feeder road and for arterial road functions.

In the residential quarters and especially the narrow roads and alleys of the old city areas need to be restricted for pedestrian only or pedestrian and NMT only. IN working paper III.4 Auto Free Zones, two areas (see Figure III.3-I) have been identified for trial introduction of auto free zoning. It the trial run is successful then more areas may be identified among the spontaneous growth centers on the eastern/southern fringe of the city.

On the server roads of the residential quarters motorized transport is generally only minor and mixed traffic should be allowed, However, restricting the MT to a maximum speed of 50km/hour on the area feeder roads only 15 km/hours on the server roads.

On these feeder roads and not the server roads in mixed and commercial areas that have higher intensities also from motorized traffic, minor segregation should be enforced. As painted dividers are largely overlooked preference is given to given to rough strips.

On the main arteries NMT is to be provided with specific lanes protected by physical, visual barriers. In case road-width is restricted the NMT may have to be banned and alternative NMT priority routes opened.

Counter to this promotion of the motorized traffic a route plan has to be developed for the NMT separate from the motorized network.

Working paper III.3 Non-motorized Transport and Cycle Rickshaw route Network provides the information on the integration and segregation of the NMT and MT route networks, with a number of detailed of detailed suggestions for the adjustment of a number of intersections and crossing.

The Figure III.3-2 Cycle Rickshaw and Proposed Rickshaw Lanes provides insight in the proposed network. A careful assessment of the implications of the proposal and a testing of the impact on the overall traffic in a transport stimulation model may result under DUTP-II to further adjustments to these proposals.

2.6 Goods Movements

Current Situation and Expected Developments

DITS already identified that goods reach Dhaka or are transported there from by river craft, by rail and by intercity trucks. From the transfer stations or terminals the goods are brought to the end-users (and the other way round) in most cases by rickshaw vans, thelagari (push cart) in the case of consumable goods and by two axle truck in case of heavy loads building materials.

Due to an expanding road network and construction of new bridges trucks have been able to increase their share of the intercity transport over rail and river transport. With the completion of the Jamuna Bridge and the possibility of a bridge over the Padma to connect Dhaka with Khulna and the South this advantage of the trucks may further be strengthened.

The city itself is however also a generator of transport demand. Goods have to be moved within the town from one place of processing to another and goods (especially building materials) have to be brought in from the country side to support the growth of Dhaka and its development projects.

DITS found that some 10.00 trucks (9,961 in 1991) are registered in Greater Dhaka. These trucks and also the non-motorized transport means, have very low utilization levels in the urban area, this is analyzed as caused by a fragmented industry, poor communication facilities and the resulting need to be spread over the city to meet the demands of the commercial sector.

Because of poor utilization rate, the qualitative state of the truck fleet is low and there is little incentive to meet the growing market as shown (Table 2) by the dip in the growth in 1990-91.

Table 2.2: No. of truck on Road in Greater Dhaka and Bangladesh [25].

Region	No. of Trucks 1988	No. of Trucks 1989	No. of Trucks 1990	No. of Trucks 1991	Rate of Growth 1988-89	Rate of Growth 1989-90	Rate of Growth 1990-91	Average Rate of Growth
Greater Dhaka	8,536	9,048	9,591	9,961	6.00	6.00	3.86	5.29
Bangladesh	22,621	23.978	25.471	26.546	6.00	6.23	4.22	5.48

The expected continuing growth of Dhaka and the stimulus for economic development by the moderate growth of Bangladesh economy will however generate an increased demand for transfer services. It is expected that the growth of the transport fleet will take off again and develop in line with the projected growth of Dhaka. The projections are given as follows in Table 3.

Table 2.3: Forecast of Trucks for greater Dhaka.

Period	No. of trucks (Base year)	Rate of Growth (Annual)	No. of Trucks Increase (approx.)	No. of Trucks (Final Year)
-1991	--	--	--	10,000
1991-1995	10,000	3.75	1,900	11,900
1996-2001	11,900	3.50	2,100	14,000
2002-2006	14,000	3.25	2,300	16,300

2.7 Existing and Required Facilities

Goods movement by rail is adequately served with present terminal facilities for container and bulk goods. River transport has a number of ghats where goods can be loaded and unloaded. As such these ghats work as transfer stations and all modes of motorized and non-motorized transport means converge on these ghats often choking movement by loaded vehicles.

An Inland Container Port has been studies and a location has been selected on the southern bank of the Buriganga River. As this location will promote urbanization in the flood zone and is not or poorly connected to the water, rail and road networks its selection has been severely criticized and rejected as not suitable in the Dhaka Structure Plan and the Dhaka Urban Area Plan. A location across the river on the North Bank in the DND Triangle, would be far more eligible and would benefit from the river, road and rail connections.

Most wholesale markets of which seven have been identified (on Map III.4.1. Main Terminals/Depots/Stands) act as transfer station for goods between the producers and end users.

DITS stated that Non-motorized Transport NMT is the main means of moving goods between the manufacturing, the wholesale and the retail levels. Old Dhaka with its numerous go downs (warehouses) is the traditional center of wholesale trade for the nation and it is the center for the wholesale supply of foodstuff for metropolitan Dhaka. The transport means for goods purchased at these wholesale markets because it enables the buyer to visit the bazar, examine the goods and return with the goods over distances up to 4 km.

NMT transport means as rickshaws (vans) and the lagers (push cart) do need but little space as parking stand. However, their sheer number and their pushers vying for the scarce space creates the impression that the MNT is the main cause of congestion.

The trucks as said above are the expanding sector in the goods movement from and to the city and between the city center and the outskirts, beyond the circle 4 km radius of the NMT goods transport.

Given the poor management at the various goods movement facilities the trucks often have to wait long to be served or to get a new consignment to move. Waiting places are scarce and if available often lack communication means to be called into action easily. Truck stands for night parking are available at a number of places, but often lack formal status and are poorly handled with trucks being parked haphazardly. Sanitary facilities are often absent or very inadequate. Repairs and servicing of vehicles takes place on the sites with the spent oil, grease and spare parts being freely discarded, polluting the subsoil and the run-off water.

Tejgaon, Mohammadpur and English Road-Armanitola are truck terminals/stands that provide parking for truck perpendicular or alongside the road. These sites may require more detailed assessment to determine if this function may continue as it is implemented now, or if the activities need to be trimmed.

These and most of the other sites surely need better management and curbing of the polluting activities as indiscriminate disposal of waste and urinating and defecating along the roadside and in the ditches.

Fourteen sites have been analyzed to determine their present size, boundaries, and capacity and to assess expansion opportunities. As a result of the assessment it was found the present locations severely underperform, and that if so wanted sufficient additional area could be made available to meet the present need.

This in the assumption that as far as possible efforts should be made to legalize the present terminals/stands/transfer stations in situ, unless they have an identified severe negative impact on their surroundings.

To meet the present demand the existing terminal/stand area of 3.05 hectares, next to the roadside parking need to be extended with some 17.45 hectares. Suitable locations have been identified near the present sites for such an extension. For the 2006 demand another 15.10 hectares of terminals/stand area has to be taken into service. Of these some 9.1 hectares are still needed. It is suggested that a suitable site along the planned Eastern Bypass will be acquired as over time there will develop a need gradually move the heavy traffic to the fringe and to serve the city with lighter crafts through transfer facilities on the fringe.

When this is going to happen, also room will become available for improvement of communications as suggested in DITS, Presently automated radio communications are seen by the truck owners as a luxury they cannot afford (given the poor state of their trucks) neither are the low skilled derives expected to be able to operate the communications facility . As long as manpower remains cheap the present system of couriers between the owner/agent and the truck driver is considered the most effective.

Chapter III

3 Methodology of the Study

This research work reviews the overall transport scenario of the Dhaka city. The water bodies in the periphery of the city have been examined along with the meager water transport activities going on in these waterways. This study includes data collection from various sources such as

i) Questionnaire survey on the movement of passengers in the identified routes
ii) Survey to understand the expectation and demand of the potential passengers on the characteristic and quality of service
iii) Data collection from secondary sources such as earlier study reports, data, information and statistics from BRTA, planning Commissions, LGED, City Corporation etc.

The questionnaire-based survey has not only considered the total traffic movement but also the hourly variation, movement during weekends etc. have been assessed.

Based on the data, information, statistics, opinions gathered during the survey, outline design of the various alternative crafts have been prepared. The various limitations such as draft restriction, maneuvering constraints etc. have been considered in this study. The speed requirement has also been determined. The procurement cost of the vessels has been estimated. The operating cost, repair and maintenance cost, financial costs and other cost have also been estimated. Some data regarding passenger fair of existing route have been collected. These data, information and estimated figures have been used to perform economic analysis of the alternative vessels operating in the routes in terms of NPV, B/C ratio.

3.1 Estimation of Trip Particulars

The route and trip particulars were calculated according to the following equations:

Trip time,

$$t_{\mathrm{trip}} = \left(\frac{R}{V} + t_{load}\right)\left(1 + \frac{t_{delay}}{100}\right) \quad \text{.............................. (3.1)}$$

Where,

R= route distance(Km)

V= speed (km/h)

t_{load} = loading and unloading time

t_{delay} = delay in time (%)

Here the trip means one complete voyage from origin to destination in the mentioned route of circular water channel. Maximum possible round trip per annum (RTPA) per transport was calculated from the trip time and total number of hours available in a year for operation according to the following equation.

$$RTPA = \frac{17D}{2t_{trip}} \quad ....(3.2)$$

Where,

D= days in operation per annum = (365- off hire days)

Operating hours were taken from 5:00 a.m. to 12:00 midnight (17 hours/day)

Round trip required per annum (RTRA) is the minimum required number of trip that was required to perform the whole transportation task. It was calculated as follows,

$$RTRA = \frac{N_{pass}}{(2C_{ap})(\frac{\delta}{100})} \quad ....(3.3)$$

Where,

C_{ap} =Capacity (ton)

δ= exploited capacity (%)

N_{pass} = total number of passenger carried (pass./year)

Amount of fuel consumption per annum (in kg/hr),

$$F_C = \frac{(h_p \times e_f) \times f \times 2R \times RTRA}{V \times 1000} \quad ....(3.4)$$

Where,

h_p= engine power (horsepower)

f= fuel consumption rate (gm/bhp-hr),

e_f= engine efficiency

Number of transport required to perform the transportation task,

$$T=\frac{RTRA}{RTPA}, \quad \text{then } \frac{RTRA}{RTPA} \text{ is an integer} \quad \text{……………} (3.5)$$

$$INT\left(\frac{RTRA}{RTPA}\right)+1, \quad \text{when } \frac{RTRA}{RTPA} \text{ is not integer}$$

In order to evaluate the environmental impact, the study considered 12 substances either consumed or released during building or operation of the vessels. The impacts were considered in six different categories (fossil fuel exhaustion, local warming, global warming, acid rain, eutrophication, air pollution). This analysis is a comparative one and the index of one of the vessels was taken standard as unity. The indices were assessed for a certain number of passengers transported by which the bodies of water are made more eutrophic (well nourished) by an increase in the nutrient supply and made more productive biologically, generating large population of algae and other organisms. Different weighing factor for each different environmental impact categories was used to arrive at a single index so as to directly compare the alternatives.

3.2 Life cycle impact assessment and the environmental destruction index

The concept of the life cycle assessment simply means that the inputs (energy, materials, etc.) to and outputs (energy, waste materials, products, etc.) from the 'cycle' are evaluated for each step of a product or process life. The standard generally used for this evolution is as ISO 14042 [17]. Life cycle impact assessment (LCIA –standardized as ISO 14042)[18] which is a tool to evaluate impact of inputs and outputs on the environment.

Twelve Compounds and substances consumed or released during the production and operation of the transports were considered here. The aspect of disposal was not taken into account because of non-availability of dependable data. The data of the construction phase were adapted from Hasegawa and Iqbal [11] based on $L \times B \times D$ ratio and the engine power (hp). The relevant inventory list for the construction phases of the vessels, the amount of emissions for steel production, the emission data for the operation phase of the water transport and the emissions during diesel oil production were taken from Semipro [10] a life cycle assessment (LCA) software database. The heat radiation values in the operation phase were adopted from Hasegawa and Iqbal[11] as the same is not available with SimaPro to ensure consistency data from a single source were used as far as possible and this case the main source was SimaPro[19] . The database in SimaPro was developed though a rigorous analysis and is being considered by many researchers[13,20] as one of the reasonable sources for this purpose. Calculating the total amount of substances and compounds released for the transportation task by various transportation systems, the environmental impact of the transportation systems in 6 different impact categories (fossil fuel exhaustion, local warming, acid rain, eutrophication, air pollution) were estimated by multiplying the total amount of emissions by respective characterization factors according to the following equation [13].

$$EP(j) = \sum (Qi \times EF(j)) \quad \text{.........................(3.6)}$$

Where, EP (j) is the sum of the potential contribution from the impact category

Q_i is the emissions of compound i

EF (j), is the characterization factor of compound I related to the impact category j

The values of the characterization factors were taken as per Eco-indicator 95 [19] only the characterization factor for heat radiation in local warming impact category was assumed unity. It was assumed so because heat radiation is the only cause responsible for local warming in this comparison process. Another reason was that the radiation heat had direct influence on the local warming developing the so called, ‘’heat island’ while other impact categories like CO_2 emission can contribute to warming only after going through some transformation.

The environmental destruction index was calculated multiplying the ratio of the amount of potential impact by one transportation system to that of another transportation system with some specific weighting factors for each impact category according to the following equation.

$$I_E = \sum_{y=1}^{y=6} \omega j \; \frac{(EP(j))_{vessel-y}}{(EP(j))_{vessel-1}} \quad \text{...............................(3.7)}$$

$\omega_j$is the weighting factor for impact category j. These values were calculated by analytic hierarchy process (AHP)[21] form the opinions of general consumers and transport users. AHP is a widely accepted method of establishing hierarchy among the parameters those are not directly related to each other; Saaty [21] explained this method in detail. The environmental destruction indices for each vessel is thus with respect to that of the vessel 1.

In order to obtain the weighting factors for conversion into single index. An approach similar to valuation according to expert panel procedures [22], was employed. A questionnaire was used to survey the opinions of people from different disciplines of society asking them to assess weighting factors to various environmental impacts. The persons questioned were asked to consider two environmental impacts at a time and compare their dominance to the climate change to determine the weighting factor. For example they were asked to compare the local warming and to judge which one is absolutely /very strongly/weakly important over another or whether both are equal in importance to the environment.

From the responses of one hundred and twelve persons, AHP was used to calculate the weighting factors. Among the responders 63.4% of the responders were Japanese, 19.6% were Bangladesh and the rest were from various countries including Pakistan, Indonesia, Australia, and Canada, of them 40% was student mostly of Naval Architecture and Environmental Engineering, Rest were professionals from various disciplines including engineer, doctor, transporter, academician, and businessman.

Chapter IV

WATER TRANSPORT SYSTEM AND DEMAND

4.1 Water Transport Routes

The overall water transport scene as of the field study is that the metropolis is encircled with the river Buriganga, Turag, Tongi, Balu, Sitalakhya and Dhaleswari covering 110km. The Flood Action Plan (FAP) has a program of flood embankment covering 90km. alongside these rivers of which 38 km. is to be raised complete and 29km. is yet to stock work. Around 25 khals/canals could be traced along with a few well recognized lakes and water bodies (Gulshan, Banani, Baridhara, Moghbazar and Dhanmondi etc.) Historically, these khals and water bodies seem to have good transport linkage with the peripheral river contributing to the attractive environmental features of the city. But since late 1940s with the rapid expansion of the city, ever growing population, accelerated housing and business growth there had been a continuous tendency to infill the water bodies and khals for building structures, roads and sewerage system resulting into the complete or partial closure of almost all the khals and water bodies and today these intra city khals water bodies hardly contribute anything to the transport to the transport network or environment, rather cause environmental pollution. The only surviving 6/7 canals and 4/5 water bodies are also in the grip of encroachment of the builders and developers due to the absence of well-defined policy and plan for city development and strong commitment for implementation of the plans and policies.

The ring/circular waterways of the city by the rivers which is shown in Figure 4.1, however, are well recognized playing significant role in the carriage of goods and passengers particularly on the south, south east, northeast and west belt of the city. The water route from Munshiganj via Fatulla to Sadarghat and further to Mirpur is operable although the year carrying passengers and goods by various types of vessels motor launches, engine boats and country boats. Sadarghat, Badamtali and Swarighat are the important landing stations of the waterfront on the city side bank and Jinjira on the opposite bank of the river. Except the BIWTA terminal at Sadarghat, the terminal/shore facilities at other ghats are not properly built up.

There is substantial river crossing traffic between the city side and Jinjira, on the opposite bank of the river. The river crossing traffic, mostly passengers are carried primarily by engine

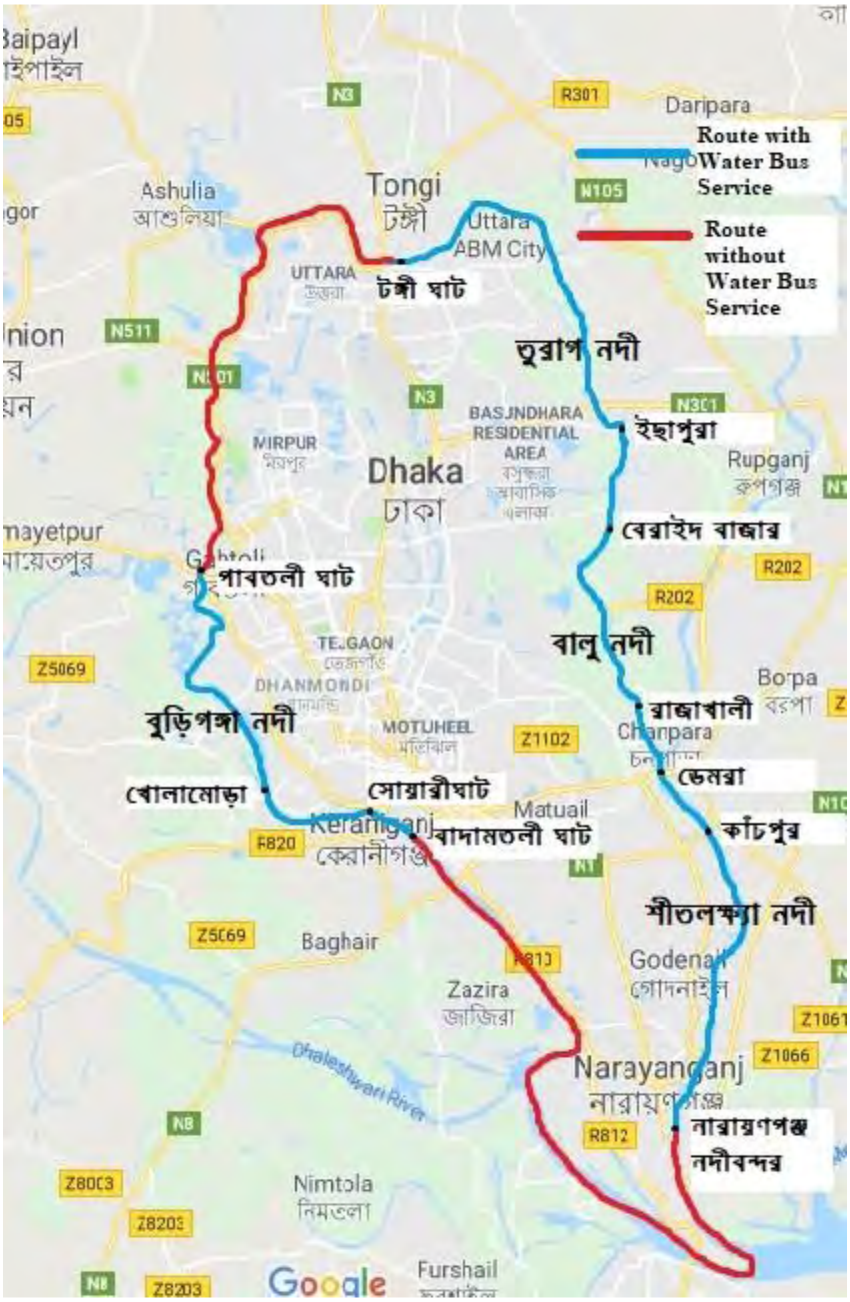

Figure 4.1: Current Water Transport Routes with Water Bus service in Dhaka City

boats of different sizes and capacity and at a lesser degree by small county boats. Between Sadarghat and Swarighat around 40 engine boats of the capacity ranging from 10 to 70 passengers and few small country boats are seen crossing the river to and from Jinjira side at a point of time. The draft of the river in this frontage is around 10.67 metre without any maintenance dredging. The river network in and around Dhaka city has been described below:

(a) Buriganga River from Sadarghat to Mirpur

The main water route along the south and south-west belt is from Sadarghat, (including Badamtoli and Swarighat) to Mirpur via Char Kamrangi, Nowabganj, Lalbagh, Hajaribagh and Rayerbazar on the city side and Kholamura, Bosila and Washpur on the opposite bank of the river Buriganga. There is regular passenger service between Sadarghat (including Badamtali and Swarighat) and Kholamura by Mechanized boats and motor launches, the journey time being 30 to 40 minutes. A good number of commuter passengers and considerable amount of cargo seem to be there is this route. The river draft in this route is quite good, around 10.67 metre. Only the improvement of terminal facilities are required. Similarly shore/terminal facilities are to be developed at all the other traffic points such as Nowabganj, Hazaribagh, Bosila and Washpur. The water route from Sadarghat to Mirpur having draft of 10.67 metre upto Kholamura and thereafter 2.50 metre upto Mirpur is quite busy with both cargo and passenger vessels plying in both directions. The mechanized boats carrying passengers and cargo are of different types and design. The passenger boats have no designed seats or any other comfortable seating arrangements and are not covered with roof for sunshade.

About 55 cargo vessels were found anchored at a point of time at Mirpur. The draft in dry season in the Buriganga River from Sadarghat to Mirpur is 2.50 metre at most of the places beyond Kholamura-while the minimum requirement for a vessel of the sizes found anchored at Mirpur is 3.0 metre for carrying full load. The cargo vessels carrying sand/stone from Sylhet, fuel wood from Monda/chalna, cement etc. from Chittagong of the average capacity of 500 M.T. ply regularly upto Mirpur via Sadarghat.

(b) The Turag River from Mirpur (Shirnirtek) to Tongi

The river on the west and northwest of the city. It is narrow and shallow and hardly any traffic was seen except a few small engine boats and country boats. The average draft of the channel is less than 1 meter in the dry season rising to about 0.31 metre in high tide. The river could conveniently be widened by utilizing the flood embankment uptoTongi at most of the locations and the draft could be improved with further excavation/ dredging. There is potentiality of regular passenger/cargo traffic between Tongi and Mirpur in all seasons. In the wet season traffic coming to Tongi from far flung areas come to Mirpur through the Turag River.

(c) Tongi River from Tongi to the Balu River

This is on the north belt of the city connecting the Balu River in the east with Turag River in the west. The travel time Tongi to Trimukh (Balu River confluence) by mechanized passenger boat is 1 hour 10 minutes. The important stations along the river upto Trimukh are Manda, Mansaid, Harbaid and Ujanpur. The width of the river is around 61 metre and depth is 1.22 metre.

In respect of navigability the Tongi River is upto an acceptable standard except draft limitations in dry season at some locations between Manda and Trimukh. The water of the river upto about 3 km. upstream of Tongi is however, extremely polluted by industrial waste and direct sewerage connections. There are 3 ghats (landing stations) at Tongi town area on the bank of the Tongi River. All these ghats are earthen, unbuilt and unhygienic. No formal loading/unloading facilities are there. The other ghats along the route upto Trimukh are no better. Maintenance dredging, pollution control and ghat improvement are the issues for the further development of this water route.

(d) The Balu River on the Eastern Belt

The river connecting the river Sitalakhya at Demra in the south east runs all along the eastern border of the city and confluence with Tongi River at Trimukh on the north east corner of the city. The length of the Balu River from Demra to Trimukh is 21 km. width is 61 to 106 metre and the average depth is about 3.10 metre except between Trimukh and Isapura where draft is limited to 1 metre. The cargo/passenger vessels coming from the areas of south and south west districts through the river via Demra to Isapura, Beraid, Trimukh and Tongi sometimes face the draft problems at some places of the river in dry season. Capital and maintenance dredging at these stretches of the river would be required.

(e) The Buriganga and the Sitalakhya River in the South

On the southern periphery of the city there is regular heavy traffic both passenger and cargo form different districts via Munshiganj, Fatullah, Pagla, Shampur and Pangaon (BIWTA) container depot to Sadarghat through the rivers Buriganga and Dhaleswari and also from Munshiganj to Narayanganj to Demra through the river Sitalakhya, frequent passenger launch service is there from Munshiganj to Narayanganj. There is no draft or route problem in this section except that the improvement of certain ghats/jetties would be required.

(f) Intra-city Khals/Canals Water bodies

The Greater Dhaka city surrounded by peripheral river once had a good network of khals/canals shooting out from these rivers and commendable environmental features of lakes and water bodies. Out of about 25 canals traceable physically and from different studies only 3 khals namely Norai/Gazaria/Badda from Gazaria in the east connecting Balu River and Char Kamrangi Khal in the west connected with the river Buriganga are navigable for small and medium size vessels in the lean season. Zirani khal in the eastern fringe is also used in this season by small country boats upto Mothertek from Trimohoni, the confluence of Gazaria/Norai and Zirani Khals.

Passenger and cargo (mainly construction materials and earth) traffic in considerable are found in the Norai and Gazaria Khals between Balu River and Rampura. From Rampura to Meradia Khal off-shoot of Gazaria/Norai Khal about $1\,{}^{1}/_{2}$ km down stream of Rampura. Private housing estates are being developed along the banks of the Norai Khal. About 100 to 150 cargo vessels ply daily through the Norai/Gazaria Khal carrying mainly construction materials (earth and sand) to the sites of the housing projects from Balu River. Norai/Gazaria Khal is extremely polluted upto Trimohoni from Rampura causing environmental hazards both for human habitation as well as once rich fisheries in the area. The course of the Norai/Gazaria channel in the housing projects area has also been distorted by the private developers in the process of developing the housing project. This Khal with some excavation and improvement and proper maintenance would be good transport arteries to penetrate into the main city areas both for passengers and cargoes. They would also be good sources of fish resources and environmental improvement. The housing projects along the Khals/canals further emphasize the importance of them from traffic and environmental point of view.

A feeder Khal originating from the river Buriganga at Swarighat penetrates into the city areas as far as Mirpur connecting some important centres such as Char Kamrangi, Nowabganj, Lalbagh, Hazaribagh, and Rayerbazar. This Khal is navigable upto Nawabganj in dry season and although upto Mirpur in wet season. The canal is a shorter route to these places than the route through the river Buriganga upto

Hazaribagh/Nowabganj, 2km. from Swarighat is quite navigable for medium size vessels with a draft of around 1 meter. A little excavation at some places, maintenance of shores and a landing facility at Nowabganj would be positive for transport as well as environment. There has been substantial encroachment of the Khals waterway by unauthorized settlements barring the water transport system and causing environmental pollution. The clearance of the unauthorized structures by itself would go a long way for the improvement of the waterway for transport and environmental purpose. The travel time by mechanized boat from Sadarghat to Hazaribagh is approximately 15 minutes.

The Badda/Satarkul Khal originating from Norai Khal, about 1km. downstream of Rampura, flows upto eastern side of Baridhara. This Khal can be improved for mainly passengers and local goods transport for all seasons.

Meradia Khal from Narai Khal, 2 km. (approx.) down-stream from Rampura running upto Madartek has also got potentiality of local goods and passengers' transportation throughout the year with some improvement and proper maintenance of the Khal. The Zerani Khal from Trimohoni may be developed upto Nandipara Bridge (about 2 km.) for movement of goods and passengers. After this point, the use of the Khal upto north end of Dholai Khal has been seized due to habitation development resulting into construction of box/pipe culverts serving only the sewerage purpose.

Manda Khal from Trimohoni to Manda has got some water traffic even in the lean season. The necessary improvements of the Khal will make it navigable for all seasons.

Begunbari Khal from Rampura to Moghbazar becomes navigable only in the rainy season and limited number of country boats and engine boats of comparatively small size could come upto to Tongi Diversion road point near Moghbazar before the construction of sluicegate at Rampura bridge. The banks of this Khal at Moghbazar end has also been encroached upon by temporary structures. Clearance of the banks and some excavation and maintenance work removal of sluicegate can make the Khal operable for transport purpose all through the year.

A branch of the Begunbari Khal connects Banani/Gulshan Khals via Tejgaon industrial area. This part of the Khal can not be used for transportation purpose as it has been closed by road bridges at three locations and there is a little chance of making this channel operable.

The Khals (Gobindapur Khal, Beuper Khal, Dumni Khal and Bhatara Khal etc.) on the north eastern side near the Balu River are in the low lying barren areas, inundated during wet season, are not practically used in the lean season for transportation and have no potentialities for development at present. However, das a long term strategy the khals are to be protected for future expansion of the city in this area.

In the north-western areas of the city, there is a network of Khals-Ibrahimpur, Abdullahpur, Demra, Diabari connected with Turag River through sluicegates. The Khals are mostly in low lying areas not used for navigation purpose in dry season and get submerged in flood water during wet season. At present these khals have little potentiality for development for the purpose of transportation. However, as a long term strategy it should be kept in consideration that these Khals should be protected in case of development of the low lying areas in future. These Khals are getting gradually filled up by natural drainage process. For environmental and transport reason they are to be protected and maintained, if cost effective, for future development of these areas of the city.

Historically the important khals in the southern region of the city were Dholai Khal, Gandaria Khal, lower part of the Zirani Khal etc. connecting old city areas with Buriganga River have practically been in-filled and closed at different places by the development structures and sewerage system structures. There is no scope for resuscitation of these dead and dying water stretches any more.

The south-east end of the city developed as DND areas has three Khals namely Shampur Khal, Paglakhal and Fatualla Khal connected with Buriganga through sluicegates. They are serving now as natural drainage system. The potentiality of developing the Khals need detailed investigation feasibility.

Two water lengths created by borro pits-one in the north along side of the Airport Road from Joarshara to possibly Tongi, and another from Demra to Jattrabari alongside of road have a strategic potentiality for development of water taxi service if technically and economically feasible on detailed study.

However, it is doubtful whether these services would be effective alongside the well-developed road service in the areas.

Some important water bodies in the west and north of the CBD such as Dhanmondi Lake, Banani/Gulshan Lake and Baridhara Lake are more or less in good shape as environmental features. However, they need proper maintenance with necessary excavation and provision of recreation facilities. Another traditional water body, the Motijheel ditch area could have been developed as a lake and RAJUK has developed it as an extension of Motijheel commercial area.

The length, depth and width of the different station/ghats alongside of the peripheral river and those of the Khals as per BIWTA's latest survey (January 1998), BWDB and other sources of information are stated in the Table.

From the table it is evident that the Buriganga and Daleshawari rivers covering Mirpur, Sadarghat, Munshiganj, Narayanganj and Demra belt has a depth of minimum 2.13 to maximum 12.20 metre and except the Sadarghat-Mirpur route no dredging or excavation will be required.

The Turag River is of shallow depth of 0.61 to 1.53 metre all along except near Tongi Bridge and Mirpur. To make it navigable for all seasons capital dredging/excavation is required almost throughout the whole route. The Tongi river though navigable although the year, there is draft limitations even to a minimum of 0.61 to 1 metre and is needed to be dredged/excavated for particularly large cargo vessels. The reasonable draft available in this river is 1.83 to 2.13 metre from Tongi to Manda.

The Balu River from Trimukh down to Demra has wide variations of depths from 0.61 to 5.18 metre. The water length from Trimukh to Isapura/Gazaria is needed to be improved in respect of depth for big cargo vessels moving from Demra to Tongi.

The twenty five Khals/canals traced in the present water transport system is of total length of 120 km. These Khals are of a maximum 8.6 km. length (Abdallahpur Khal) to the minimum of 2 km. length. The details of depth of these canals/khals could not be ascertain due to the disruption, and closure of most of them. A few Khals operable in all seasons are found to have a depth of 0.61 to 1.20 metre. The present water transport network in the greater Dhaka is presented in Fig.

4.2 Water Transport Demand

At present the waterborne traffic, passenger and cargo in Greater Dhaka areas are mainly on the following water routes.

(a) Munshiganj-Fatulla-Pagla-Shampur-Sadarghat(Dhaleshwari and Buriganga river)
(b) Sadarghat-Swarighat-Zinjira-Barishore-Kholamura area-Bosila-Mirpur (Buriganga river)
(c) Sadarghat-Swarighat-Nowabganj-Hazaribagh (Char Kamrangi Khal)
(d) Mirpur-Sirnirtek-Goran, Chatbari-Berulia-RustompurDhoar/Ashulia-Tongi (Turag river)
(e) Mirpur-Chapraghat, (Chapra Khal)
(f) Mirpur-Sadullapur (Branch of Turag river)
(g) Tongi-Manda-Mawsaid-Harbaid-Ujanpur-Trimukh(Tongi river)
(h) Trimukh-Hordibazar(Khorki)-Isapura-Beraid-Kayetpara-Demra(Balu river)
(i) Isapura-Fakirkhali-Trimohoni (Balu river, Fakir Khal andGazaria/NaraiKhal)
(j) Trimohoni-Rampura
(k) Narayanganj-Munshiganj.

Besides, the care water routes, considerable volume of traffic move into the Greater Dhaka from different points of Balu river through the Gobindapur Khal, Beuper Khal, Dummi Khal, Badda Khal, Zirani and Manda Khal etc. in the wet season. Similarly, Abdullapur, Degun, Kallyanpur, Ibrahimpur, Ramehandra pur, Gabtoli, KatasurSarai-jafrabad etc. Khals in the west used for traffic movement in the wet season but are barred direct connection with Turag and Buriganga because of flood embankment.

The annual local passenger traffic in the above identified routes obtained from the field survey and secondary sources along with the route distances are shown in table 4.1.

Table 4.1: Annual Local Passenger Traffic and Route Distances

Route	Distances		Annual Load
	Road (km)	Water (km)	No.of passenger (lacs)
Munshiganj-Sadarghat	32	23	94.20
Sadarghat-Mirpur	16.5	16.5	34.00
Sadarghat-Hazaribagh	8.2	7.5	3.10
Mirpur-Tongi	18.0	19.0	3.00

Mirpur-Sadullapur	8	6.5	0.70
Tongi-Trimukh	7.45	8.0	3.60
Trimukh-Demra	35	22.0	3.50
Isapura-Trimohini	8	8.5(river)	1.80
Isapura-Trimohini	8	6.5(canal)	1.80
Trimohini-Rampura	6.15	4.5	0.60
Narayanganj-Munshiganj	17	20.5	24.50
Narayanganj- Demra	13	12	4.90

As seen above, the estimated demand for water transport in and around Dhaka in 1998 including inter-district traffic as about 170 lac passenger and 59 lac tons of cargo. The major traffic flow is on the water route of Narayanganj-Munshiganj- Sadarghat-Mirpur through Sitalakkhya, Dhaleshwari and Buriganga river as these river are perfectly navigable for big vessels round the year. But traffic in the peripheral rivers of Turag, Tongi and Balu and in the intra-city Khals is insignificant compared to the total movement of traffic in the city area. The reasons for low demand for water transport are: (a) Poor navigability of the peripheral waterways except the rivers in the southern periphery,(b) Gradual closing of the intra-city Khals/canals, and (c) Flood embankment disconnects some Khals from the peripheral waterways, (e) Non-availability of the regular and standard water transport services and (f) Competitiveness of the road transport system.

Infra-structural improvement of the waterways along with the development of ghats and terminal facilities and protection of the canals/Khals for navigational purpose with their integration to road transport system would encouraging for greater water transport demand. Incentives to the private sector similar to that given for the road transport sector in the city area would induce private entrepreneurs to come forward for introduction of regular and standard water transport service, which in turn would boost up demand for water transport by generated and diverted traffic.

The passenger traffic pattern by mechanized and non-mechanized boats is represented in Figures.

It is to be noted that at present passenger traffic in the Demra- Narayanganj water route is almost nil.

The cargo handled at the ports/ghats at Sadarghat, Mirpur, Tongi, Demra and Rampura would be indicative of cargo traffic movement along the water routes of the Greater Dhaka. The Sadarghat areas cover Swarighat, Badamtoli, MunshiKhola, Pagla, Fatullaghat and Narayanganj port covers Narayanganj terminal and ghats, Gudnail, Siddhirgonj, Adamjee jute mills ghats.

The main cargo handle at Sadarghat areas are food grain, cement, iron and steel, fish fertilizer, jute goods, edible oil, boulders and shingles, salt and other general cargo and building materials. At Mirpur ghat the major commodities are bolder and shingles cattles sand, cement, brick and fire-wood/timber and vegetables. At Tongi the major commodities are general goods, vegetables, food grain timber, fire wood etc. The main cargo handle at derma are stone/boulders and sand.

Mainly used clothes for processing's and general merchandise of small traders. With the construction of the planned 2^{nd} Buriganga Bridge close to Sadarghat and Jinjira, the river crossing traffic is presumed to be reduced substantially.

Chapter V

ECONOMIC ANALYSIS OF ALTERNATIVE WATERCRAFTS

Any passenger service must be very reliable otherwise the passengers will quickly return to other means of transport if they get delayed. Currently all over the world, water transport is catching up again with modern high-speed crafts, which closely match road and rail transport in terms of comfort and convenience. On many of the shorter routes speed on the water is not very important and the overall journey time can be reduced by the development of efficient terminals, which allow quick embarkation and disembarkation facilities. As most of the world’s major cities are on the bank of some river or other, the alternative mode using ferries to provide commercial operations essential characteristic are not only speed but also economy, reliability, safety, and comfort. The difficulty of achieving an acceptable compromise among all these often conflicting requirements is reflected in the number of solutions which have emerged [32]: (i) Monohull (ii) Catamaran, (iii) Trimaran, (iv) Planning, (v) Hydrofoil craft (vi) Hover craft (vii) Hybrid craft. However, whatever type of vessels are selected, the fleet must meet the transport demand and also consider the expectation of the recipient of the service.

The passenger transport services are required to serve two distinct areas in the passenger market, (i) to provide link between two points e.g. across a river or estuary and (ii) to provide services from suburbs to cities i. e. commuter ferries. As mentioned earlier, currently all over the world, water transport is catching up again with modern high speed ferries which closely match road and rail transport in terms of comfort and convenience. Any passenger service must be very reliable otherwise the passengers will quickly turn to other means of transport if they get delayed .On many of the routes speed on the water is not very important and the overall journey time can be reduced by the development of efficient terminals which allow quick embarkation and disembarkation facilities. As most of the world’s major cities are on the bank of some river or other, the alternative mode using ferries to provide commuter services are beginning to provide attractive to transport authorities.

In commercial ferry operations essential characteristics are not only speed but also economy, reliability, safety and comfort. The difficulty of achieving an acceptable compromise between all these often conflicting requirements are reflected in the number of solutions which have been tried.

To meet the requirements the following types of vessels have emerged: (i) Monohull (ii) Catamaran, (iii) Trimaran, (iv) Planning craft (v) Hydrofoil (vi) Hover craft (vii) Hybrid craft.

5.1 Monohull

This is a displacement craft and is one of the oldest types. Practically, all the country craft are of monohull type. The major drawback of this craft is its poor stability. However, stability can be improved but at the cost of power and maneuverability. At higher speeds this craft generates a lot of waves which causes high bank erosion in narrow canals and rivers and may also cause damage to flora and fauna.

5.2 Catamaran

This is also a displacement craft and is made by connecting abreast two fine-form hulls .This type of vessels have four basic advantages over the monohulls.

(i) It has over 50% greater deck area than monohull of the same length and displacement.

(ii) It offers excellent turning ability of wide separation of its two propellers. With one engine ahead and the other astern, a catamaran can virtually revolve about its central vertical axis.

(iii) Because of the hull configuration, catamarans have much higher stability than the monohull vessels.

(iv) Owing to its high stability it offers better disposition of the available space.

(v) It is possible to attain low wash hulls.

Because of the above advantages, catamarans are used for numerous applications e.g. passenger ferry, research ferry, research vessel, landing craft, fishing vessel, small dredgers, car ferries etc.

5.3 Trimaran

Trimaran is also a multihull displacement craft like catamaran and has the advantages of catamaran. It has an additional central hull, which helps in reducing the wash' and makes the journey more comfortable , Also if the vessel is small only one engine is required to power the vessel, which can be fitted in the central hull.

5.4 Planning Craft

A planning craft is not a displacement craft. A part of the hull load is supported by buoyancy whereas the rest of the load is supported by the hydrodynamic lift force generated during the forward motion of the vessel. By judicial hull design the hydrodynamic forces developed during the forward motion support major portion of the load with a substantial portion of the hull out of the water which helps in achieving very high speed. While at rest the planning craft resorts to buoyancy for support. This vessel comes under the category of high speed small craft.

5.5 Hydrofoil Craft

Hydrofoil craft makes use of the same principle involved in the flight of an aircraft. Hydrodynamic supporting forces are developed on fully or partially submerged extensions or appendages fixed to the main hull. The supporting forces result from submerged foils in forward motion. These vessels also can attain very high speed.

5.6 Hovercraft

The hovercraft introduces a new principle as far as ships are concerned. A normal ship is supported by the hydrostatic acting on the immersed surface. In the hovercraft the support is generated by an air cushion created by blowing air out of a curtain or skirt surrounding the boat .and a pressure is built- up which supports the craft. Propulsion is usually, but not necessarily by means of air screws. The effect of air cushion is to reduce the resistance to the motion through the water so that higher speeds are possible for a given expenditure of power. The system has been used successfully in cross-channel services between the United Kingdom and the Continent. The behavior of hovercraft in rough weather is being satisfactorily resolved, in particular for cross- channel service.

5.7 Hybrid Craft

Amongst all the approaches of high speed boat design, there is a trend towards the use of hybrids which incorporate some of the features of each of these high speed concepts in order to develop a design which come closer to requirements of speed and comfort These crafts are essentially sidewall hovercraft but to reduce the maintenance requirements created by flexible skirts they use an entirely rigid hull which has reasonably low wash characteristics with same maintenance requirements as that of a conventional rigid hull and considerably improved efficiency over a monohull or catamaran hybrid crafts have initial construction costs which are similar to that of a monohull or a catamaran.

Selection of a craft depends on the type of requirement which can be classified as follows:

(i) Commuter service across rivers or canals.
(ii) Commuter service within urban waters
(iii) Commuter service in rural areas
(iv) VIP executive service within urban area or between urban and rural areas.
(v) For tourists within urban areas, urban to rural (historical places) and inter island services.

5.8 Scope of Small Craft in Bangladesh

A significant share of foreign exchange earned by the country is through tourism industries. To benefit maximum from the tourism potential of our country a good transportation system is required. Where waterways or waterfront is available, the foreign tourists normally prefer to make use of small boats and ferries for pleasure cruise and or for sightseeing. Elegant and comfortable small craft can be designed and produced indigenously which can be either self-driven of hired in line with rent a car facility. This will give the tourists a lot more comfort, flexibility and privacy, which would greatly satisfy their holidaying requirements. Such a water taxi' can be designed for a wise capacity range of 6 to 80 persons. Accordingly, a small single engine to a twin screw propulsion system can be installed. The basic designs with minor modifications can also be used for other specialized purposes.

5.9 Water Taxi

The design of a water Taxi should possess the following features:

(i) Simple design from construction and maintenance viewpoint.
(ii) High displacement to power ratio
(iii) Good stability
(iv) Low wash
(v) Good maneuvering qualities
(vi) Comfortable
(vii) Low initial cost
(viii) Low operating cost
(ix) Low upkeep cost
(x) High reliability

5.10 Design

A water taxi should have a simple design so that it can also be constructed in places other than conventional shipyards. The construction should be possible without extensive use of heavy machinery or sophisticated equipment. Workforce can be easily trained for the execution of the work and construction carried out under supervision. This will open avenues for employment, especially for people in rural areas.

Hull form and configuration should be designed on the basis of minimum resistance and low wash for its operating speed. As such not much data are available for non-conventional hull forms, which calls for proper tank for ensuring minimum resistance.

The craft should have good stability so as to satisfy the following requirements:

(i) To provide adequate righting moment in the event of excessive healing due to uneven load distribution or rough weather,

(ii) To provide a fear-free, comfortable ride.

(iii) Should be capable of taking nearly 100% overloading to account for local condition and in case of emergency.

It should have good maneuverability and be capable of negotiating sharp bends as well as obstacles quickly and efficiently so that the craft can be operated in confined and/or congested areas also.

The taxi should have good motion characteristics for providing comfortable ride. The material, and the construction method should be judiciously chosen to keep the initial investments and hull maintenance cost to the minimum. The maintenance cost of the machinery and fitting is also to be kept at the lowest level.

Lastly, the vessel should satisfy all the reliability criteria i.e., operational reliability, safety reliability and machinery reliability

It is not always possible to have all the bests in a particular craft. It is therefore necessary to optimize the conflicting to get the best combination for an operationally economic design.

5.11 Configuration

Considering the above requirements, in Bangladeshi context, a catamaran built with fiber reinforced plastic is best suited for water taxi. As stated earlier, catamarans are displacement craft. They have good stability and maneuvering capabilities. As they may be operated in restricted waters i.e., restricted draft and width of rivers, channels and canals, very high speed is not desired. As a matter of fact in port areas, maximum speed limits are imposed by the port authorities. In many rivers fishing operations by local residents or the bank conditions (erosion) also impose unwritten speed limitations. The power requirement can be either met with the help of outboard motors or standard two stroke engines with some modification or four stroke engines.

For a very small size catamaran a single engine is sufficient to achieve the desired speed but this propulsion system is not very efficient. A twin screw arrangement chances the efficiency to a great extent and is suitable for 8 m to 10m long catamarans. For smaller craft, it is advisable to use single engine and the propulsion efficiency can be improved by inclusion of a central hull

In view of the above two types of vessels are considered to provide services in the area under study. The important parameters, which influence the selection, are present transport network, traffic movement, draft restrictions, safety aspect, nature of service socio-economic condition of the passengers, etc. The first category is a mono hull vessel with three different sizes. This is a displacement craft and is one of the oldest types. Practically, all the country craft are of mono hull type. The major drawback of this craft is its poor stability. However, stability can be improved but at the cost of power and maneuverability. At higher speeds this craft generates a lot of waves, which causes high bank erosion in narrow canals and rivers and may also cause damage to flora and fauna.

The second category of choice is a catamaran water taxi of three different sizes. The design of the vessels should possess the following features:

(i) Simple design from construction and maintenance viewpoint, (ii) High displacement to power ratio, (iii) Good stability , (iv) Low wash, (v) Good maneuvering qualities, (vi) Comfortable, (vii) Low operating cost, (viii) Low upkeep cost, and (ix) High reliability

The major characteristics of these vessels are shown in Table 5.1

Table 5.1: Principal Particulars and Costs of Alternative Water Crafts

	Water Taxi (monohull)			Water Taxi (catamaran)		
Items	Large (Ves.1)	Medium (Ves.2)	Small (Ves.3)	Large (Ves.4)	Medium (Ves.5)	Small (Ves.6)
Length (m)	21.3	18.3	15.3	22.5	17.5	14
Breadth(m)	4.3	3.65	3.0	8.25	6.5	5.5
Depth(m)	1.0	1.0	0.9	2.2	2.2	2.1
Vessel cost (Tk.)	64,00,000	48,00,000	33,00,000	124,00,000	90,00,000	70,00,000
Eng. Power (HP)	150	120	100	2×180	2×150	2×120
Capacity (nos)	100	75	50	100	75	50
Speed (Knot)	10	10	9	25	25	22

5.12 Projected Economics of Operation

In order to have a quick look into the possible economic performance of the vessels in the various routes, the projected economic analysis has been prepared and presented here. It is to be noted that though the factors affecting the economics as well as the transport demands are same in a particular route, since there are six standard type of vessels, the projected economic performances are evaluated separately. However, the following assumptions are common in all cases.

(i) When an individual vessel starts commercial operation, it generally operates at a rate lower than the full capacity.

(ii) The load of the vessel increases at the same rate as increases in the movement of passengers in the route. However, no vessel operates at more than 20% overload.

(iii) The annual escalation rate is as in Table 5.2.

(iv) The rates of depreciation of hull and machinery have been assumed to be as 5% and 10% respectively.

(v) Provisions for routine renovation of the vessel have been made on the 3rd, 6th, 9th year.

(vi) A Provision of a massive engine overhauling has been made on the 6th year of the operation.

(vii) It is also assumed that the operator will acquire the vessels with no down payment (100% on loan).

The following economic indices of performance have been presented for each type vessels in individual routes

- Net Present Value (NPV) of the investment based on 10% discount rate and
- Benefit cost ratio based on 10% discount rate.

Table 5.2: Annual rates of escalation

Items	Increase (%)
Hull Maintenance	5.0
Engine and Machinery	10.0
Fuel and Lubricating oil cost	5.0
Insurance, Registration, Port charges etc.	5.0
Passenger fare	5.0
Crew wages	5.0

For economic analysis, the fare rate given in Table 5.3 is used. This fair rate is chosen on the basis of fair rate exist in waterways and bus route (see Appendix C). For crew cost estimation, data of Table 5.4 is used for economic analysis which is collected from Govt. office.

The projected economic performances based on the NPV and B/C ratio of vessels operating in the route are given in Table 5.3.The detailed calculation of projected economic performances is shown in Appendix A.

Table 5.3: Passenger Fare Assumed for the Analysis

Items	Ordinary Passenger Vessel (mono hull)	Water Taxi (Catamaran)
First Class (Tk./Km/Passenger)	2.75	3.50

Table 5.4: Cost estimation for crews

Crew cost					
Serial No.	Designation	Pay scale BDT	Monthly Average Pay	Dearness Allowance	Festival Allowance
1	Inland Master Officer	16000-38640	BDT 27,320.00	BDT 5,464.00	BDT 54,640.00
2	Inland Engine Officer	16000-38640	BDT 27,320.00	BDT 5,464.00	BDT 54,640.00
3	Inland Junior Master Officer	12000-32240	BDT 22,120.00	BDT 4,424.00	BDT 44,240.00
4	Inland Junior Engine Officer	12000-32240	BDT 22,120.00	BDT 4,424.00	BDT 44,240.00
5	Wheel Succany	9300-22490	BDT 15,895.00	BDT -	BDT -
6	Greaser	9000-21800	BDT 15,400.00	BDT 3,080.00	BDT 30,800.00
7	Deck Tandel	9000-21800	BDT 15,400.00	BDT 3,080.00	BDT 30,800.00
8	Lascar	8500-20570	BDT 14,535.00	BDT -	BDT -
9	Bhandari	8500-20570	BDT 14,535.00	BDT -	BDT -
10	Sweeper	8500-20570	BDT 14,535.00	BDT -	BDT -

Table 5.5: Projected Economic Performances of the Vessels using updated data

Items	**Ordinary Passenger Vessel (mono hull)**			**Water Taxi (Catamaran)**		
Vessel Category	Ves.1	Ves.2	Ves.3	Ves.4	Ves.5	Ves.6
NPV(000Tk.) (at 10% discount rate)	38442	21232	5015	61866	26627	-17200
Cost Benefit Ratio	1.314	1.22	1.07	1.26	1.13	0.89

The economic analyses presented here are based on some assumptions of the price of the proposed vessels, a close to actual for Sadarghat to Mirpur route. There are two categories of the fares. The first category is for the ordinary mono hull passenger vessels with less speed and fare data of which is very close to the existing rate. The second category is for the catamaran type water taxi with moderately high speed. Analysis and studies reveal that with the currently prevailing fare rate operation of passenger vessels in the route will be at a considerable profit (except vessel 6) provided the vessels are efficient and the management is effective. Even with vessels making small profits, after maintaining reserve for the depreciation and payment of interest, there will be no loss during the operating years in case of vessel 1 to vessel 5. However, it is seen that vessel 4 (Catamaran hull) is the best on the basis of the evaluated economic performance.

Chapter VI

ENVIRONMENTAL IMPACT ASSESSMENT

6.1 General Discussion:

The climate of the earth is changing. Inland and coastline are disappearing under water. More frequent occurrence of strong hurricanes and typhoons, heat wave, melting polar Ice caps, shift of agricultural zones, coral bleaching are some of the evidences that show the certainty of climate change. Scientists believe that in all of the human history, climate has never changed as fast as it is changing today. Plenty of reasons are behind this change. Some of them are natural and some are human induced [1] Ever increasing human activity is having a negative effect on the climate.

The transport system is a major source of greenhouse gases and other harmful emissions. Special attention is being paid to the transport sector to reduce the emissions caused by transporting goods and people. Measures being considered include raises in excise duties, stepping up enforcement of speed limit, finding alternative transport modes and infrastructure. Some research has showed that the marine transports with conventional speed are environmental friendlier the road transports [2-4]

Dhaka is the capital city of Bangladesh where almost ten million people are living in the city area. The major contribution of air pollution in Dhaka city come road transport vehicles. The pollutants most often of concern are carbon monoxide, hydrocarbons (HC), sulfur oxides (SOX), nitrogen oxides (NOX) and suspended particulate matter (SPM). Recent studies also indicate that road transport vehicles are also a major or primary source of other toxic air pollutants including 1-3- butadiene, benzene and a number of carcinogens associated with particulate matter [5] Very high demand of local transports for the huge number of inhabitants of this city put a large number of road vehicles on the road. On top it is the fact that most these vehicles are outdated with the engines burning fuel inefficiently. This huge number of transports has deteriorated the traffic system and also the environment of this city.

This thesis work contains an assessment of likely environmental impacts of six different water transport crafts belonging to two different categories(conventional and catamaran) while operating in some of the routes in the intended circular water channel. The results are expected to be used for comparison of environmental performances of these proposed crafts.

Finally, the scope of use of these findings in future planning in inland water transport is discussed on the basis of assessment results.

For environmental impact assessment various data are needed. Table 6.1 show the particulars of three different size of mono hulls with data for fuel consumption and steel weight considered during construction phase. Inventory list of the compounds and substances for the construction phase of different types of vessels is given in Table 6.2. Emissions for the production of 1 ton electrolytic chrome coated steel and emissions through burning of 1kg diesel (3% Sulphur content) by a ship engine are given in Table 6.3 and Table 6.4 respectively.

In addition, emissions for the production of 1 kg diesel (BUWAL 132) and Characterization factors for various impact categories are given in Table 6.5 and Table 6.6. Weighting factors for various environmental impact categories are given in Table 6.7.

The detailed calculation of environmental index for six different types of ship with six different routes such as Munshiganj-Sadarghat, Sadarghat-Mirpur, Mirpur-Tongi, Tongi-Demra, Demra-Narayanganj and Narayanganj-Munshiganj is shown in the Appendix B-1, B-2, B-3, B-4, B-5 and B-6. The summary of the overall results of environmental destruction index is given in Table 6.8.

Table 6.1: Principal Particulars of Alternative Water Crafts with fuel consumption and steel weight

	Water Taxi (monohull)			Water Taxi (catamaran)		
Items	Large (Ves.1)	Medium (Ves.2)	Small (Ves.3)	Large (Ves.4)	Medium (Ves.5)	Small (Ves.6)
Length(m)	21.30	18.30	15.30	22.50	17.50	14.00
Breadth (m)	4.30	3.65	3.00	8.25	6.50	5.50
Depth (m)	1.00	1.00	0.90	2.20	2.20	2.10
Eng. Power (hp)	150	120	100	2×180	2×150	2×120
Fuel consumption rate (gm/bhp-hr)	200	200	200	200	200	200
Capacity (nos.)	100	80	60	100	80	60
Speed (knot)	10	10	9	25	25	22
Steel Weight (tons)	23	18	13	48	33	25

Table 6.2: Inventory list of the compounds and substances for the construction phase of vessels

Vessel Type	Parts of Vessel	Energy consumption (MJ)	Co_2 emission (kg)	NO_xemission (kg)	SO_xemission (kg)	Phosphorous emission (kg)
Vessel 1	Hull	2.11×10^6	1.63×10^5	739.59	199.21	146.54
	Engine	4.93×10^3	378.92	0.47	20.70	0.65
Vessel 2	Hull	1.54×10^6	1.19×10^5	539.37	145.28	106.87
	Engine	3.94×10^3	303.13	0.37	16.56	0.52
Vessel 3	Hull	9.53×10^5	7.33×10^4	333.58	89.85	66.10
	Engine	3.29×10^3	252.61	0.31	13.80	0.43
Vessel 4	Hull	9.42×10^6	7.25×10^5	3.30×10^3	888.22	653.4
	Engine	1.18×10^4	909.40	1012	49.68	1.55
Vessel 5	Hull	5.77×10^6	4.44×10^5	2.02×10^3	544.29	400.40
	Engine	9.86×10^3	757.83	0.93	41.40	1.29
Vessel 6	Hull	3.73×10^6	2.87×10^5	1.31×10^3	351.70	258.72
	Engine	7.89×10^3	606.26	0.74	33.12	1.03

Table 6.3: Emissions for the production of 1 ton electrolytic chrome coated steel (BUWAL 250)

Co_2 (gm)	NO_x (gm)	SO_x (gm)	N_2O (gm)	HF (gm)	HCI (gm)	Methane (gm)	Ammonia (gm)	CxHy (gm)	Suspended Particulate Matter (gm)
2.95×10	4540	6180	9.52	11	86.30	1.08×10^4	1.97	5.23	1410

Table 6.4: Emissions through burning of 1kg diesel (3% Sulphur content) by a ship engine (Chalmers 1991)

Co_2 (gm)	NO_x (gm)	SO_x (gm)	N_2O (gm)	Suspended Particulate Matter (gm)
322.55	3.15	5.45	4.26	0.468

Table 6.5: Emissions for the production of 1 kg diesel (BUWAL 132)

Co_2 (gm)	NO_x (gm)	SO_x (gm)	N_2O (gm)	Ammonia (gm)	C_xH_y (gm)	Suspended Particulate Matter (gm)
312.000	1.900	3.860	0.048	0.020	6.790	0.220

Table 6.6: Characterization factors for various impact categories

Impact category	Responsible substances or compounds	Characterization factor	Unit
Fossil fuel exhaustion	Energy consumption	1.000	MJ
Local warming	Heat radiation	1.000	MJ
Global warming	Co_2	1.000	Kg
	N_2O	270.000	Kg
	CH_4	11.000	Kg
Acid rain	Ammonia	1.880	Kg
	HCL	0.880	Kg
	NO_x	0.700	Kg
	SO_x	1.000	Kg
Eutrophication	NO_x	0.130	Kg
	Ammonia	0.330	Kg
	Phosphorous	3.060	Kg
Local air Pollution	Particulate matter	1.000	Kg
	SO_x	1.000	Kg
	C_xH_y	0.398	Kg

Table 6.7: Weighting factors for various environmental impact categories

impact category	Weighting factor
Fossil fuel exhaustion	0.143
Local warming	0.105
Global warming	0.271
Acid rain	0.165
Eutrophication	0.096
Local air Pollution	0.220

Table 6.8: The environmental destruction index (comparison with vessel 1)

Environmental Index						
Vessel Type/ Route	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
Munshiganj-Sadarghat	1	0.92	0.91	1.84	1.35	1.26
Sadarghat-Mirpur	1	0.89	0.87	1.94	1.55	1.33
Mirpur-Tongi	1	0.83	1.02	2.97	1.98	1.47
Tongi-Demra	1	0.82	0.69	1.65	1.15	0.92
Demra-Narayanganj	1	1.32	1.02	2.96	1.97	1.47
Narayanganj-Munshiganj	1	0.90	0.90	1.80	1.49	1.31
Total	6	5.69	5.42	13.16	9.49	7.75

In addition to use database for calculating the environmental destruction index in comparison with vessel 1, the main input data has been used for modeling of a commercial software tool (Simapro LCA). There are various methods available in the software for environmental impact assessment. Of them, Eco-indicator 99 (H) has been used for comparison.

Eco-indicator 99 uses the damage-oriented approach. The development of the Eco-indicator 99 methodology started with the design of the weighting procedure. Traditionally in LCA the emissions and resource extractions are expressed as 10 or more different impact categories, like acidification, ozone layer depletion, eco toxicity and resource extraction. Eco indicator 99 (I) assess the seriousness of three damage categories:

a. Damage to Human Health, expressed as the number of year life lost and the number of years lived disabled. These are combined as Disability Adjusted Life Years (DALYs), an index that is also used by the World Bank and WHO.

b. Damage to Ecosystem Quality, express as the loss of species over a certain area, during a certain time.

c. Damage to Resources, expressed as the surplus energy needed for future extractions of minerals and fossil fuels.

In order to be able to use the weights for the three damage categories a series of complex damage models needs to be developed and in order to calculate the Eco- indicator score three steps are needed:

- Inventory of all relevant emissions, resource extractions and land use.

- Calculation of damages these flows cause to human health, ecosystem quality and resources.
- Weighting of these three damage categories.

Figure 6.1 shows the concept of Eco Indicator 99

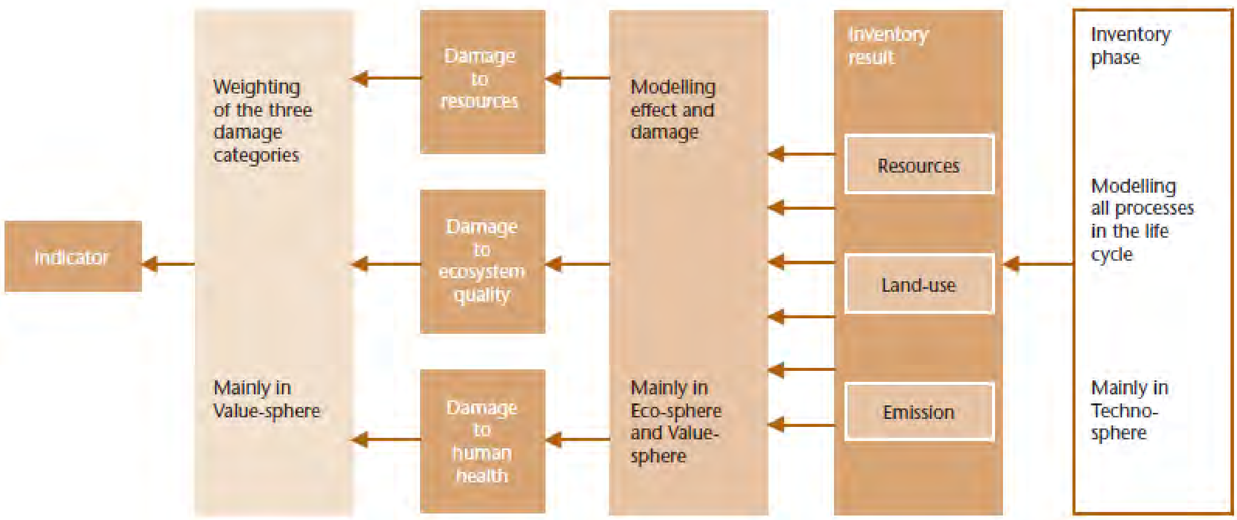

Fig 6.1: The Concept of Eco-Indicator 99 (H)

The Eco-indicator values for a certain impact are expressed as a sum of impacts for each of the three categories. Each of the impact categories are expressed in one unit. Impact on human health is expressed as DALY, Disability Adjusted Life Years, that is the number of years of life lost and the number of years lived disabled. Impact on ecosystem quality is expressed as the loss of species over a certain area during a certain time PDF *x* m2 *x* year (PDF=Potentially Disappeared Fraction). Depletion of resources is expressed as surplus energy needed for future extractions of minerals and fossil fuels. The principle of damage assessment is shown in Figure 6.2 below:

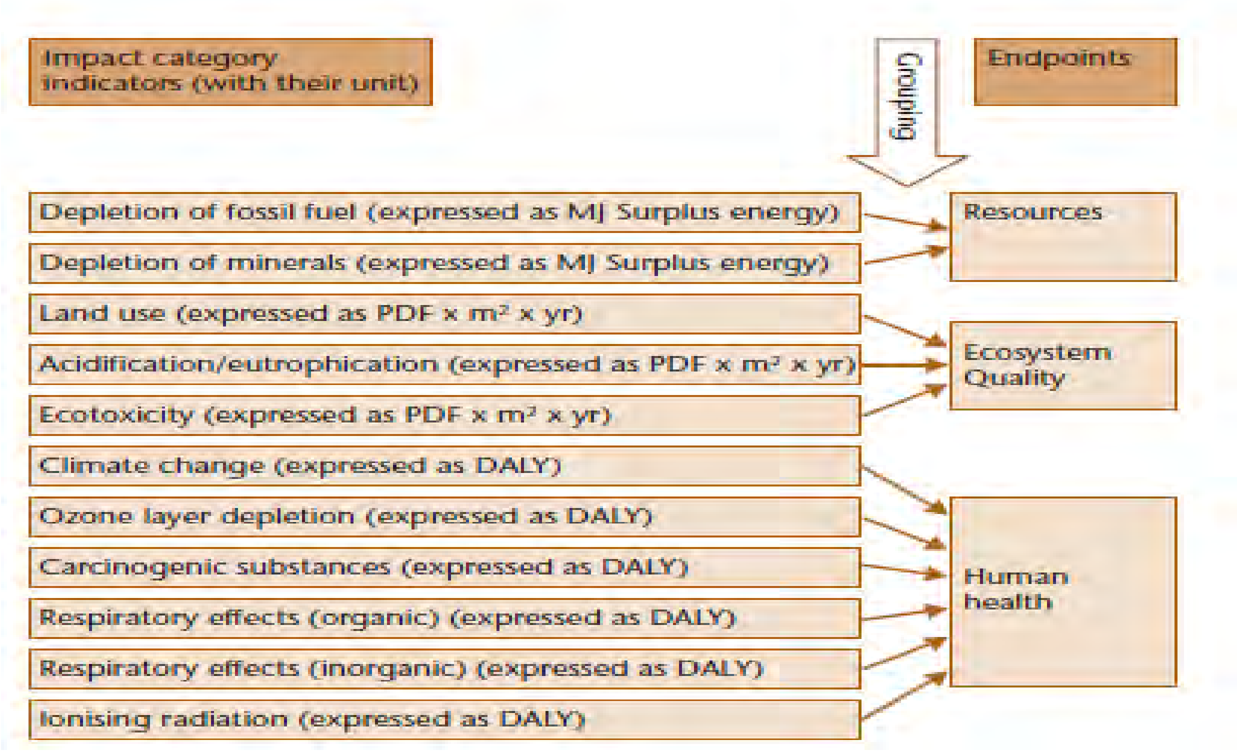

Fig 6.2: Principle of Damage Assessment in Eco-indicator 99 (H)

Detailed explanation regarding Eco-indicator 99 (H) can be found in the literature [kosar, 2012].

For environmental assessment by Eco-indicator 99, modeling is needed for each vessel and each route. For example, Figures 5.3 to 5.8 show the modeling for six vessels for Shadarghat-Mirpur route. This input data will be used for environmental assessment by Eco-indicator 99.

Assessment result for different types of vessels (3 monohul and 3 catamaran) have been shown in the Figures 6.9 to 6.14. Similar calculation needs to be done for all vessels in all 6 routes considered in this study.

Figure 6.15 shows the overall impact for different types of vessels in different routes in a single graph. This implies that environmental assessment by Eco-indicator methods leads to similar conclusions that we found from the relative environmental impact of the various ships earlier.

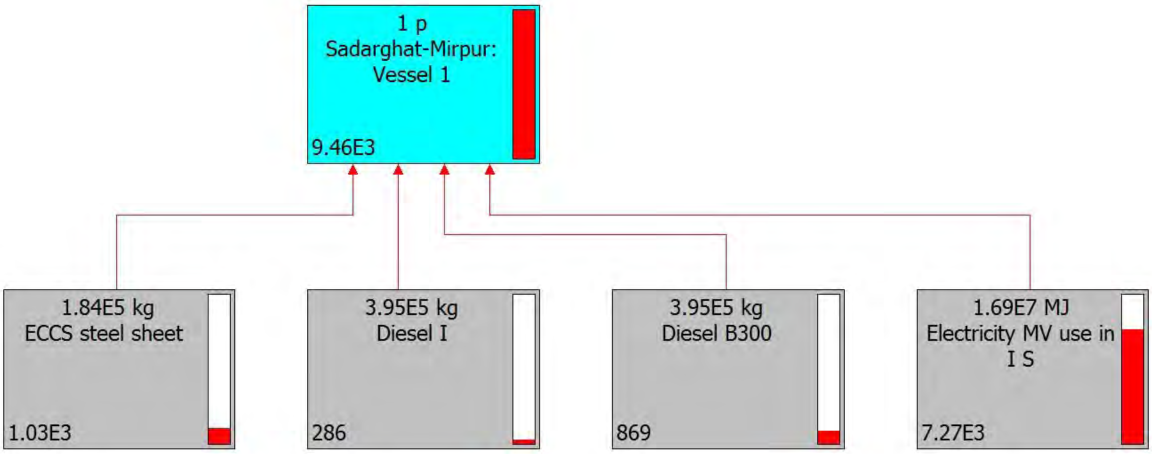

Figure 6.3: Environmental modeling for vessel 1 of Sadarghat-Mirpur route

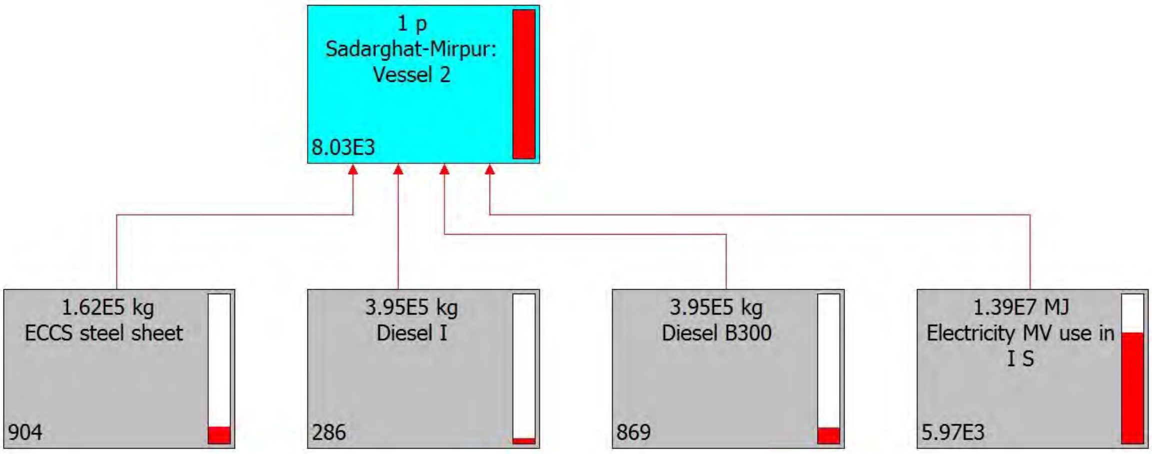

Figure 6.4: Environmental modeling for vessel 2 of Sadarghat-Mirpur route

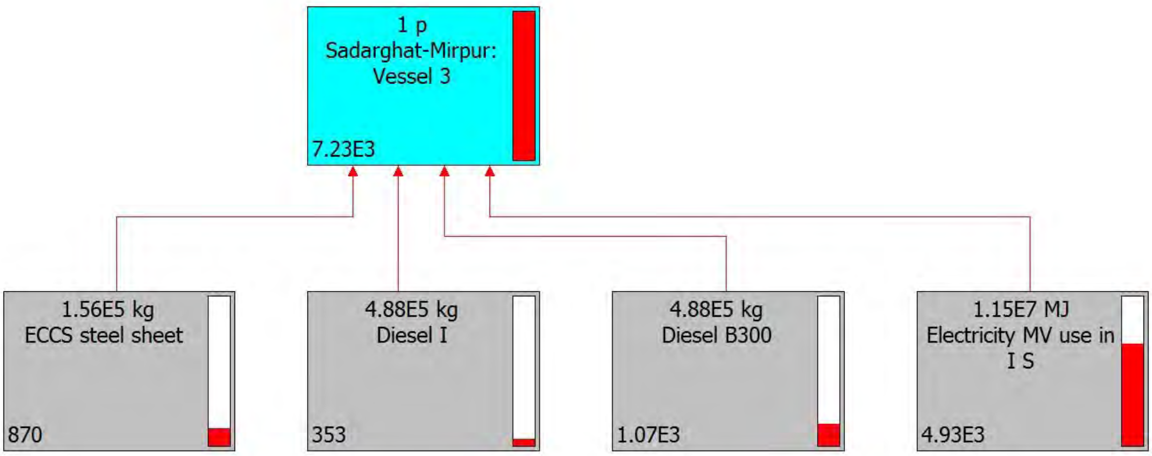

Figure 6.5 Environmental modeling for vessel 3 of Sadarghat-Mirpur route

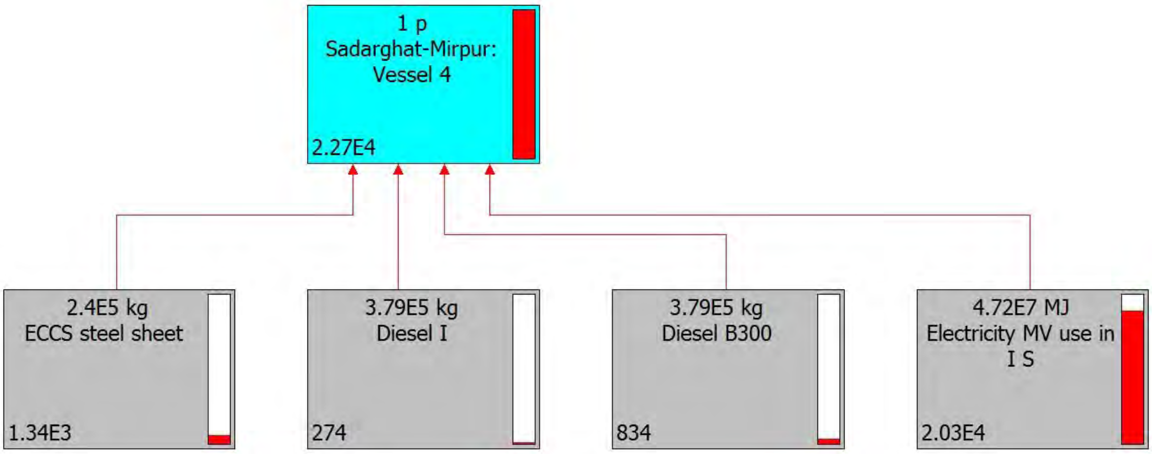

Figure 6.6: Environmental modeling for vessel 4 of Sadarghat-Mirpur route

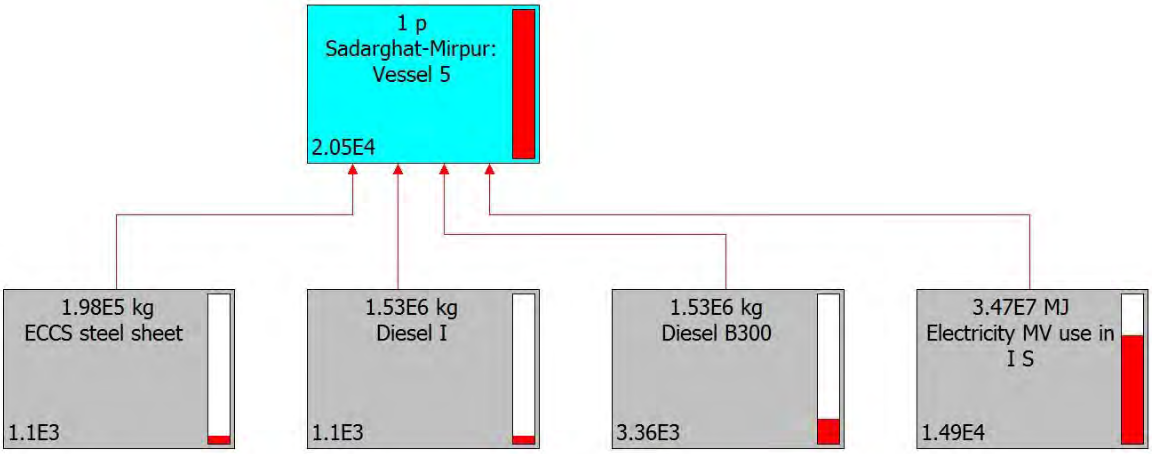

Figure 6.7: Environmental modeling for vessel 5 of Sadarghat-Mirpur route

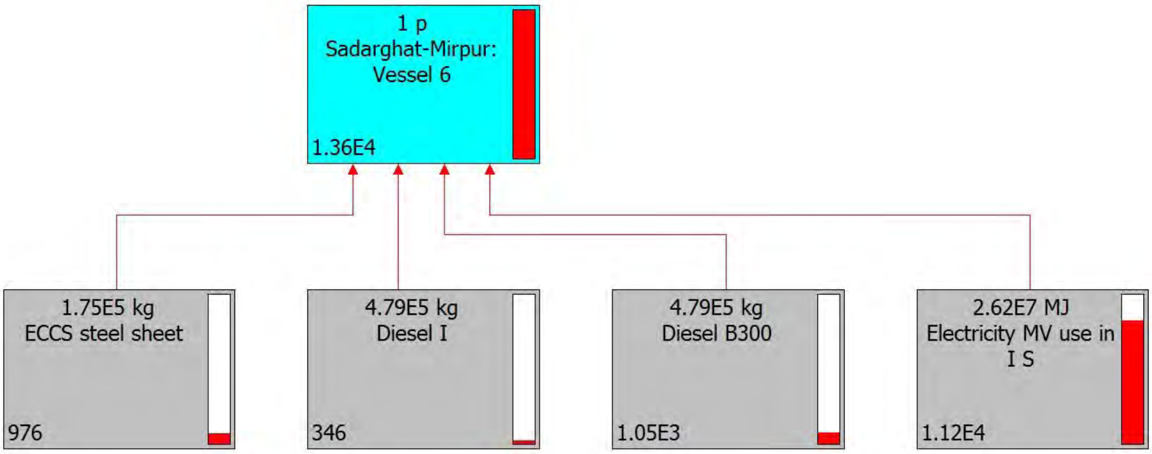

Figure 6.8: Environmental modeling for vessel 6 of Sadarghat-Mirpur route

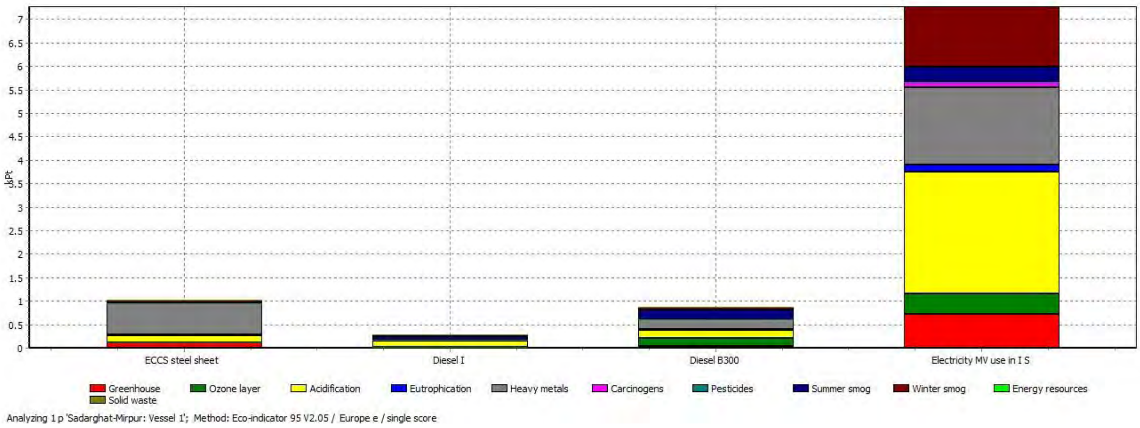

Figure 6.9: Assessment results of vessel 1 for Sadarghat-Mirpur route

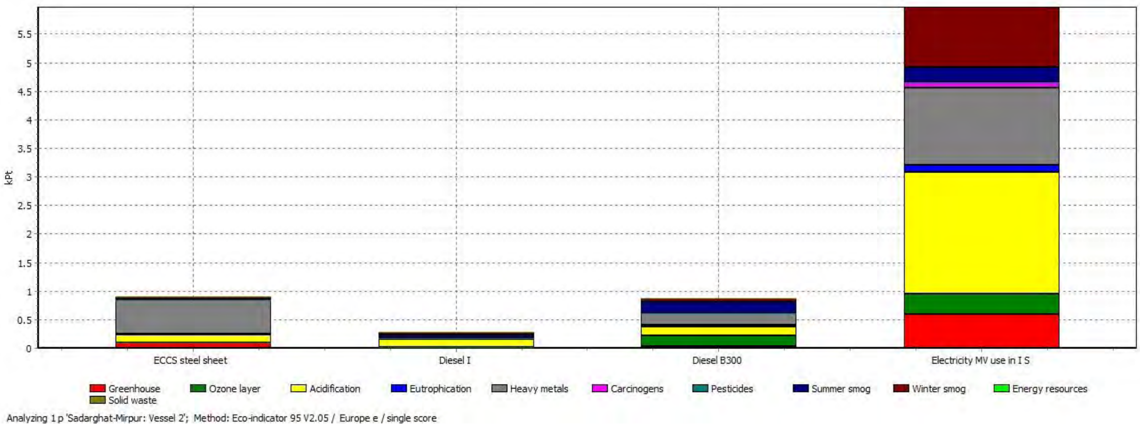

Figure 6.10: Assessment results of vessel 2 for Sadarghat-Mirpur route

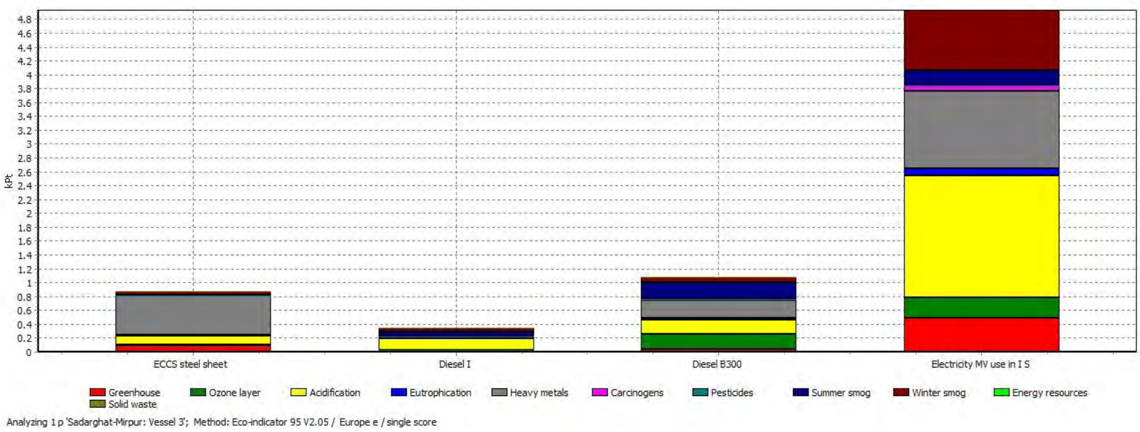

Figure 6.11: Assessment results of vessel 3 for Sadarghat-Mirpur route

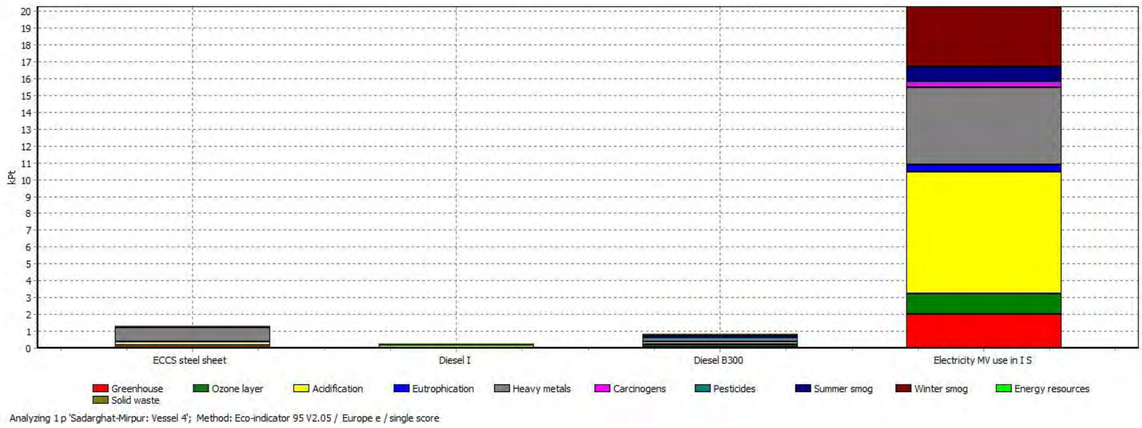

Figure 6.12: Assessment results of vessel 4 for Sadarghat-Mirpur route

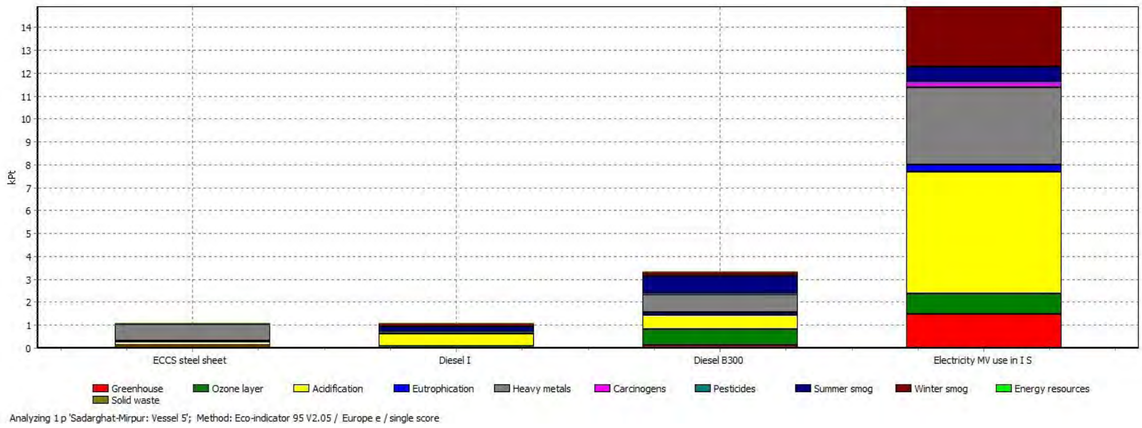

Figure 6.13: Assessment results of vessel 5 for Sadarghat-Mirpur route

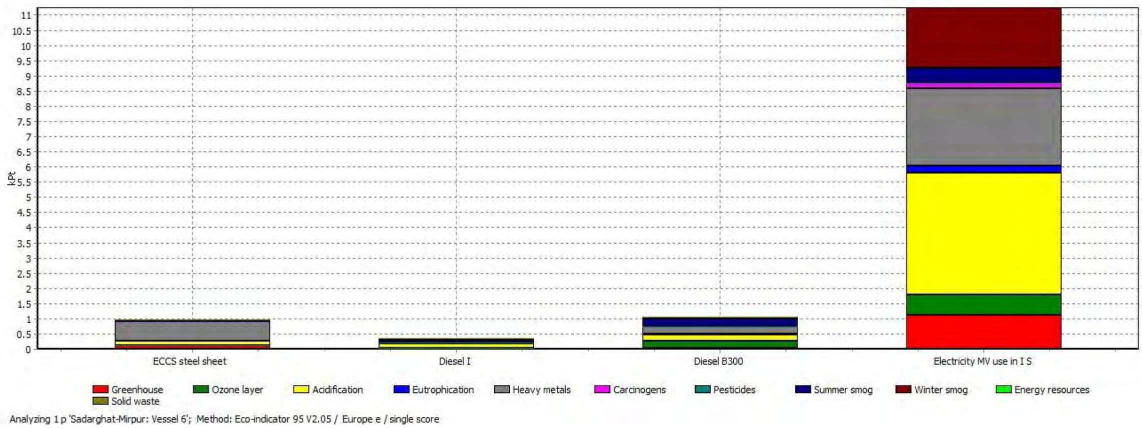

Figure 6.14: Assessment results of vessel 6 for Sadarghat-Mirpur route

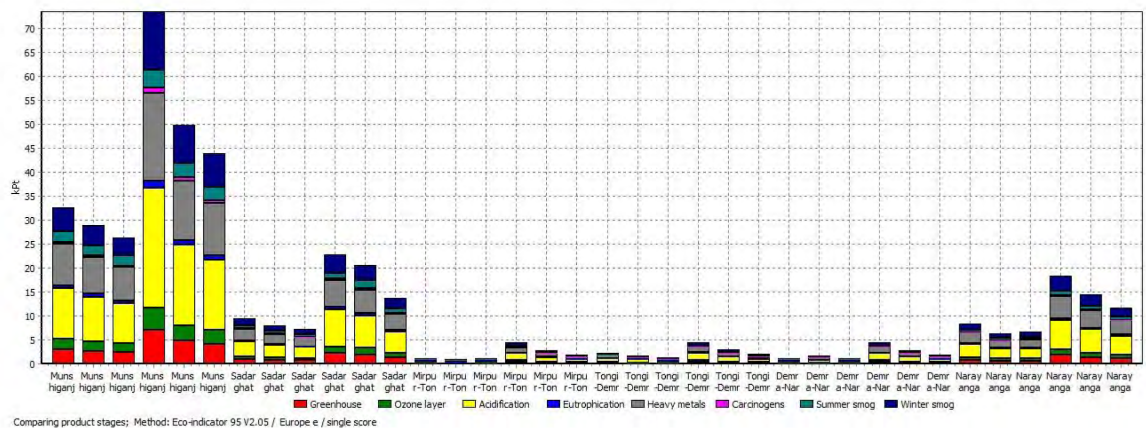

Figure 6.15: Overall assessment results of vessel 6 for different routes

6.2 Results and Discussions

The environmental destruction index for the vessel-3 showed the least value, which means that this type of vessel is less detrimental to the environment compared to the vessel-1 against which the values were normalized. Vessel-4 is with the highest value of index. The result showed that the catamaran type water transport would not be suitable from the environmental point of view.

Similar findings have been found from the environmental assessment result by Eco-indicator 99.

Vessel 3 (60 passengers with 9 knot speed) was found to be the environmental friendliest among the six alternatives considered. The catamaran vessels, though it would provide superior quality service with its high speed and comfort, would not be attractive if the environmental aspects are in concern.

CHAPTER VII

EXISTING CONDITION OF WATER TRANSPORT ROUTES IN AND AROUND DHAKA

Although the operation of vessel for carrying passengers in and around Dhaka city was introduced in 2010 and gradually number of water buses was increasing from year 2010 to 2014, unfortunately in the recent time it was found that water buses operation operated by Bangladesh Inland Water Transport Corporation (BIWTC) have been shrunken and only two water vessels are now operating in only few routes. Table 7.1 shows the statistics of water bus services from year 2010 and Table 7.2 shows annual local water borne local passenger demand. Again, Figure 6.1shows the current operating routes of water vessels.

Although demand of water craft for various routes is still high, but it is apparent that due to some inherent problems, water transport services have been unpopular. It has been tried through field study to find out the reasons behind this deplorable condition of water bus services. A survey was conducted physically considering the following factors:

-Identification of existing operating route

-Frequency and time schedule

-Demand of passenger with loading factor

- Physical condition of Ghat

-Fare (both bus & water taxi)

-Comfort ability of the passenger /vessel design

-Environment and traffic of existing water routes

-Any physical constraints for operation of the vessel

-Suggestions from all stake holders: operators/ users

A survey data form has been developed to gather the information of the above mentioned factors. The collected information from the field survey has been given in Appendix B.

From the survey, it has been found that water buses are currently operational in two routes: Badamtoli to Gabtoli and Narayanganj to Tongi.

Survey data shows that the passenger Loading Factor of these routes has been decreased tremendously over the years. The percentage of passengers load on the routes Badamtoli to Gabtoli and Narayanganj to Tongi are 30-50% and 10-20%respectively.

From the field study it has been observed that the present condition of the various ghats such as Badamtoli Ghat, Narayanganj Ghat are not satisfactory at all. The Ghats are surrounded by dirty and unhealthy environment. It seems that concerned authority of ghat operation i.e., BIWTA shows little attention regarding fulfillment of basic facilities needed for passenger. Even some landing Pontoons of Narayanganj Ghat are not well connected to the Bank of river or land road. The Pontoon of Water Bus Ghat also is not well connected to land road. As a result, the passengers of water vehicles have been suffering a lots and hence some of them are turning to road transport.

The design of water bus is very ordinary in nature and quality of the seat arrangement inside the water Bus or Water Boats are not enough to satisfy the passengers. From the field study it has been observed that the fares of water buses for the specified routes are comparatively lower than the fares for road services. That is, the existing fares of water transport services are still competitive with respect to other modes of transports specially buses. But in spite of this matter the passengers are moving to road transport services because of above mentioned reasons. Frequency of water bus is rather very insufficient and there is no guarantee that bus will go on time. Reliability and serviceability condition are very deplorable. Passengers believe that there is ample opportunity to attract the service and passengers are ready to pay even higher price if service is better. One more point mentioned by the passenger was its unawareness of passengers regarding this service. Service provider authority has not given due importance regarding the publicity of this service. As a result, people are unaware about this service. During the dry season, due to water pollution in the river Buriganga, bad smell surrounds many routes, as a result passenger feel very discomfort to avail it during dry season (see appendix D).

Figure 7.1: Current Water Transport Routes in Dhaka City

Table 7.1: History of Water Buses in and around Dhaka city

Year	Introduced Number of Water Buses	Route Details	
		Route	Number of Water Buses
2010	2	Badamtoli-Gabtoli	2 (abandoned after 11 months)
2013	4	Badamtoli-Gabtoli	4
2014	6	Badamtoli-Gabtoli	2
		Narayanganj-Tongi	3
		Chittagong-Rangamati	1

Table 7.2: Annual Waterborne Local Passenger Traffic

Route	No. of Passengers Annually using the route (Lacs)
Badamtoli-Gabtoli	14.50
Narayanganj-Tongi	1.50

CHAPTER VIII

8 CONCLUSIONS & RECOMMENDATIONS

8.1 Conclusions

As mentioned earlier, feasibility of the water transport for transportation of passengers in the circular water channel around the Dhaka city has been investigated and the outcome has been presented in this study. Data and information used in the analysis were collected though discussions with relevant stakeholder, GOB agencies, donor agencies, BIWTA and other implementing agencies. Alternative design of the suitable vessels with special emphasis to water taxi services based on the transport demand in the area were examined considering various important factors such as socioeconomic condition of the passengers, nature of journey, safety requirement and comfort, infrastructure facilities required, etc. The configuration of the alternative water crafts is evaluated on the basis of the transport demand, route identification, proposed vessel types, frequency of services, speed of the vessels required, water draft in the proposed routes, etc. Economic analysis of the vessels with respect to the NPV, B/C Ratio in the prescribed route was made. It is seen from the study that

i) Suitable water crafts especially high speed catamaran water taxi can be introduced successfully and profitably in the circular water channel around Dhaka city.

ii) The economic analysis shows that NPV and B/C Ratio are generally high for the large to medium sized vessels of the both categories.

iii) The service will ease load on the passenger congestion in the roads of the Dhaka city and will partially divert traffic load from the core of the city and thus will assist in reduction of air pollution in Dhaka city.

iv) Since water transport is one of the most fuel-efficient and least expensive modes of transportation, the service will provide economic benefit to the passengers as well as comfort.

The comparative environmental impacts of the alternative vessels are shown by some indices that help easy understanding.

Vessel 3 (60 passengers with 9 knot speed) was found to be the environmental friendliest among the six alternatives considered. The catamaran vessels, though it would provide superior quality service with its high speed and comfort, would not be attractive if the environmental aspects are in concern.

In spite of having huge potentiality regarding water taxi services in and around Dhaka city, it is very regrettable that we are yet to utilize its full capacity. There are few points identified in this study which needs proper attention to make this service popular one.

8.2 Recommendations:

There is a necessity to improve the quality of data as well as arriving at realistic weighing factors used for arriving at the single criteria. Passengers only consider fare and time while choosing a transport mode or vehicle. Well-to-do people also consider comfort. In order to improve the situation it is important to persuade them to consider environment as well.

The study is expected to assist the decision makers in taking appropriate decisions on the various measures that need to be taken for introduction of an appropriate passenger transport service in the circular water channel.

Studies in the following directions are still left:

- The economic profitability and the service quality should be studied in detail.
- The change in the fuel consumption with the change in loading should be considered.

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Appendix A

Table A1 : Economic Analysis for Vessel 1														
Ship speed	10					Knots	Discount Rate		10.00%					
Year	Revenue/ Benefit (Thousand Tk.)	Crew cost (Thousand Tk.)	Fuel Oil Cost (Thousand Tk.)	Lub Oil Cost (Thousand Tk.)	Other Cost (Thousand Tk.)	Cost			Profit & Loss (Thousand Tk.)	PWF	Discounted value			Net Present Value (Thousand Tk.)
						Operating cost (Thousand Tk.)	Principal Investment (Thousand Tk.)	Total cost (Thousand Tk.)			Benefits (Thousand Tk.)	Cost (Thousand Tk.)	Profit &Loss (Thousand Tk.)	
1	0	0	0	0	0	0	4000	4000	-4000	1.00	0	4000	-4000	-4000
2	0	0	0	0	0	0	2500	2500	-2500	0.91	0	2273	-2273	-2273
3	17010	868	11096	51	245	12260	0	12260	4750	0.83	14058	10132	3925	3925
4	17010	868	11096	51	245	12260	0	12260	4750	0.75	12780	9211	3569	3569
5	17010	868	11096	51	245	12260	0	12260	4750	0.68	11618	8374	3244	3244
6	17861	911	11651	54	257	12873	0	12873	4987	0.62	11090	7993	3097	3097
7	17861	911	11651	54	257	12873	0	12873	4987	0.56	10082	7267	2815	2815
8	17861	911	11651	54	257	12873	0	12873	4987	0.51	9165	6606	2559	2559
9	17861	911	11651	54	257	12873	0	12873	4987	0.47	8332	6005	2327	2327
10	17861	911	11651	54	257	12873	0	12873	4987	0.42	7575	5459	2115	2115
11	18754	957	12233	56	270	13517	0	13517	5237	0.39	7230	5211	2019	2019
12	18754	957	12233	56	270	13517	0	13517	5237	0.35	6573	4738	1835	1835
13	18754	957	12233	56	270	13517	0	13517	5237	0.32	5975	4307	1669	1669
14	18754	957	12233	56	270	13517	0	13517	5237	0.29	5432	3915	1517	1517
15	18754	957	12233	56	270	13517	0	13517	5237	0.26	4938	3559	1379	1379
16	19691	1005	12845	59	284	14193	0	14193	5499	0.24	4714	3398	1316	1316
17	19691	1005	12845	59	284	14193	0	14193	5499	0.22	4285	3089	1197	1197
18	19691	1005	12845	59	284	14193	0	14193	5499	0.20	3896	2808	1088	1088
19	19691	1005	12845	59	284	14193	0	14193	5499	0.18	3542	2553	989	989
20	19691	1005	12845	59	284	14193	0	14193	5499	0.16	3220	2321	899	899
21	20676	1055	13487	62	298	14902	0	14902	5773	0.15	3073	2215	858	858
22	20676	1055	13487	62	298	14902	0	14902	5773	0.14	2794	2014	780	780
23	20676	1055	13487	62	298	14902	0	14902	5773	0.12	2540	1831	709	709

24	20676	1055	13487	62	298	14902	0	14902	5773	0.11	2309	1664	645	645
25	20676	1055	13487	62	298	14902	0	14902	5773	0.10	2099	1513	586	586
26	21710	1108	14162	65	313	15647	0	15647	6062	0.09	2004	1444	560	560
27	21710	1108	14162	65	313	15647	0	15647	6062	0.08	1822	1313	509	509
28	21710	1108	14162	65	313	15647	0	15647	6062	0.08	1656	1194	462	462
29	21710	1108	14162	65	313	15647	0	15647	6062	0.07	1505	1085	420	420
30	21710	1108	14162	65	313	15647	0	15647	6062	0.06	1369	986	382	382
31	21710	0	0	0	0	0		0	21710	0.06	0	0	1244	1244
(all amounts in thousand taka)											155676	118478	0	38442
										BCR	1.31396202			

Table A2: Economic Analysis for Vessel 2														
Ship speed	10					Knots	Discount Rate		10.00%					
						Cost					Discounted value			
Year	Revenue/ Benefit (Thousand Tk.)	Crew cost (Thousand Tk.)	Fuel Oil Cost (Thousand Tk.)	Lub Oil Cost (Thousand Tk.)	Other Cost (Thousand Tk.)	Operating cost (Thousand Tk.)	Principal Investment (Thousand Tk.)	Total cost (Thousand Tk.)	Profit & Loss (Thousand Tk.)	PWF	Benefits (Thousand Tk.)	Cost (Thousand Tk.)	Profit &Loss (Thousand Tk.)	Net Present Value (Thousand Tk.)
1	0	0	0	0	0	0	2400	2400	-2400	1.00	0	2400	-2400	-2400
2	0	0	0	0	0	0	2400	2400	-2400	0.91	0	2182	-2182	-2182
3	12758	615	8877	41	174	9707	0	9707	3050	0.83	10543	8022	2521	2521
4	12758	868	8877	41	174	9960	0	9960	2798	0.75	9585	7483	2102	2102
5	12758	868	8877	41	174	9960	0	9960	2798	0.68	8714	6803	1911	1911
6	13395	911	9321	43	183	10458	0	10458	2938	0.62	8317	6493	1824	1824
7	13395	911	9321	43	183	10458	0	10458	2938	0.56	7561	5903	1658	1658
8	13395	911	9321	43	183	10458	0	10458	2938	0.51	6874	5366	1507	1507
9	13395	911	9321	43	183	10458	0	10458	2938	0.47	6249	4879	1370	1370
10	13395	911	9321	43	183	10458	0	10458	2938	0.42	5681	4435	1246	1246
11	14065	957	9787	45	192	10981	0	10981	3085	0.39	5423	4233	1189	1189
12	14065	957	9787	45	192	10981	0	10981	3085	0.35	4930	3849	1081	1081
13	14065	957	9787	45	192	10981	0	10981	3085	0.32	4482	3499	983	983
14	14065	957	9787	45	192	10981	0	10981	3085	0.29	4074	3181	893	893
15	14065	957	9787	45	192	10981	0	10981	3085	0.26	3704	2892	812	812
16	14768	1005	10276	47	201	11530	0	11530	3239	0.24	3535	2760	775	775
17	14768	1005	10276	47	201	11530	0	11530	3239	0.22	3214	2509	705	705

18	14768	1005	10276	47	201	11530	0	11530	3239	0.20	2922	2281	641	641
19	14768	1005	10276	47	201	11530	0	11530	3239	0.18	2656	2074	583	583
20	14768	1005	10276	47	201	11530	0	11530	3239	0.16	2415	1885	530	530
21	15507	1055	10790	50	211	12106	0	12106	3401	0.15	2305	1799	505	505
22	15507	1055	10790	50	211	12106	0	12106	3401	0.14	2095	1636	460	460
23	15507	1055	10790	50	211	12106	0	12106	3401	0.12	1905	1487	418	418
24	15507	1055	10790	50	211	12106	0	12106	3401	0.11	1732	1352	380	380
25	15507	1055	10790	50	211	12106	0	12106	3401	0.10	1574	1229	345	345
26	16282	1108	11329	52	222	12711	0	12711	3571	0.09	1503	1173	330	330
27	16282	1108	11329	52	222	12711	0	12711	3571	0.08	1366	1067	300	300
28	16282	1108	11329	52	222	12711	0	12711	3571	0.08	1242	970	272	272
29	16282	1108	11329	52	222	12711	0	12711	3571	0.07	1129	881	248	248
30	16282	1108	11329	52	222	12711	0	12711	3571	0.06	1026	801	225	225
31	16282	0	0	0	0	0		0	16282	0.06	0	0	0	0
(all amounts in thousand taka)											116757	95525	21232	21232
										BCR	1.222269			

Table A3: Economic Analysis for Vessel 3														
Ship speed	10					Knots	Discount Rate		10.00%					
						Cost					Discounted value			
Year	Revenue/ Benefit (Thousand Tk.)	Crew cost (Thousand Tk.)	Fuel Oil Cost (Thousand Tk.)	Lub Oil Cost (Thousand Tk.)	Other Cost (Thousand Tk.)	Operating cost (Thousand Tk.)	Principal Investment (Thousand Tk.)	Total cost (Thousand Tk.)	Profit & Loss (Thousand Tk.)	PWF	Benefits (Thousand Tk.)	Cost (Thousand Tk.)	Profit &Loss (Thousand Tk.)	Net Present Value (Thousand Tk.)
1	0	0	0	0	0	0	2200	2200	-2200	1.00	0	2200	-2200	-2200
2	0	0	0	0	0	0	1100	1100	-1100	0.91	0	1000	-1000	-1000
3	8505	615	6637	31	117	7400	0	7400	1105	0.83	7029	6116	913	913
4	8505	868	6637	31	117	7653	0	7653	852	0.75	6390	5750	640	640
5	8505	868	6637	31	117	7653	0	7653	852	0.68	5809	5227	582	582
6	8930	911	6637	32	123	7704	0	7704	1227	0.62	5545	4783	762	762
7	8930	911	6969	32	123	8035	0	8035	895	0.56	5041	4536	505	505
8	8930	911	6969	32	123	8035	0	8035	895	0.51	4583	4123	459	459
9	8930	911	6969	32	123	8035	0	8035	895	0.47	4166	3749	417	417
10	8930	911	6969	32	123	8035	0	8035	895	0.42	3787	3408	380	380
11	9377	957	7318	34	129	8437	0	8437	940	0.39	3615	3253	362	362
12	9377	957	7318	34	129	8437	0	8437	940	0.35	3286	2957	329	329
13	9377	957	7318	34	129	8437	0	8437	940	0.32	2988	2688	299	299
14	9377	957	7318	34	129	8437	0	8437	940	0.29	2716	2444	272	272
15	9377	957	7318	34	129	8437	0	8437	940	0.26	2469	2222	247	247

16	9846	1005	7683	35	135	8859	0	8859	987	0.24	2357	2121	236	236
17	9846	1005	7683	35	135	8859	0	8859	987	0.22	2143	1928	215	215
18	9846	1005	7683	35	135	8859	0	8859	987	0.20	1948	1753	195	195
19	9846	1005	7683	35	135	8859	0	8859	987	0.18	1771	1593	177	177
20	9846	1005	7683	35	135	8859	0	8859	987	0.16	1610	1449	161	161
21	10338	1055	8068	37	142	9302	0	9302	1036	0.15	1537	1383	154	154
22	10338	1055	8068	37	142	9302	0	9302	1036	0.14	1397	1257	140	140
23	10338	1055	8068	37	142	9302	0	9302	1036	0.12	1270	1143	127	127
24	10338	1055	8068	37	142	9302	0	9302	1036	0.11	1155	1039	116	116
25	10338	1055	8068	37	142	9302	0	9302	1036	0.10	1050	944	105	105
26	10855	1108	8471	39	149	9767	0	9767	1088	0.09	1002	901	100	100
27	10855	1108	8471	39	149	9767	0	9767	1088	0.08	911	820	91	91
28	10855	1108	8471	39	149	9767	0	9767	1088	0.08	828	745	83	83
29	10855	1108	8471	39	149	9767	0	9767	1088	0.07	753	677	75	75
30	10855	1108	8471	39	149	9767	0	9767	1088	0.06	684	616	69	69
31		0	0	0	0	0		0	0	0.06	0	0	0	0
(all amounts in thousand taka)											77838	72823	0	5015
										BCR	1.0688615			

Table A4: Economic Analysis for Vessel 4															
Ship speed	10					Knots	Discount Rate		10.00%						
Year	Revenue/ Benefit (Thousand Tk.)	Crew cost (Thousand Tk.)	Fuel Oil Cost (Thousand Tk.)	Lub Oil Cost (Thousand Tk.)	Other Cost (Thousand Tk.)	Cost			Profit & Loss (Thousand Tk.)	PWF	Discounted value			Net Present Value (Thousand Tk.)	
						Operating cost (Thousand Tk.)	Principal Investment (Thousand Tk.)	Total cost (Thousand Tk.)			Benefits (Thousand Tk.)	Cost (Thousand Tk.)	Profit &Loss (Thousand Tk.)		
1	0	0	0	0	0	0	8000	8000	-8000	1.00	0	8000	-8000	-8000	
2	0	0	0	0	0	0	4400	4400	-4400	0.91	0	4000	-4000	-4000	
3	32886	854	23404	105	452	24815	0	24815	8071	0.83	27179	20508	6670	6670	
4	32886	854	23404	105	452	24815	0	24815	8071	0.75	24708	18644	6064	6064	
5	32886	854	23404	105	452	24815	0	24815	8071	0.68	22462	16949	5513	5513	
6	34530	896	24575	110	475	26056	0	26056	8475	0.62	21441	16179	5262	5262	
7	34530	896	24575	110	475	26056	0	26056	8475	0.56	19491	14708	4784	4784	
8	34530	896	24575	110	475	26056	0	26056	8475	0.51	17720	13371	4349	4349	
9	34530	896	24575	110	475	26056	0	26056	8475	0.47	16109	12155	3953	3953	
10	34530	896	24575	110	475	26056	0	26056	8475	0.42	14644	11050	3594	3594	
11	36257	941	25803	116	498	27359	0	27359	8898	0.39	13979	10548	3431	3431	
12	36257	941	25803	116	498	27359	0	27359	8898	0.35	12708	9589	3119	3119	
13	36257	941	25803	116	498	27359	0	27359	8898	0.32	11553	8717	2835	2835	
14	36257	941	25803	116	498	27359	0	27359	8898	0.29	10502	7925	2578	2578	
15	36257	941	25803	116	498	27359	0	27359	8898	0.26	9548	7204	2343	2343	

16	38070	988	27093	121	523	28726	0	28726	9343	0.24	9114	6877	2237	2237
17	38070	988	27093	121	523	28726	0	28726	9343	0.22	8285	6252	2033	2033
18	38070	988	27093	121	523	28726	0	28726	9343	0.20	7532	5683	1848	1848
19	38070	988	27093	121	523	28726	0	28726	9343	0.18	6847	5167	1680	1680
20	38070	988	27093	121	523	28726	0	28726	9343	0.16	6225	4697	1528	1528
21	39973	1038	28448	128	549	30163	0	30163	9810	0.15	5942	4484	1458	1458
22	39973	1038	28448	128	549	30163	0	30163	9810	0.14	5402	4076	1326	1326
23	39973	1038	28448	128	549	30163	0	30163	9810	0.12	4911	3705	1205	1205
24	39973	1038	28448	128	549	30163	0	30163	9810	0.11	4464	3369	1096	1096
25	39973	1038	28448	128	549	30163	0	30163	9810	0.10	4058	3062	996	996
26	41972	1090	29871	134	577	31671	0	31671	10301	0.09	3874	2923	951	951
27	41972	1090	29871	134	577	31671	0	31671	10301	0.08	3522	2657	864	864
28	41972	1090	29871	134	577	31671	0	31671	10301	0.08	3202	2416	786	786
29	41972	1090	29871	134	577	31671	0	31671	10301	0.07	2910	2196	714	714
30	41972	1090	29871	134	577	31671	0	31671	10301	0.06	2646	1997	649	649
31	41972	0	0	0	0	0		0	41972	0.06	0	0	0	0
(all amounts in thousand taka)											300973	239107	61866	61866

BCR 1.25874

Table A5: Economic Analysis for Vessel 5

Ship speed	10					Knots	Discount Rate		10.00%					
						Cost					Discounted value			
Year	Revenue/ Benefit (Thousand Tk.)	Crew cost (Thousand Tk.)	Fuel Oil Cost (Thousand Tk.)	Lub Oil Cost (Thousand Tk.)	Other Cost (Thousand Tk.)	Operating cost (Thousand Tk.)	Principal Investment (Thousand Tk.)	Total cost (Thousand Tk.)	Profit & Loss (Thousand Tk.)	PWF	Benefits (Thousand Tk.)	Cost (Thousand Tk.)	Profit &Loss (Thousand Tk.)	Net Present Value (Thousand Tk.)
1	0	0	0	0	0	0	6000	6000	-6000	1.00	0	6000	-6000	-6000
2	0	0	0	0	0	0	3000	3000	-3000	0.91	0	2727	-2727	-8727
3	24665	868	19504	90	340	20802	0	20802	3863	0.83	20384	17191	3193	-5535
4	24665	868	19504	90	340	20802	0	20802	3863	0.75	18531	15629	2902	-2632
5	24665	868	19504	90	340	20802	0	20802	3863	0.68	16846	14208	2638	6
6	25898	911	20479	95	357	21842	0	21842	4056	0.62	16080	13562	2519	2525
7	25898	911	20479	95	357	21842	0	21842	4056	0.56	14619	12329	2290	4814
8	25898	911	20479	95	357	21842	0	21842	4056	0.51	13290	11208	2081	6895
9	25898	911	20479	95	357	21842	0	21842	4056	0.47	12081	10189	1892	8788
10	25898	911	20479	95	357	21842	0	21842	4056	0.42	10983	9263	1720	10508
11	27193	957	21503	99	375	22934	0	22934	4259	0.39	10484	8842	1642	12150
12	27193	957	21503	99	375	22934	0	22934	4259	0.35	9531	8038	1493	13643
13	27193	957	21503	99	375	22934	0	22934	4259	0.32	8664	7307	1357	15000
14	27193	957	21503	99	375	22934	0	22934	4259	0.29	7877	6643	1234	16233
15	27193	957	21503	99	375	22934	0	22934	4259	0.26	7161	6039	1122	17355
16	28552	1005	22578	104	394	24080	0	24080	4472	0.24	6835	5765	1071	18425
17	28552	1005	22578	104	394	24080	0	24080	4472		6214	5241	973	19398

										0.22				
18	28552	1005	22578	104	394	24080	0	24080	4472	0.20	5649	4764	885	20283
19	28552	1005	22578	104	394	24080	0	24080	4472	0.18	5135	4331	804	21088
20	28552	1005	22578	104	394	24080	0	24080	4472	0.16	4669	3937	731	21819
21	29980	1055	23707	109	413	25284	0	25284	4695	0.15	4456	3758	698	22517
22	29980	1055	23707	109	413	25284	0	25284	4695	0.14	4051	3417	634	23151
23	29980	1055	23707	109	413	25284	0	25284	4695	0.12	3683	3106	577	23728
24	29980	1055	23707	109	413	25284	0	25284	4695	0.11	3348	2824	524	24252
25	29980	1055	23707	109	413	25284	0	25284	4695	0.10	3044	2567	477	24729
26	31479	1108	24892	115	434	26549	0	26549	4930	0.09	2905	2450	455	25184
27	31479	1108	24892	115	434	26549	0	26549	4930	0.08	2641	2228	414	25598
28	31479	1108	24892	115	434	26549	0	26549	4930	0.08	2401	2025	376	25974
29	31479	1108	24892	115	434	26549	0	26549	4930	0.07	2183	1841	342	26316
30	31479	1108	24892	115	434	26549	0	26549	4930	0.06	1984	1674	311	26627
31	31479	0	0	0	0	0		0	31479	0.06	0	0	0	0
(all amounts in thousand taka)											225730	199103	26627	0

BCR 1.13373

Table A6: Economic Analysis for Vessel 6

Ship speed	10					Knots	Discount Rate		10.00%					
						Cost					Discounted value			
Year	Revenue/ Benefit (Thousand Tk.)	Crew cost (Thousand Tk.)	Fuel Oil Cost (Thousand Tk.)	Lub Oil Cost (Thousand Tk.)	Other Cost (Thousand Tk.)	Operating cost (Thousand Tk.)	Principal Investment (Thousand Tk.)	Total cost (Thousand Tk.)	Profit & Loss (Thousand Tk.)	PWF	Benefits (Thousand Tk.)	Cost (Thousand Tk.)	Profit &Loss (Thousand Tk.)	Net Present Value (Thousand Tk.)
1	0	0	0	0	0	0	6000	6000	-6000	1.00	0	6000	-6000	-6000
2	0	0	0	0	0	0	1000	1000	-1000	0.91	0	909	-909	-909
3	16443	615	16605	77	270	17567	0	17567	-1124	0.83	13589	14519	-929	-929
4	16443	615	16605	77	270	17567	0	17567	-1124	0.75	12354	13199	-845	-845
5	16443	615	16605	77	270	17567	0	17567	-1124	0.68	11231	11999	-768	-768
6	17265	646	17436	80	284	18446	0	18446	-1181	0.62	10720	11453	-733	-733
7	17265	646	17436	80	284	18446	0	18446	-1181	0.56	9746	10412	-666	-666
8	17265	646	17436	80	284	18446	0	18446	-1181	0.51	8860	9466	-606	-606
9	17265	646	17436	80	284	18446	0	18446	-1181	0.47	8054	8605	-551	-551
10	17265	646	17436	80	284	18446	0	18446	-1181	0.42	7322	7823	-501	-501
11	18128	678	18307	84	298	19368	0	19368	-1240	0.39	6989	7467	-478	-478
12	18128	678	18307	84	298	19368	0	19368	-1240	0.35	6354	6788	-434	-434
13	18128	678	18307	84	298	19368	0	19368	-1240	0.32	5776	6171	-395	-395
14	18128	678	18307	84	298	19368	0	19368	-1240	0.29	5251	5610	-359	-359
15	18128	678	18307	84	298	19368	0	19368	-1240	0.26	4774	5100	-326	-326

16	19035	712	19223	89	313	20336	0	20336	-1302	0.24	4557	4868	-312	-312
17	19035	712	19223	89	313	20336	0	20336	-1302	0.22	4143	4426	-283	-283
18	19035	712	19223	89	313	20336	0	20336	-1302	0.20	3766	4023	-258	-258
19	19035	712	19223	89	313	20336	0	20336	-1302	0.18	3424	3658	-234	-234
20	19035	712	19223	89	313	20336	0	20336	-1302	0.16	3112	3325	-213	-213
21	19987	748	20184	93	328	21353	0	21353	-1367	0.15	2971	3174	-203	-203
22	19987	748	20184	93	328	21353	0	21353	-1367	0.14	2701	2885	-185	-185
23	19987	748	20184	93	328	21353	0	21353	-1367	0.12	2455	2623	-168	-168
24	19987	748	20184	93	328	21353	0	21353	-1367	0.11	2232	2385	-153	-153
25	19987	748	20184	93	328	21353	0	21353	-1367	0.10	2029	2168	-139	-139
26	20986	785	21193	98	345	22421	0	22421	-1435	0.09	1937	2069	-132	-132
27	20986	785	21193	98	345	22421	0	22421	-1435	0.08	1761	1881	-120	-120
28	20986	785	21193	98	345	22421	0	22421	-1435	0.08	1601	1710	-109	-109
29	20986	785	21193	98	345	22421	0	22421	-1435	0.07	1455	1555	-100	-100
30	20986	785	21193	98	345	22421	0	22421	-1435	0.06	1323	1413	-90	-90
31	20986	0	0	0	0	0		0	20986	0.06	0	0	0	0
(all amounts in thousand taka)											150487	167686	-17200	-17200
										BCR	0.89743			

Appendix B

B-1: Munshiganj-Sadarghat

Table B-1.1 Inventory list of the compound and substances for the construction phase of vessels						
Emission\Vessel	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
Energy consumption (MJ)	57103110	49406080	41120470	150908800	98257110	82233580
CO_2 emission (kg)	4411230.84	3817700.16	3162762.23	11614550.4	7560883.11	6327337.72
NOx emission (kg)	19981.62	17271.68	14357.27	52817.92	34355.81	28836.28
SOx emission (kg)	5937.57	5178.88	4456.95	15006.4	9956.73	8466.04
Phosphorus emission (kg)	3974.13	3436.48	2860.79	10479.2	6828.73	5714.5

Table B-1.2 Emissions for the production of electrolytic chrome coated steel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	1831950	1699200	1649050	2265600	1654950	1622500
NOx	2819.34	2615.04	2537.86	3486.72	2546.94	2497
SOx	3837.78	3559.68	3454.62	4746.24	3466.98	3399
N_2O	5.91192	5.48352	5.32168	7.31136	5.34072	5.236
HF	6.831	6.336	6.149	8.448	6.171	6.05
HCl	53.5923	49.7088	48.2417	66.2784	48.4143	47.465
Methane	6706.8	6220.8	6037.2	8294.4	6058.8	5940
Ammonia	1.22337	1.13472	1.10123	1.51296	1.10517	1.0835
CxHy	3.24783	3.01248	2.92357	4.01664	2.93403	2.8765
Suspended Particulate Matter	875.61	812.16	788.19	1082.88	791.01	775.5

Table B-1.3: Emissions for the production of diesel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	476086.3931	476086.393	587760.9791	457042.9374	476086.3931	577074.4159
NOx	2899.24406	2899.24406	3579.313655	2783.274298	2899.24406	3514.235225
SOx	5890.043197	5890.0432	7271.658267	5654.441469	5890.043197	7139.446299
N2O	73.24406048	73.2440605	90.42476602	70.31429806	73.24406048	88.78067936
Ammonia	30.51835853	30.5183585	37.67698584	29.29762419	30.51835853	36.99194973
CxHy	10360.98272	10360.9827	12791.33669	9946.543413	10360.98272	12558.76694
Suspended Particulate Matter	33.57019438	33.5701944	41.44468443	32.22738661	33.57019438	40.69114471

Table B-1.4: Emissions through burning of diesel by a ship engine (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	492184.8272	492184.827	607635.5892	472497.4341	492184.8272	596587.6694
NOx	4806.641469	4806.64147	5934.12527	4614.37581	4806.641469	5826.232083
SOx	8316.2527	8316.2527	10266.97864	7983.602592	8316.2527	10080.3063
CxHy	6500.410367	6500.41037	8025.197984	6240.393952	6500.410367	7879.285294
Suspended Particulate Matter	714.1295896	714.12959	881.6414687	685.564406	714.1295896	865.6116238

Table B-1.5: Detail calculation of sum of the potential contribution from the impact category for vessel 1						
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	EP(j)
Fossil fuel exhaustion	Energy consumption	MJ	1.000	57103110	57103110	57103110
Local warming	Heat radiation	MJ	1.000	1.000	1	1
Global warming	CO_2	Kg	1.000	7211452.06	7211452.06	7418335.225
	N_2O	Kg	270.000	79.15598048	21372.11473	
	C_xH_y	Kg	11.000	16864.64092	185511.0501	
Acid rain	Ammonia	Kg	1.880	31.74172853	59.67444964	45443.27344
	HCl	Kg	0.880	53.5923	47.161224	
	NO_x	Kg	0.700	30506.84553	21354.79187	
	SO_x	Kg	1.000	23981.6459	23981.6459	
Eutrophication	NO_x	Kg	0.130	30506.84553	3965.889919	16137.20249
	Ammonia	Kg	0.330	31.74172853	10.47477042	
	Phosphorus	Kg	3.060	3974.13	12160.8378	
Local air pollution	Particulate Matter	Kg	1.000	1623.309784	1623.309784	32317.08277
	SO_x	Kg	1.000	23981.6459	23981.6459	
	C_xH_y	Kg	0.398	16864.64092	6712.127086	

Table B-1.6: Detail calculation of environmental destruction index for vessel 2

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_2$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_2/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_2/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	49406080	49406080	49406080	57103110	0.143	0.123724775	0.92347235
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	6485171.38	6485171.38	6691936.288	7418335.2	0.271	0.244463843	
	N_2O	kg	270.000	78.72758048	21256.44673					
	C_xH_y	kg	11.000	16864.40557	185508.4613					
Acid rain	Ammonia	kg	1.880	31.65307853	59.50778764	42362.9313	45443.273	0.165	0.153815584	
	HCl	kg	0.880	49.7088	43.743744					
	NO_x	kg	0.700	27592.60553	19314.82387					
	SO_x	kg	1.000	22944.8559	22944.8559					
Eutrophication	NO_x	kg	0.130	27592.60553	3587.038719	14113.11303	16137.202	0.096	0.083958719	
	Ammonia	kg	0.330	31.65307853	10.44551592					
	Phosphorus	kg	3.060	3436.48	10515.6288					
Local air pollution	Particulate Matter	kg	1.000	1559.859784	1559.859784	31216.7491	32317.083	0.22	0.212509429	
	SO_x	kg	1.000	22944.8559	22944.8559					
	C_xH_y	kg	0.398	16864.40557	6712.033416					

Table B-1.7: Detail calculation of environmental destruction index for vessel 3										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_3$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_3/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_3/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	41120470	41120470	41120470	57103110	0.143	0.102975603	0.910571477
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	6007208.798	6007208.798	6262074.379	7418335.2	0.271	0.228760511	
	N_2O	kg	270.000	95.74644602	25851.54043					
	C_xH_y	kg	11.000	20819.45825	229014.0407					
Acid rain	Ammonia	kg	1.880	38.77821584	72.90304578	44051.5609	45443.273	0.165	0.15994683	
	HCl	kg	0.880	48.2417	42.452696					
	NO_x	kg	0.700	26408.56892	18485.99825					
	SO_x	kg	1.000	25450.20691	25450.20691					
Eutrophication	NO_x	kg	0.130	26408.56892	3433.11396	12199.92817	16137.202	0.096	0.072577208	
	Ammonia	kg	0.330	38.77821584	12.79681123					
	Phosphorus	kg	3.060	2860.79	8754.0174					
Local air pollution	Particulate Matter	kg	1.000	1711.276153	1711.276153	35447.62744	32317.083	0.22	0.241311324	
	SO_x	kg	1.000	25450.20691	25450.20691					
	C_xH_y	kg	0.398	20819.45825	8286.144382					

Table B-1.8: Detail calculation of environmental destruction index for vessel 4

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_4$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_4/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_4/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	150908800	150908800	150908800	57103110	0.143	0.377912138	1.838289081
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	14809690.77	14809690.77	15008750.19	7418335.2	0.271	0.548286264	
	N_2O	kg	270.000	77.62565806	20958.92768					
	C_xH_y	kg	11.000	16190.95401	178100.4941					
Acid rain	Ammonia	kg	1.880	30.81058419	57.92389828	78098.53603	45443.273	0.165	0.283568006	
	HCl	kg	0.880	66.2784	58.324992					
	NO_x	kg	0.700	63702.29011	44591.60308					
	SO_x	kg	1.000	33390.68406	33390.68406					
Eutrophication	NO_x	kg	0.130	63702.29011	8281.297714	40357.81721	16137.202	0.096	0.24008811	
	Ammonia	kg	0.330	30.81058419	10.16749278					
	Phosphorus	kg	3.060	10479.2	32066.352					
Local air pollution	Particulate Matter	kg	1.000	1800.671793	1800.671793	41635.35555	32317.083	0.22	0.283434563	
	SO_x	kg	1.000	33390.68406	33390.68406					
	C_xH_y	kg	0.398	16190.95401	6443.999694					

Table B-1.9: Detail calculation of environmental destruction index for vessel 5

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_5$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_5/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_5/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	98257110	98257110	98257110	57103110	0.143	0.246059571	1.347849207
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	10184104.33	10184104.33	10390829.82	7418335.2	0.271	0.379588519	
	N_2O	kg	270.000	78.58478048	21217.89073					
	C_xH_y	kg	11.000	16864.32712	185507.5983					
Acid rain	Ammonia	kg	1.880	31.62352853	59.45223364	58958.10758	45443.273	0.165	0.214071017	
	HCl	kg	0.880	48.4143	42.604584					
	NO_x	kg	0.700	44608.63553	31226.04487					
	SO_x	kg	1.000	27630.0059	27630.0059					
Eutrophication	NO_x	kg	0.130	44608.63553	5799.122619	26705.47218	16137.202	0.096	0.158870494	
	Ammonia	kg	0.330	31.62352853	10.43576442					
	Phosphorus	kg	3.060	6828.73	20895.9138					
Local air pollution	Particulate Matter	kg	1.000	1538.709784	1538.709784	35880.71787	32317.083	0.22	0.244259607	
	SO_x	kg	1.000	27630.0059	27630.0059					
	C_xH_y	kg	0.398	16864.32712	6712.002193					

Table B-1.10: Detail calculation of environmental destruction index for vessel 6

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_6$	$(EP(j))_1$	ω_j	$\omega_j*(EP(j))_6/(EP(j))_1$	$\sum\omega_j*(EP(j))_6/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	82233580	82233580	82233580	57103110	0.143	0.205932776	1.263143269
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	9123499.805	9123499.805	9373734.525	7418335.2	0.271	0.342432902	
	N_2O	kg	270.000	94.01667936	25384.50343					
	C_xH_y	kg	11.000	20440.92873	224850.216					
Acid rain	Ammonia	kg	1.880	38.07544973	71.5818455	57669.76676	45443.273	0.165	0.20939318	
	HCl	kg	0.880	47.465	41.7692					
	NO_x	kg	0.700	40673.74731	28471.62312					
	SO_x	kg	1.000	29084.7926	29084.7926					
Eutrophication	NO_x	kg	0.130	40673.74731	5287.58715	22786.52205	16137.202	0.096	0.135556712	
	Ammonia	kg	0.330	38.07544973	12.56489841					
	Phosphorus	kg	3.060	5714.5	17486.37					
Local air pollution	Particulate Matter	kg	1.000	1681.802769	1681.802769	38902.085	32317.083	0.22	0.2648277	
	SO_x	kg	1.000	29084.7926	29084.7926					
	C_xH_y	kg	0.398	20440.92873	8135.489634					

B-2: Sadarghat-Mirpur

B-2.1 Inventory list of the compound and substances for the construction phase of vessels						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
Energy consumption (MJ)	16919440	13895460	11475480	47159000	34678980	26165230
CO_2 emission (kg)	1307031.36	1073728.17	882631.32	3629547	2668546.98	2013243.82
NOx emission (kg)	5920.48	4857.66	4006.68	16505.6	12125.58	9175.18
SOx emission (kg)	1759.28	1456.56	1243.8	4689.5	3514.14	2693.74
Phosphorus emission (kg)	1177.52	966.51	798.36	3274.75	2410.14	1818.25

B-2.2 Emissions for the production of electrolytic chrome coated steel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	542800	477900	460200	708000	584100	516250
NOx	835.36	735.48	708.24	1089.6	898.92	794.5
SOx	1137.12	1001.16	964.08	1483.2	1223.64	1081.5
N_2O	1.75168	1.54224	1.48512	2.2848	1.88496	1.666
HF	2.024	1.782	1.716	2.64	2.178	1.925
HCl	15.8792	13.9806	13.4628	20.712	17.0874	15.1025
Methane	1987.2	1749.6	1684.8	2592	2138.4	1890
Ammonia	0.36248	0.31914	0.30732	0.4728	0.39006	0.34475
CxHy	0.96232	0.84726	0.81588	1.2552	1.03554	0.91525
Suspended Particulate Matter	259.44	228.42	219.96	338.4	279.18	246.75

B-2.3 Emissions for the production of diesel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	123273.5468	123273.547	152189.564	118342.605	123273.5468	149422.481
NOx	750.7042915	750.704291	926.7954216	720.67612	750.7042915	909.9445957
SOx	1525.115034	1525.11503	1882.858067	1464.11043	1525.115034	1848.624284
N2O	18.96516105	18.965161	23.41377907	18.2065546	18.96516105	22.988074
Ammonia	7.902150437	7.90215044	9.75574128	7.58606442	7.902150437	9.578364166
CxHy	2682.780073	2682.78007	3312.074165	2575.46887	2682.780073	3251.854634
Suspended Particulate Matter	8.69236548	8.69236548	10.73131541	8.34467086	8.69236548	10.53620058

B-2.4 Emissions through burning of diesel by a ship engine (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	127441.9312	127441.931	157335.7175	122344.254	127441.9312	154475.0681
NOx	1244.588694	1244.58869	1536.529252	1194.80515	1244.588694	1508.592356
SOx	2153.335994	2153.33599	2658.439499	2067.20255	2153.335994	2610.104235
CxHy	1683.158043	1683.15804	2077.972893	1615.83172	1683.158043	2040.191567
Suspended Particulate Matter	184.9103202	184.91032	228.2843459	177.513907	184.9103202	224.1337215

Table B-2.5: Detail calculation of sum of the potential contribution from the impact category for vessel 1

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	EP(j)
Fossil fuel exhaustion	Energy consumption	MJ	1.000	16919440	16919440	16919440
Local warming	Heat radiation	MJ	1.000	1.000	1	1
Global warming	CO_2	Kg	1.000	2100546.84	2100546.838	2154176.29
	N_2O	Kg	270.000	20.716841	5593.547083	
	C_xH_y	Kg	11.000	4366.90044	48035.9048	
Acid rain	Ammonia	Kg	1.880	8.26463044	15.53750522	12730.15532
	HCl	Kg	0.880	15.8792	13.973696	
	NO_x	Kg	0.700	8751.13299	6125.79309	
	SO_x	Kg	1.000	6574.85103	6574.851028	
Eutrophication	NO_x	Kg	0.130	8751.13299	1137.647288	4743.585816
	Ammonia	Kg	0.330	8.26463044	2.727328044	
	Phosphorus	Kg	3.060	1177.52	3603.2112	
Local air pollution	Particulate Matter	Kg	1.000	453.042686	453.0426857	8765.920088

	SO_x	Kg	1.000	6574.85103	6574.851028	
	C_xH_y	Kg	0.398	4366.90044	1738.026374	

Table B-2.6: Detail calculation of environmental destruction index forVessel 2

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_2$	$(EP(j))_1$	ω_j	$\omega_j*(EP(j))_2/(EP(j))_1$	$\sum\omega_j*(EP(j))_2/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	13895460	13895460	13895460	16919440	0.143	0.1174419	0.89274634
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	1802343.65	1802343.648	1855915.285	2154176	0.271	0.2334781	
	N_2O	Kg	270.000	20.507401	5536.998283					
	C_xH_y	Kg	11.000	4366.78538	48034.63914					
Acid rain	Ammonia	Kg	1.880	8.22129044	15.45602602	11475.83307	12730.16	0.165	0.1487423	
	HCl	Kg	0.880	13.9806	12.302928					
	NO_x	Kg	0.700	7588.43299	5311.90309					
	SO_x	Kg	1.000	6136.17103	6136.171028					
Eutrophication	NO_x	Kg	0.130	7588.43299	986.4962881	3946.729914	4743.586	0.096	0.0798733	

	Ammonia	Kg	0.330	8.22129044	2.713025844					
	Phosphorus	Kg	3.060	966.51	2957.5206					
Local air pollution	Particulate Matter	Kg	1.000	422.022686	422.0226857	8296.174294	8765.92	0.22	0.2082107	
	SO_x	Kg	1.000	6136.17103	6136.171028					
	C_xH_y	Kg	0.398	4366.78538	1737.98058					

Table B-2.7: Detail calculation of environmental destruction index forVessel 3										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_3$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_3/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_3/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	11475480	11475480	11475480	16919440	0.143	0.0969886	0.87431478
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	1652356.6	1652356.601	1718378.797	2154176	0.271	0.2161757	
	N_2O	Kg	270.000	24.8988991	6722.702749					
	C_xH_y	Kg	11.000	5390.86294	59299.49231					
Acid rain	Ammonia	kg	1.880	10.0630613	18.91855521	11804.71466	12730.16	0.165	0.153005	
	HCl	Kg	0.880	13.4628	11.847264					

	NO_x	Kg	0.700	7178.24467	5024.771271					
	SO_x	Kg	1.000	6749.17757	6749.177566					
Eutrophication	NO_x	Kg	0.130	7178.24467	933.1718075	3379.474218	4743.586	0.096	0.0683933	
	Ammonia	Kg	0.330	10.0630613	3.320810222					
	Phosphorus	Kg	3.060	798.36	2442.9816					
Local air pollution	Particulate Matter	Kg	1.000	458.975661	458.9756614	9353.716676	8765.92	0.22	0.234752	
	SO_x	Kg	1.000	6749.17757	6749.177566					
	C_xH_y	Kg	0.398	5390.86294	2145.563449					

Table B-2.8: Detail calculation of environmental destruction index forVessel 4

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_4$	$(EP(j))_1$	ω_j	$\omega_j*(EP(j))_4/(EP(j))_1$	$\sum\omega_j*(EP(j))_4/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	47159000	47159000	47159000	16919440	0.143	0.3985792	1.94201979
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	4578233.86	4578233.859	4629884.638	2154176	0.271	0.5824494	

	N_2O	Kg	270.000	20.4913546	5532.665744					
	C_xH_y	Kg	11.000	4192.55579	46118.11371					
Acid rain	Ammonia	Kg	1.880	8.05886442	15.15066511	23394.8671	12730.16	0.165	0.3032291	
	HCl	Kg	0.880	20.712	18.22656					
	NO_x	Kg	0.700	19510.6813	13657.47689					
	SO_x	Kg	1.000	9704.01299	9704.012987					
Eutrophication	NO_x	Kg	0.130	19510.6813	2536.388565	12559.78299	4743.586	0.096	0.2541831	
	Ammonia	Kg	0.330	8.05886442	2.659425258					
	Phosphorus	Kg	3.060	3274.75	10020.735					
Local air pollution	Particulate Matter	Kg	1.000	524.258578	524.2585783	11896.90877	8765.92	0.22	0.298579	
	SO_x	Kg	1.000	9704.01299	9704.012987					
	C_xH_y	Kg	0.398	4192.55579	1668.637205					

Table B-2.9: Detail calculation of environmental destruction index forVessel 5										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_5$	$(EP(j))_1$	ω_j	$\omega_j*(EP(j))_5/(EP(j))_1$	$\sum\omega_j*(EP(j))_5/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	34678980	34678980	34678980	16919440	0.143	0.2931004	1.54687429
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	3503362.46	3503362.458	3557028.701	2154176	0.271	0.4474818	
	N_2O	Kg	270.000	20.850121	5629.532683					
	C_xH_y	Kg	11.000	4366.97366	48036.71022					
Acid rain	Ammonia	Kg	1.880	8.29221044	15.58935562	18960.71239	12730.16	0.165	0.2457564	
	HCl	Kg	0.880	17.0874	15.036912					
	NO_x	Kg	0.700	15019.793	10513.85509					
	SO_x	Kg	1.000	8416.23103	8416.231028					
Eutrophication	NO_x	Kg	0.130	15019.793	1952.573088	9330.337918	4743.586	0.096	0.188826	
	Ammonia	Kg	0.330	8.29221044	2.736429444					
	Phosphorus	Kg	3.060	2410.14	7375.0284					
Local air pollution	Particulate Matter	Kg	1.000	472.782686	472.7826857	10627.06923	8765.92	0.22	0.2667096	
	SO_x	Kg	1.000	8416.23103	8416.231028					
	C_xH_y	Kg	0.398	4366.97366	1738.055515					

Table B-2.10: Detail calculation of environmental destruction index forVessel 6										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	$Q_i \times EF_i$	$(EP(j))_6$	$(EP(j))_1$	ω_j	$\omega_j * (EP(j))_6/(EP(j))_1$	$\sum \omega_j * (EP(j))_6/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	26165230	26165230	26165230	16919440	0.143	0.2211437	1.32714789
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	2833391.37	2833391.369	2898270.545	2154176	0.271	0.3646087	
	N_2O	Kg	270.000	24.654074	6656.599979					
	C_xH_y	Kg	11.000	5292.96145	58222.57597					
Acid rain	Ammonia	Kg	1.880	9.92311417	18.65545463	16937.66604	12730.16	0.165	0.219535	
	HCl	Kg	0.880	15.1025	13.2902					
	NO_x	Kg	0.700	12388.217	8671.751866					
	SO_x	Kg	1.000	8233.96852	8233.968519					
Eutrophication	NO_x	Kg	0.130	12388.217	1610.468204	7177.587831	4743.586	0.096	0.145259	
	Ammonia	Kg	0.330	9.92311417	3.274627675					
	Phosphorus	Kg	3.060	1818.25	5563.845					
Local air pollution	Particulate Matter	Kg	1.000	481.419922	481.4199221	10821.9871	8765.92	0.22	0.2716015	
	SO_x	Kg	1.000	8233.96852	8233.968519					
	C_xH_y	Kg	0.398	5292.96145	2106.598658					

B-3: Mirpur-Tongi

B-3.1: Inventory list of the compound and substances for the construction phase of vessels						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
Energy consumption (MJ)	2114930	1543940	1912580	9431800	5779830	3737890
CO_2 emission (kg)	163378.92	119303.13	147105.22	725909.4	444757.83	287606.26
NOx emission (kg)	740.06	539.74	667.78	3301.12	2020.93	1310.74
SOx emission (kg)	219.91	161.84	207.3	937.9	585.69	384.82
Phosphorus emission (kg)	147.19	107.39	133.06	654.95	401.69	259.75

B-3.2: Emissions for the production of electrolytic chrome coated steel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	67850	53100	76700	141600	97350	73750
NOx	104.42	81.72	118.04	217.92	149.82	113.5
SOx	142.14	111.24	160.68	296.64	203.94	154.5
N2O	0.21896	0.17136	0.24752	0.45696	0.31416	0.238
HF	0.253	0.198	0.286	0.528	0.363	0.275
HCl	1.9849	1.5534	2.2438	4.1424	2.8479	2.1575
Methane	248.4	194.4	280.8	518.4	356.4	270
Ammonia	0.04531	0.03546	0.05122	0.09456	0.06501	0.04925
CxHy	0.12029	0.09414	0.13598	0.25104	0.17259	0.13075
Suspended Particulate Matter	32.43	25.38	36.66	67.68	46.53	35.25

B-3.3: Emissions for the production of diesel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	12525.11973	12525.11973	15463.11078	12024.11494	12525.11973	15181.96331
NOx	76.27476758	76.27476758	94.16637973	73.22377688	76.27476758	92.45426374
SOx	154.958212	154.958212	191.3064346	148.7598836	154.958212	187.8281358
N_2O	1.926941497	1.926941497	2.37894012	1.849863837	1.926941497	2.335686663
Ammonia	0.80289229	0.80289229	0.99122505	0.770776599	0.80289229	0.973202776
CxHy	272.5819326	272.5819326	336.5209044	261.6786553	272.5819326	330.4023425
Suspended Particulate Matter	0.883181519	0.883181519	1.090347555	0.847854259	0.883181519	1.070523054

B-3.4: Emissions through burning of diesel by a ship engine (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	12948.64541	12948.64541	15985.98199	12430.6996	12948.64541	15695.32777
NOx	126.4555357	126.4555357	156.1179453	121.3973143	126.4555357	153.2794372
SOx	218.7881491	218.7881491	270.1088261	210.0366232	218.7881491	265.1977565
CxHy	171.0160578	171.0160578	211.1309356	164.1754155	171.0160578	207.2921913
Suspended Particulate Matter	18.78767959	18.78767959	23.19466617	18.03617241	18.78767959	22.77294496

Table B-3.5: Detail calculation of sum of the potential contribution from the impact category for vessel 1

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	EP(j)
Fossil fuel exhaustion	Energy consumption	MJ	1.000	2114930	2114930	2114930
Local warming	Heat radiation	MJ	1.000	1.000	1	1
Global warming	CO_2	Kg	1.000	256702.6851	256702.6851	262162.9796
	N_2O	Kg	270.000	2.145901497	579.3934042	
	C_xH_y	Kg	11.000	443.7182804	4880.901085	
Acid rain	Ammonia	Kg	1.880	0.84820229	1.594620306	1472.184906
	HCl	Kg	0.880	1.9849	1.746712	
	NO_x	Kg	0.700	1047.210303	733.0472123	
	SO_x	Kg	1.000	735.7963612	735.7963612	
Eutrophication	NO_x	Kg	0.130	1047.210303	136.1373394	586.8186462
	Ammonia	Kg	0.330	0.84820229	0.279906756	
	Phosphorus	Kg	3.060	147.19	450.4014	
Local air pollution	Particulate Matter	Kg	1.000	52.10086111	52.10086111	964.4970979
	SO_x	Kg	1.000	735.7963612	735.7963612	
	C_xH_y	Kg	0.398	443.7182804	176.5998756	

Table B-3.6 : Detail calculation of environmental destruction index forVessel 2

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_2$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_2/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_2/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	1543940	1543940	1543940	2114930	0.143	0.104393	0.826486
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	197876.8951	197876.8951	203324.05	262163	0.271	0.210178	
	N_2O	Kg	270.000	2.098301497	566.5414042					
	C_xH_y	Kg	11.000	443.6921304	4880.613435					
Acid rain	Ammonia	Kg	1.880	0.83835229	1.576102306	1226.702668	1472.185	0.165	0.137487	
	HCl	Kg	0.880	1.5534	1.366992					
	NO_x	Kg	0.700	824.1903033	576.9332123					
	SO_x	Kg	1.000	646.8263612	646.8263612					
Eutrophication	NO_x	Kg	0.130	824.1903033	107.1447394	436.0347957	586.8186	0.096	0.071333	
	Ammonia	Kg	0.330	0.83835229	0.276656256					
	Phosphorus	Kg	3.060	107.39	328.6134					
Local air pollution	Particulate Matter	Kg	1.000	45.05086111	45.05086111	868.4666902	964.4971	0.22	0.198096	
	SO_x	Kg	1.000	646.8263612	646.8263612					
	C_xH_y	Kg	0.398	443.6921304	176.5894679					

Table B-3.7 : Detail calculation of environmental destruction index forVessel 3

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_3$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_3/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_3/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	1912580	1912580	1912580	2114930	0.143	0.129318	1.02134
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	255254.3128	255254.3128	261989.123	262163	0.271	0.27082	
	N_2O	Kg	270.000	2.62646012	709.1442323					
	C_xH_y	Kg	11.000	547.78782	6025.66602					
Acid rain	Ammonia	Kg	1.880	1.04244505	1.959796694	1558.602629	1472.185	0.165	0.174686	
	HCl	Kg	0.880	2.2438	1.974544					
	NO_x	Kg	0.700	1036.104325	725.2730276					
	SO_x	Kg	1.000	829.3952607	829.3952607					
Eutrophication	NO_x	Kg	0.130	1036.104325	134.6935623	542.2011691	586.8186	0.096	0.088701	
	Ammonia	Kg	0.330	1.04244505	0.344006866					
	Phosphorus	Kg	3.060	133.06	407.1636					
Local air pollution	Particulate Matter	Kg	1.000	60.94501372	60.94501372	1108.359827	964.4971	0.22	0.252815	
	SO_x	Kg	1.000	829.3952607	829.3952607					
	C_xH_y	Kg	0.398	547.78782	218.0195524					

Table B-3.8 : Detail calculation of environmental destruction index forVessel 4

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_4$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_4/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_4/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	9431800	9431800	9431800	2114930	0.143	0.637727	2.969528
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	891964.2145	891964.2145	897274.2132	262163	0.271	0.92752	
	N_2O	Kg	270.000	2.306823837	622.842436					
	C_xH_y	Kg	11.000	426.1051108	4687.156219					
Acid rain	Ammonia	Kg	1.880	0.865336599	1.626832806	4198.171415	1472.185	0.165	0.470524	
	HCl	Kg	0.880	4.1424	3.645312					
	NO_x	Kg	0.700	3713.661091	2599.562764					
	SO_x	Kg	1.000	1593.336507	1593.336507					
Eutrophication	NO_x	Kg	0.130	3713.661091	482.7759419	2487.208503	586.8186	0.096	0.406892	
	Ammonia	Kg	0.330	0.865336599	0.285561078					
	Phosphorus	Kg	3.060	654.95	2004.147					
Local air pollution	Particulate Matter	Kg	1.000	86.56402667	86.56402667	1849.490367	964.4971	0.22	0.421865	
	SO_x	Kg	1.000	1593.336507	1593.336507					
	C_xH_y	Kg	0.398	426.1051108	169.5898341					

Table B-3.9 : Detail calculation of environmental destruction index forVessel 5

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_5$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_5/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_5/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	5779830	5779830	5779830	2114930	0.143	0.3908	1.97761
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	567581.5951	567581.5951	573068.1689	262163	0.271	0.592385	
	N_2O	Kg	270.000	2.241101497	605.0974042					
	C_xH_y	Kg	11.000	443.7705804	4881.476385					
Acid rain	Ammonia	Kg	1.880	0.86790229	1.631656306	2828.950382	1472.185	0.165	0.317064	
	HCl	Kg	0.880	2.8479	2.506152					
	NO_x	Kg	0.700	2373.480303	1661.436212					
	SO_x	Kg	1.000	1163.376361	1163.376361					
Eutrophication	NO_x	Kg	0.130	2373.480303	308.5524394	1538.010247	586.8186	0.096	0.251609	
	Ammonia	Kg	0.330	0.86790229	0.286407756					
	Phosphorus	Kg	3.060	401.69	1229.1714					
Local air pollution	Particulate Matter	Kg	1.000	66.20086111	66.20086111	1406.197913	964.4971	0.22	0.320751	
	SO_x	Kg	1.000	1163.376361	1163.376361					
	C_xH_y	Kg	0.398	443.7705804	176.620691					

Table B-3.10: Detail calculation of environmental destruction index forVessel 6										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_6$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_6/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_6/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	3737890	3737890	3737890	2114930	0.143	0.252736	1.466949
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	392233.5511	392233.5511	398844.5246	262163	0.271	0.412289	
	N_2O	Kg	270.000	2.573686663	694.895399					
	C_xH_y	Kg	11.000	537.8252838	5916.078122					
Acid rain	Ammonia	Kg	1.880	1.022452776	1.922211219	2165.148294	1472.185	0.165	0.242666	
	HCl	Kg	0.880	2.1575	1.8986					
	NO_x	Kg	0.700	1669.973701	1168.981591					
	SO_x	Kg	1.000	992.3458923	992.3458923					
Eutrophication	NO_x	Kg	0.130	1669.973701	217.0965811	1012.268991	586.8186	0.096	0.165601	
	Ammonia	Kg	0.330	1.022452776	0.337409416					
	Phosphorus	Kg	3.060	259.75	794.835					
Local air pollution	Particulate Matter	Kg	1.000	59.09346802	59.09346802	1265.493823	964.4971	0.22	0.288657	
	SO_x	Kg	1.000	992.3458923	992.3458923					
	C_xH_y	Kg	0.398	537.8252838	214.054463					

B-4: Tongi-Demra

B-4.1: Inventory list of the compound and substances for the construction phase of vessels						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
Energy consumption (MJ)	4229860	3087880	1912580	9431800	5779830	3737890
CO_2 emission (kg)	326757.84	238606.3	147105.22	725909.4	444757.83	287606.3
NOx emission (kg)	1480.12	1079.48	667.78	3301.12	2020.93	1310.74
SOx emission (kg)	439.82	323.68	207.3	937.9	585.69	384.82
Phosphorus emission (kg)	294.38	214.78	133.06	654.95	401.69	259.75

B-4.2:Emissions for the production of electrolytic chrome coated steel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	135700	106200	76700	141600	97350	73750
NOx	208.84	163.44	118.04	217.92	149.82	113.5
SOx	284.28	222.48	160.68	296.64	203.94	154.5
N_2O	0.43792	0.34272	0.24752	0.45696	0.31416	0.238
HF	0.506	0.396	0.286	0.528	0.363	0.275
HCl	3.9698	3.1068	2.2438	4.1424	2.8479	2.1575
Methane	496.8	388.8	280.8	518.4	356.4	270
Ammonia	0.09062	0.07092	0.05122	0.09456	0.06501	0.04925
CxHy	0.24058	0.18828	0.13598	0.25104	0.17259	0.13075
Suspended Particulate Matter	64.86	50.76	36.66	67.68	46.53	35.25

B-4.3: Emissions for the production of diesel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	23072.58898	23072.59	28484.67775	22149.685	23072.589	27966.77
NOx	140.5061508	140.5062	173.4643837	134.8859	140.50615	170.3105
SOx	285.449338	285.4493	352.4065901	274.03136	285.44934	345.9992
N_2O	3.549629073	3.549629	4.382258115	3.4076439	3.5496291	4.302581
Ammonia	1.479012114	1.479012	1.825940881	1.4198516	1.4790121	1.792742
CxHy	502.1246126	502.1246	619.9069292	482.03963	502.12461	608.6359
Suspended Particulate Matter	1.626913325	1.626913	2.008534969	1.5618368	1.6269133	1.972016

B-4.4:Emissions through burning of diesel by a ship engine (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	23852.76787	23852.77	29447.86156	22898.657	23852.768	28912.45
NOx	232.9444079	232.9444	287.5856888	223.62663	232.94441	282.3569
SOx	403.030801	403.0308	497.5688901	386.90957	403.0308	488.5222
CxHy	315.0295802	315.0296	388.9254077	302.4284	315.02958	381.854
Suspended Particulate Matter	34.60888346	34.60888	42.72701662	33.224528	34.608883	41.95016

Table B-4.5: Detail calculation of sum of the potential contribution from the impact category forVessel 1						
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	EP(j)
Fossil fuel exhaustion	Energy consumption	MJ	1.000	4229860	4229860	4229860
Local warming	Heat radiation	MJ	1.000	1.000	1	1
Global warming	CO_2	kg	1.000	509383.2	509383.2	519451.2
	N_2O	kg	270.000	3.9875491	1076.6382	
	C_xH_y	kg	11.000	817.39477	8991.3425	
Acid rain	Ammonia	kg	1.880	1.5696321	2.9509084	2862.712
	HCl	kg	0.880	3.9698	3.493424	
	NO_x	kg	0.700	2062.4106	1443.6874	
	SO_x	kg	1.000	1412.5801	1412.5801	
Eutrophication	NO_x	kg	0.130	2062.4106	268.11337	1169.434
	Ammonia	kg	0.330	1.5696321	0.5179786	
	Phosphorus	kg	3.060	294.38	900.8028	
Local air pollution	Particulate Matter	kg	1.000	101.0958	101.0958	1838.999
	SO_x	kg	1.000	1412.5801	1412.5801	
	C_xH_y	kg	0.398	817.39477	325.32312	

Table B-4.6: Detail calculation of environmental destruction index forVessel 2										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_2$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_2/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_2/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	3087880	3087880	3087880	4229860	0.143	0.104393	0.823969
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	391731.62	391731.62	401773.3	519451.2	0.271	0.209607	
	N_2O	kg	270.000	3.8923491	1050.9342					
	C_xH_y	kg	11.000	817.34247	8990.7672					
Acid rain	Ammonia	kg	1.880	1.5499321	2.9138724	2371.747	2862.712	0.165	0.136702	
	HCl	kg	0.880	3.1068	2.733984					
	NO_x	kg	0.700	1616.3706	1131.4594					
	SO_x	kg	1.000	1234.6401	1234.6401					
Eutrophication	NO_x	kg	0.130	1616.3706	210.12817	867.8665	1169.434	0.096	0.071244	
	Ammonia	kg	0.330	1.5499321	0.5114776					
	Phosphorus	kg	3.060	214.78	657.2268					
Local air pollution	Particulate Matter	kg	1.000	86.995797	86.995797	1646.938	1838.999	0.22	0.197024	
	SO_x	kg	1.000	1234.6401	1234.6401					
	C_xH_y	kg	0.398	817.34247	325.3023					

Table B-4.7: Detail calculation of environmental destruction index forVessel 3

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_3$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_3/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_3/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	1912580	1912580	1912580	4229860	0.143	0.064659	0.694173
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	281737.76	281737.76	294086.5	519451.2	0.271	0.153426	
	N_2O	kg	270.000	4.6297781	1250.0401					
	C_xH_y	kg	11.000	1008.9683	11098.651					
Acid rain	Ammonia	kg	1.880	1.8771609	3.5290625	2096.268	2862.712	0.165	0.120824	
	HCl	kg	0.880	2.2438	1.974544					
	NO_x	kg	0.700	1246.8701	872.80905					
	SO_x	kg	1.000	1217.9555	1217.9555					
Eutrophication	NO_x	kg	0.130	1246.8701	162.09311	569.8762	1169.434	0.096	0.046782	
	Ammonia	kg	0.330	1.8771609	0.6194631					
	Phosphorus	kg	3.060	133.06	407.1636					
Local air pollution	Particulate Matter	kg	1.000	81.395552	81.395552	1700.92	1838.999	0.22	0.203482	
	SO_x	kg	1.000	1217.9555	1217.9555					
	C_xH_y	kg	0.398	1008.9683	401.56939					

Table B-4.8: Detail calculation of environmental destruction index forVessel 4

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_4$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_4/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_4/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	9431800	9431800	9431800	4229860	0.143	0.318863	1.653389
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	912557.74	912557.74	922233.1	519451.2	0.271	0.481133	
	N_2O	kg	270.000	3.8646039	1043.4431					
	C_xH_y	kg	11.000	784.71907	8631.9097					
Acid rain	Ammonia	kg	1.880	1.5144116	2.8470939	4616.26	2862.712	0.165	0.26607	
	HCl	kg	0.880	4.1424	3.645312					
	NO_x	kg	0.700	3877.5525	2714.2868					
	SO_x	kg	1.000	1895.4809	1895.4809					
Eutrophication	NO_x	kg	0.130	3877.5525	504.08183	2508.729	1169.434	0.096	0.205944	
	Ammonia	kg	0.330	1.5144116	0.4997558					
	Phosphorus	kg	3.060	654.95	2004.147					
Local air pollution	Particulate Matter	kg	1.000	102.46636	102.46636	2310.265	1838.999	0.22	0.276378	
	SO_x	kg	1.000	1895.480 9	1895.480 9					
	C_xH_y	kg	0.398	784.7190 7	312.3181 9					

Table B-4.9: Detail calculation of environmental destruction index forVessel 5										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_5$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_5/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_5/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	5779830	5779830	5779830	4229860	0.143	0.1954	1.154832
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	589033.19	589033.19	599067	519451.2	0.271	0.312536	
	N_2O	kg	270.000	3.8637891	1043.223					
	C_xH_y	kg	11.000	817.32678	8990.5946					
Acid rain	Ammonia	kg	1.880	1.5440221	2.9027616	3264.459	2862.712	0.165	0.188156	
	HCl	kg	0.880	2.8479	2.506152					
	NO_x	kg	0.700	2544.2006	1780.9404					
	SO_x	kg	1.000	1478.1101	1478.1101					
Eutrophication	NO_x	kg	0.130	2544.2006	330.74607	1560.427	1169.434	0.096	0.128097	
	Ammonia	kg	0.330	1.5440221	0.5095273					
	Phosphorus	kg	3.060	401.69	1229.1714					
Local air pollution	Particulate Matter	kg	1.000	82.765797	82.765797	1886.172	1838.999	0.22	0.225643	
	SO_x	kg	1.000	1478.1101	1478.1101					
	C_xH_y	kg	0.398	817.32678	325.29606					

Table B-4.10: Detail calculation of environmental destruction index forVessel 6										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_6$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_6/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_6/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	3737890	3737890	3737890	4229860	0.143	0.126368	0.917428
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	kg	1.000	418235.48	418235.48	430358.3	519451.2	0.271	0.22452	
	N_2O	kg	270.000	4.5405807	1225.9568					
	C_xH_y	kg	11.000	990.62068	10896.827					
Acid rain	Ammonia	kg	1.880	1.841992	3.4629449	2693.038	2862.712	0.165	0.15522	
	HCl	kg	0.880	2.1575	1.8986					
	NO_x	kg	0.700	1876.9073	1313.8351					
	SO_x	kg	1.000	1373.8414	1373.8414					
Eutrophication	NO_x	kg	0.130	1876.9073	243.99795	1039.441	1169.434	0.096	0.085329	
	Ammonia	kg	0.330	1.841992	0.6078573					
	Phosphorus	kg	3.060	259.75	794.835					
Local air pollution	Particulate Matter	kg	1.000	79.172178	79.172178	1847.281	1838.999	0.22	0.220991	
	SO_x	kg	1.000	1373.8414	1373.8414					
	C_xH_y	kg	0.398	990.62068	394.26703					

B-5: Demra-Narayanganj

B-5.1: Inventory list of the compound and substances for the construction phase of vessels						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
Energy consumption (MJ)	2114930	3087880	1912580	9431800	5779830	3737890
CO_2 emission (kg)	163378.92	238606.26	147105.22	725909.4	444757.83	287606.26
NOx emission (kg)	740.06	1079.48	667.78	3301.12	2020.93	1310.74
SOx emission (kg)	219.91	323.68	207.3	937.9	585.69	384.82
Phosphorus emission (kg)	147.19	214.78	133.06	654.95	401.69	259.75

B-5.2: Emissions for the production of electrolytic chrome coated steel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	67850	106200	76700	141600	97350	73750
NOx	104.42	163.44	118.04	217.92	149.82	113.5
SOx	142.14	222.48	160.68	296.64	203.94	154.5
N_2O	0.21896	0.34272	0.24752	0.45696	0.31416	0.238
HF	0.253	0.396	0.286	0.528	0.363	0.275
HCl	1.9849	3.1068	2.2438	4.1424	2.8479	2.1575
Methane	248.4	388.8	280.8	518.4	356.4	270
Ammonia	0.04531	0.07092	0.05122	0.09456	0.06501	0.04925
CxHy	0.12029	0.18828	0.13598	0.25104	0.17259	0.13075
Suspended Particulate Matter	32.43	50.76	36.66	67.68	46.53	35.25

B-5.3: Emissions for the production of diesel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	12920.64983	12920.64983	15951.41954	12403.82383	12920.6498	15661.3937
NOx	78.68344445	78.68344445	97.14005488	75.53610668	78.6834445	95.3738721
SOx	159.8516293	159.8516293	197.3476904	153.4575641	159.851629	193.759551
N_2O	1.987792281	1.987792281	2.454064544	1.90828059	1.98779228	2.40944519
Ammonia	0.828246784	0.828246784	1.022526894	0.795116912	0.82824678	1.0039355
CxHy	281.1897831	281.1897831	347.1478803	269.9421918	281.189783	340.836101
Suspended Particulate Matter	0.911071462	0.911071462	1.124779583	0.874628604	0.91107146	1.10432904

B-5.4:Emissions through burning of diesel by a ship engine (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	13357.55	13357.55	16490.80247	12823.248	13357.55	16190.9697
NOx	130.4488684	130.4488684	161.0479857	125.2309137	130.448868	158.119841
SOx	225.6972486	225.6972486	278.6385785	216.6693586	225.697249	273.572423
CxHy	176.4165649	176.4165649	217.7982283	169.3599023	176.416565	213.838261
Suspended Particulate Matter	19.38097474	19.38097474	23.92712931	18.60573575	19.3809747	23.4920906

Table B-5.5: Detail calculation of sum of the potential contribution from the impact category forVessel 1						
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	EP(j)
Fossil fuel exhaustion	Energy consumption	MJ	1.000	2114930	2114930	2114930
Local warming	Heat radiation	MJ	1.000	1.000	1	1
Global warming	CO_2	kg	1.000	257507.1198	257507.12	263137.936
	N_2O	kg	270.000	2.206752281	595.823116	
	C_xH_y	kg	11.000	457.726638	5034.99302	
Acid rain	Ammonia	kg	1.880	0.873556784	1.64228675	1488.5165
	HCl	kg	0.880	1.9849	1.746712	
	NO_x	kg	0.700	1053.612313	737.528619	
	SO_x	kg	1.000	747.5988778	747.598878	
Eutrophication	NO_x	kg	0.130	1053.612313	136.969601	587.659274
	Ammonia	kg	0.330	0.873556784	0.28827374	
	Phosphorus	kg	3.060	147.19	450.4014	
Local air pollution	Particulate Matter	kg	1.000	52.7220462	52.7220462	982.496126
	SO_x	kg	1.000	747.5988778	747.598878	
	C_xH_y	kg	0.398	457.726638	182.175202	

Table B-5.6: Detail calculation of environmental destruction index forVessel 2

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_2$	$(EP(j))_1$	ω_j	$\omega_j*(EP(j))_2/(EP(j))_1$	$\sum\omega_j*(EP(j))_2/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	3087880	3087880	3087880	2114930	0.143	0.208786	1.321818
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	371084.4598	371084.46	376749.439	263137.9	0.271	0.388006	
	N_2O	Kg	270.000	2.330512281	629.238316					
	C_xH_y	Kg	11.000	457.794628	5035.74091					
Acid rain	Ammonia	Kg	1.880	0.899166784	1.69043355	1952.56991	1488.516	0.165	0.21644	
	HCl	Kg	0.880	3.1068	2.733984					
	NO_x	Kg	0.700	1452.052313	1016.43662					
	SO_x	Kg	1.000	931.7088778	931.708878					
Eutrophication	NO_x	Kg	0.130	1452.052313	188.766801	846.290326	587.6593	0.096	0.13825	
	Ammonia	Kg	0.330	0.899166784	0.29672504					
	Phosphorus	Kg	3.060	214.78	657.2268					
Local air pollution	Particulate Matter	Kg	1.000	71.0520462	71.0520462	1184.96319	982.4961	0.22	0.265336	
	SO_x	Kg	1.000	931.7088778	931.708878					
	C_xH_y	Kg	0.398	457.794628	182.202262					

Table B-5.7: Detail calculation of environmental destruction indexVessel 3

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_3$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_3/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_3/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	1912580	1912580	1912580	2114930	0.143	0.129318	1.022281
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	256247.442	256247.442	263192.773	263137.9	0.271	0.271056	
	N_2O	Kg	270.000	2.701584544	729.427827					
	C_xH_y	kg	11.000	565.0820887	6215.90298					
Acid rain	Ammonia	Kg	1.880	1.073746894	2.01864416	1578.76509	1488.516	0.165	0.175004	
	HCl	Kg	0.880	2.2438	1.974544					
	NO_x	Kg	0.700	1044.008041	730.805628					
	SO_x	Kg	1.000	843.9662689	843.966269					
Eutrophication	NO_x	Kg	0.130	1044.008041	135.721045	543.238982	587.6593	0.096	0.088744	
	Ammonia	Kg	0.330	1.073746894	0.35433647					
	Phosphorus	Kg	3.060	133.06	407.1636					
Local air pollution	Particulate Matter	Kg	1.000	61.71190889	61.7119089	1130.58085	982.4961	0.22	0.253159	
	SO_x	Kg	1.000	843.9662689	843.966269					
	C_xH_y	Kg	0.398	565.0820887	224.902671					

Table B-5.8: Detail calculation of environmental destruction indexVessel 4										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_4$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_4/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_4/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	9431800	9431800	9431800	2114930	0.143	0.637727	2.959321
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	892736.4718	892736.472	898210.171	263137.9	0.271	0.925047	
	N_2O	Kg	270.000	2.36524059	638.614959					
	C_xH_y	Kg	11.000	439.5531341	4835.08448					
Acid rain	Ammonia	Kg	1.880	0.889676912	1.6725926	4213.84974	1488.516	0.165	0.467099	
	HCl	Kg	0.880	4.1424	3.645312					
	NO_x	Kg	0.700	3719.80702	2603.86491					
	SO_x	Kg	1.000	1604.666923	1604.66692					
Eutrophication	NO_x	Kg	0.130	3719.80702	483.574913	2488.01551	587.6593	0.096	0.406442	
	Ammonia	Kg	0.330	0.889676912	0.29359338					
	Phosphorus	Kg	3.060	654.95	2004.147					
Local air pollution	Particulate Matter	Kg	1.000	87.16036435	87.1603644	1866.76943	982.4961	0.22	0.418006	
	SO_x	Kg	1.000	1604.666923	1604.66692					
	C_xH_y	Kg	0.398	439.5531341	174.942147					

Table B-5.9: Detail calculation of environmental destruction indexVessel 5

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_5$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_5/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_5/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	5779830	5779830	5779830	2114930	0.143	0.3908	1.972683
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	568386.0298	568386.03	574043.125	263137.9	0.271	0.591194	
	N_2O	Kg	270.000	2.301952281	621.527116					
	C_xH_y	Kg	11.000	457.778938	5035.56832					
Acid rain	Ammonia	Kg	1.880	0.893256784	1.67932275	2845.28197	1488.516	0.165	0.315396	
	HCl	Kg	0.880	2.8479	2.506152					
	NO_x	Kg	0.700	2379.882313	1665.91762					
	SO_x	Kg	1.000	1175.178878	1175.17888					
Eutrophication	NO_x	Kg	0.130	2379.882313	309.384701	1538.85088	587.6593	0.096	0.251387	
	Ammonia	Kg	0.330	0.893256784	0.29477474					
	Phosphorus	Kg	3.060	401.69	1229.1714					
Local air pollution	Particulate Matter	Kg	1.000	66.8220462	66.8220462	1424.19694	982.4961	0.22	0.318905	
	SO_x	kg	1.000	1175.178878	1175.17888					
	C_xH_y	Kg	0.398	457.778938	182.196017					

Table B-5.10: Detail calculation of environmental destruction indexVessel 6										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_6$	$(EP(j))_1$	ω_j	$\omega_j * (EP(j))_6/(EP(j))_1$	$\sum \omega_j * (EP(j))_6/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	3737890	3737890	3737890	2114930	0.143	0.252736	1.465697
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	393208.6234	393208.623	400026.29	263137.9	0.271	0.411978	
	N_2O	Kg	270.000	2.647445189	714.810201					
	C_xH_y	Kg	11.000	554.8051112	6102.85622					
Acid rain	Ammonia	Kg	1.880	1.053185495	1.97998873	2184.94416	1488.516	0.165	0.242198	
	HCl	Kg	0.880	2.1575	1.8986					
	NO_x	Kg	0.700	1677.733713	1174.4136					
	SO_x	Kg	1.000	1006.651973	1006.65197					
Eutrophication	NO_x	kg	0.130	1677.733713	218.105383	1013.28793	587.6593	0.096	0.165531	
	Ammonia	Kg	0.330	1.053185495	0.34755121					
	Phosphorus	Kg	3.060	259.75	794.835					
Local air pollution	Particulate Matter	Kg	1.000	59.84641964	59.8464196	1287.31083	982.4961	0.22	0.288254	
	SO_x	Kg	1.000	1006.651973	1006.65197					
	C_xH_y	Kg	0.398	554.8051112	220.812434					

B-6: Narayanganj-Munshiganj

A-6.1: Inventory list of the compound and substances for the construction phase of vessels						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
Energy consumption (MJ)	14804510	12351520	10519190	37727200	28899150	22427340
CO_2 emission (kg)	1143652.44	954425.04	809078.71	2903637.6	2223789.15	1725637.56
NOx emission (kg)	5180.42	4317.92	3672.79	13204.48	10104.65	7864.44
SOx emission (kg)	1539.37	1294.72	1140.15	3751.6	2928.45	2308.92
Phosphorus emission (kg)	1030.33	859.12	731.83	2619.8	2008.45	1558.5

B-6.2: Emissions for the production of electrolytic chrome coated steel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	474950	424800	421850	566400	486750	442500
NOx	730.94	653.76	649.22	871.68	749.1	681
SOx	994.98	889.92	883.74	1186.56	1019.7	927
N_2O	1.53272	1.37088	1.36136	1.82784	1.5708	1.428
HF	1.771	1.584	1.573	2.112	1.815	1.65
HCl	13.8943	12.4272	12.3409	16.5696	14.2395	12.945
Methane	1738.8	1555.2	1544.4	2073.6	1782	1620
Ammonia	0.31717	0.28368	0.28171	0.37824	0.32505	0.2955
CxHy	0.84203	0.75312	0.74789	1.00416	0.86295	0.7845
Suspended Particulate Matter	227.01	203.04	201.63	270.72	232.65	211.5

B-6.3: Emissions for the production of diesel (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	110363.8839	110363.8839	136251.7086	105949.3286	110363.8839	133774.4048
NOx	672.0877547	672.0877547	829.7379688	645.2042445	672.0877547	814.6518239
SOx	1365.399333	1365.399333	1685.678189	1310.78336	1365.399333	1655.029495
N_2O	16.97905907	16.97905907	20.96180132	16.2998967	16.97905907	20.58067766
Ammonia	7.074607944	7.074607944	8.734083882	6.791623627	7.074607944	8.575282357
CxHy	2401.829397	2401.829397	2965.221478	2305.756221	2401.829397	2911.30836
Suspended Particulate Matter	7.782068739	7.782068739	9.60749227	7.470785989	7.782068739	9.432810593

B-6.4: Emissions through burning of diesel by a ship engine (in kg)						
	Vessel 1	Vessel 2	Vessel 3	Vessel 4	Vessel 5	Vessel 6
CO_2	114095.7396	114095.7396	140858.9378	109531.91	114095.7396	138297.8662
NOx	1114.250751	1114.250751	1375.618211	1069.680721	1114.250751	1350.606971
SOx	1927.830665	1927.830665	2380.037858	1850.717438	1927.830665	2336.764442
CxHy	1506.891492	1506.891492	1860.359867	1446.615832	1506.891492	1826.535142
Suspended Particulate Matter	165.5458259	165.5458259	204.3775628	158.9239929	165.5458259	200.6616072

Table B-6.5: Detail calculation of sum of the potential contribution from the impact category forVessel 1						
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	EP(j)
Fossil fuel exhaustion	Energy consumption	MJ	1.000	14804510	14804510	14804510
Local warming	Heat radiation	MJ	1.000	1.000	1	1
Global warming	CO_2	Kg	1.000	1843062.064	1843062.064	1891065.436
	N_2O	Kg	270.000	18.51177907	4998.180348	
	C_xH_y	Kg	11.000	3909.562919	43005.19211	
Acid rain	Ammonia	Kg	1.880	7.391777944	13.89654254	11242.09248
	HCl	Kg	0.880	13.8943	12.226984	
	NO_x	Kg	0.700	7697.698506	5388.388954	
	SO_x	Kg	1.000	5827.579998	5827.579998	
Eutrophication	NO_x	Kg	0.130	7697.698506	1000.700806	4155.949892
	Ammonia	Kg	0.330	7.391777944	2.439286722	
	Phosphorus	Kg	3.060	1030.33	3152.8098	
Local air pollution	Particulate Matter	Kg	1.000	400.3378946	400.3378946	7783.923935
	SO_x	Kg	1.000	5827.579998	5827.579998	
	C_xH_y	Kg	0.398	3909.562919	1556.006042	

Table B-6.6.: Detail calculation of environmental destruction index forVessel 2

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_2$	$(EP(j))_1$	ω_j	$\omega_j*(EP(j))_2/(EP(j))_1$	$\sum\omega_j*(EP(j))_2/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	12351520	12351520	12351520	14804510	0.143	0.119306	0.901702
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	1603684.664	1603684.664	1651643.361	1891065	0.271	0.23669	
	N_2O	Kg	270.000	18.34993907	4954.483548					
	C_xH_y	Kg	11.000	3909.474009	43004.2141					
Acid rain	Ammonia	Kg	1.880	7.358287944	13.83358134	10233.25247	11242.09	0.165	0.150193	
	HCl	Kg	0.880	12.4272	10.935936					
	NO_x	Kg	0.700	6758.018506	4730.612954					
	SO_x	Kg	1.000	5477.869998	5477.869998					
Eutrophication	NO_x	Kg	0.130	6758.018506	878.5424058	3509.877841	4155.95	0.096	0.081076	
	Ammonia	Kg	0.330	7.358287944	2.428235022					
	Phosphorus	Kg	3.060	859.12	2628.9072					
Local air pollution	Particulate Matter	Kg	1.000	376.3678946	376.3678946	7410.208548	7783.924	0.22	0.209438	
	SO_x	Kg	1.000	5477.869998	5477.869998					
	C_xH_y	Kg	0.398	3909.474009	1555.970656					

Table B-6.7: Detail calculation of environmental destruction index forVessel 3										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_3$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_3/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_3/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	10519190	10519190	10519190	14804510	0.143	0.101607	0.897585
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	1508039.356	1508039.356	1567156.232	1891065	0.271	0.224582	
	N_2O	Kg	270.000	22.32316132	6027.253556					
	C_xH_y	Kg	11.000	4826.329235	53089.62158					
Acid rain	Ammonia	Kg	1.880	9.015793882	16.9496925	10686.57206	11242.09	0.165	0.156847	
	HCl	Kg	0.880	12.3409	10.859992					
	NO_x	Kg	0.700	6527.36618	4569.156326					
	SO_x	Kg	1.000	6089.606047	6089.606047					
Eutrophication	NO_x	Kg	0.130	6527.36618	848.5576034	3090.932615	4155.95	0.096	0.071399	
	Ammonia	Kg	0.330	9.015793882	2.975211981					
	Phosphorus	Kg	3.060	731.83	2239.3998					
Local air pollution	Particulate Matter	Kg	1.000	415.6150551	415.6150551	8426.100138	7783.924	0.22	0.23815	
	SO_x	Kg	1.000	6089.606047	6089.606047					
	C_xH_y	Kg	0.398	4826.329235	1920.879035					

Table B-6.8: Detail calculation of environmental destruction index forVessel 4

Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_4$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_4/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_4/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	37727200	37727200	37727200	14804510	0.143	0.364415	1.801866
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	3685518.839	3685518.839	3731700.466	1891065	0.271	0.534773	
	N_2O	Kg	270.000	18.1277367	4894.48891					
	C_xH_y	Kg	11.000	3753.376214	41287.13835					
Acid rain	Ammonia	Kg	1.880	7.169863627	13.47934362	19181.45287	11242.09	0.165	0.281526	
	HCl	Kg	0.880	16.5696	14.581248					
	NO_x	Kg	0.700	15791.04497	11053.73148					
	SO_x	Kg	1.000	8099.660798	8099.660798					
Eutrophication	NO_x	Kg	0.130	15791.04497	2052.835846	10071.7899	4155.95	0.096	0.232652	
	Ammonia	Kg	0.330	7.169863627	2.366054997					
	Phosphorus	Kg	3.060	2619.8	8016.588					
Local air pollution	Particulate Matter	Kg	1.000	437.1147789	437.1147789	10030.61931	7783.924	0.22	0.283499	
	SO_x	Kg	1.000	8099.660798	8099.660798					
	C_xH_y	Kg	0.398	3753.376214	1493.843733					

Table B-6.9.: Detail calculation of environmental destruction index forVessel 5										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor ($EF(j)_i$)	Q_i	Q_i x EF_i	$(EP(j))_5$	$(EP(j))_1$	ω_j	$\omega_j*(EP(j))_5/(EP(j))_1$	$\sum\omega_j*(EP(j))_5/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	28899150	28899150	28899150	14804510	0.143	0.279143	1.488255
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	2934998.774	2934998.774	2983012.658	1891065	0.271	0.427482	
	N_2O	Kg	270.000	18.54985907	5008.461948					
	C_xH_y	Kg	11.000	3909.583839	43005.42223					
Acid rain	Ammonia	Kg	1.880	7.399657944	13.91135694	16115.88407	11242.09	0.165	0.236533	
	HCl	Kg	0.880	14.2395	12.53076					
	NO_x	Kg	0.700	12640.08851	8848.061954					
	SO_x	Kg	1.000	7241.379998	7241.379998					
Eutrophication	NO_x	Kg	0.130	12640.08851	1643.211506	7791.510393	4155.95	0.096	0.179979	
	Ammonia	Kg	0.330	7.399657944	2.441887122					
	Phosphorus	Kg	3.060	2008.45	6145.857					
Local air pollution	Particulate Matter	Kg	1.000	405.9778946	405.9778946	9203.372261	7783.924	0.22	0.260118	
	SO_x	Kg	1.000	7241.379998	7241.379998					
	C_xH_y	Kg	0.398	3909.583839	1556.014368					

Table B-6.10.: Detail calculation of environmental destruction index forVessel 6										
Impact category (j)	Responsible substances or compounds (i)	Unit	Characterization factor $(EF(j)_i)$	Q_i	Q_i x EF_i	$(EP(j))_6$	$(EP(j))_1$	ω_j	$\omega_{j*}(EP(j))_6/(EP(j))_1$	$\sum\omega_{j*}(EP(j))_6/(EP(j))_1$
Fossil fuel exhaustion	Energy consumption	MJ	1.000	22427340	22427340	22427340	14804510	0.143	0.216631	1.308073
Local warming	Heat radiation	MJ	1.000	1.000	1	1	1	0.105	0.105	
Global warming	CO_2	Kg	1.000	2440209.831	2440209.831	2498277.082	1891065	0.271	0.358017	
	N_2O	Kg	270.000	22.00867766	5942.342967					
	C_xH_y	Kg	11.000	4738.628002	52124.90802					
Acid rain	Ammonia	Kg	1.880	8.870782357	16.67707083	14753.27176	11242.09	0.165	0.216534	
	HCl	Kg	0.880	12.945	11.3916					
	NO_x	Kg	0.700	10710.6988	7497.489157					
	SO_x	Kg	1.000	7227.713937	7227.713937					
Eutrophication	NO_x	Kg	0.130	10710.6988	1392.390843	6164.328202	4155.95	0.096	0.142392	
	Ammonia	Kg	0.330	8.870782357	2.927358178					
	Phosphorus	Kg	3.060	1558.5	4769.01					
Local air pollution	Particulate Matter	Kg	1.000	421.5944177	421.5944177	9535.2823	7783.924	0.22	0.269499	
	SO_x	Kg	1.000	7227.713937	7227.713937					
	C_xH_y	Kg	0.398	4738.628002	1885.973945					

Appendix C

Route: Badamtoli – Gabtoli

Route Distance: 16 km

Number of vessels operating in the route: 4

I. Water Bus-5

II. Water Bus-6

III. M.L. Baral

IV. M.L. Dorola

Table A-C.1: Ghat/Route Distances and Water Bus Fares for the Route: Badamtoli – Gabtoli

Ghat – Ghat	Distance (km)	Fare (Tk)	Travel Duration (min)
Badamtoli – ShowariGhat	0.96	--	6
Badamtoli – Kholamora	4.98	10	30 (Dry) 40 (Rainy)
Badamtoli – Gabtoli	15.76	40	90 (Dry) 150 (Rainy)

Route: Narayanganj to Tongi

Route Distance: 41.84 km

Table A-C.2: Ghat/Route Distances and Water Bus Fares for the Route:Narayanganj toTongi

Ghat – Ghat	Distance (km)	Fare (Tk)
Narayanganj – Kanchpur	10.62	30
Narayanganj – Demra	14.32	40
Narayanganj – Rajakhali	22	80
Narayanganj – Beraidbazar	25.75	85
Narayanganj – Ichapura	34	100
Narayanganj – Tongi	41.84	110

Table- A-C.3: Water Bus Fares in various water routes in Dhaka city

2/26/2019 Narayanganj tongi 2.png

ডেমরা-টঙ্গী	৭০.০০
রাজাখালী(নলছাড়া)-বেরাইদবাজার	১০.০০
রাজাখালী (নলছাড়া)-ইছাপুরা	২০.০০
রাজাখালী (নলছাড়া)-টঙ্গী	৪০.০০
বেরাইদবাজার-ইছাপুরা	১৫.০০
বেরাইদবাজার-টঙ্গী	৩০.০০
ইছাপুরা-টঙ্গী	২০.০০

Table- A-C.4: Fares in Sadarghat –Gabtoli Water Bus Services

2/26/2019 sadarghat gabloli.png

সদরঘাট-গাবতলী ওয়াটার বাস সার্ভিস

স্টেশন হতে স্টেশন	যাত্রী প্রতি ভাড়া	এক্সপ্রেস ভাড়া
সদর ঘাট/বাদামতলী-সোয়ারী ঘাট	১০/-টাকা	-
সদর ঘাট/বাদামতলী-খোলামুড়া	২০/-টাকা	-
সদর ঘাট/বাদামতলী-বসিলা	৩০/-টাকা	৪০/-টাকা
সদর ঘাট/বাদামতলী-গাবতলী	৪০/-টাকা	৫০/-টাকা
সোয়ারী ঘাট-খোলামুড়া	১০/-টাকা	-
সোয়ারী ঘাট-বসিলা	৩০/-টাকা	-
সোয়ারী ঘাট-গাবতলী	৩৫/-টাকা	-
খোলামুড়া- বসিলা	২০/-টাকা	-
খোলামুড়া-গাবতলী	৩০/-টাকা	-
বসিলা-গাবতলী	১০/-টাকা	৩০/-টাকা
গাবতলী-সদর ঘাট/বাদামতলী	৪০/-টাকা	৫০/-টাকা

Table- A-C.5: Fares in Narayanganj –Tongi Water Bus Services

2/26/2019 Narayanganj tongi 1.png

নারায়নগঞ্জ-টঙ্গী ওয়াটার বাস সার্ভিস :

স্টেশন হতে স্টেশন	যাত্রী প্রতি ভাড়া
নারায়ণগঞ্জ নদী বন্দর-কাঁচপুর	৩০.০০
নারায়ণগঞ্জ নদী বন্দর-ডেমরা	৪০.০০
না:গঞ্জ নদীবন্দর-রাজাখালী (গলঘাড়া)	৮০.০০
নারায়ণগঞ্জ নদী বন্দর-বেরাইদবাজার	৮৫.০০
নারায়ণগঞ্জ নদী বন্দর-ইছাপুরা	১০০.০০
নারায়ণগঞ্জ নদী বন্দর-টঙ্গী	১১০.০০
কাঁচপুর-ডেমরা	১০.০০
কাঁচপুর-বেরাইদবাজার	৫৫.০০
কাঁচপুর-ইছাপুরা	৭০.০০
কাঁচপুর-টঙ্গী	৮০.০০
ডেমরা-রাজাখালী (গলঘাড়া)	৪০.০০
ডেমরা-বেরাইদবাজার	৫০.০০
ডেমরা-ইছাপুরা	৬০.০০

Appendix D

Figure A-D.1: Badamtoli Ghat

Figure A-D.2: Badamtoli Ghat

Figure A-D.3: Narayanganj Ghat

Figure A-D.4: Narayanganj Ghat

Figure A-D.5: Narayanganj Ghat

Figure A-D.6: Water Bus Ghat

Figure A-D.7: Water Bus outside

Figure A-D.8: Water Bus inside Seats

Figure A-D.9: Water Bus Engine Room

Figure A-D.10: Water Bus Engine

Figure A-D.11: Water Boat

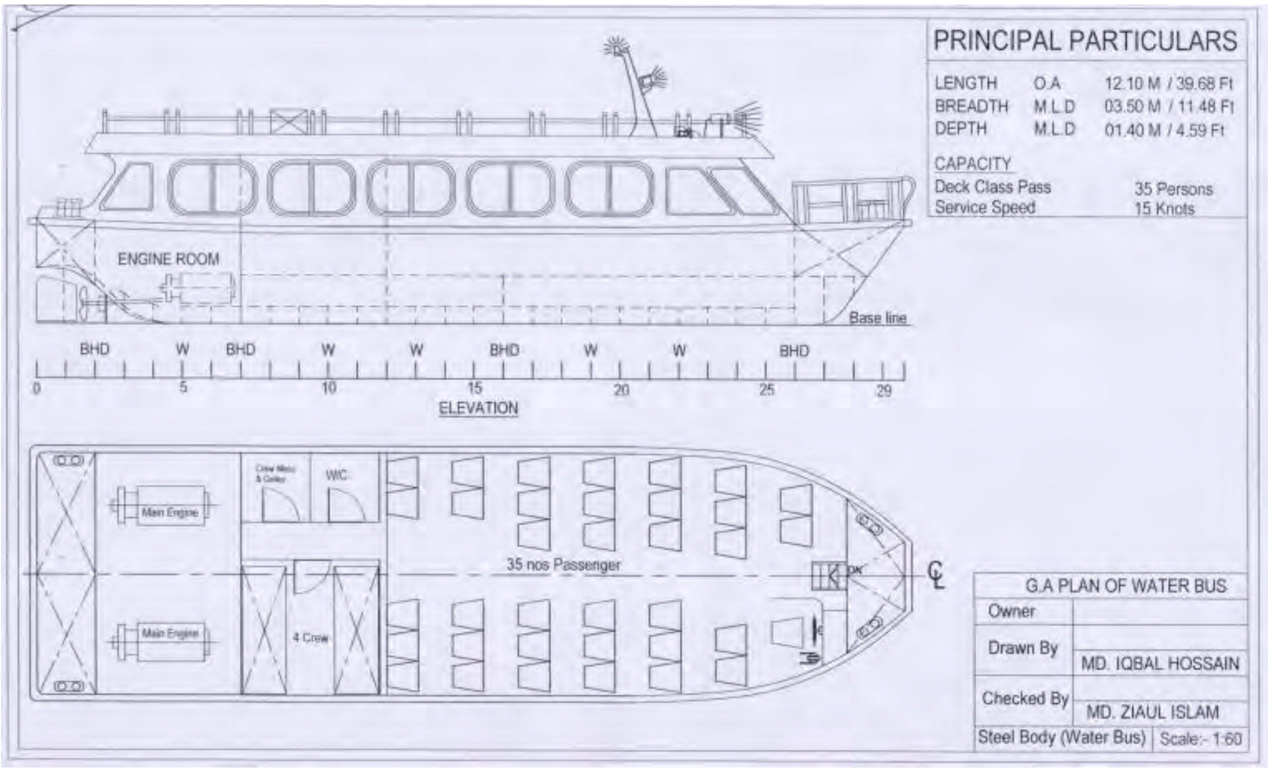

Figure A-D.12: G.A. Drawings of running one Water Bus

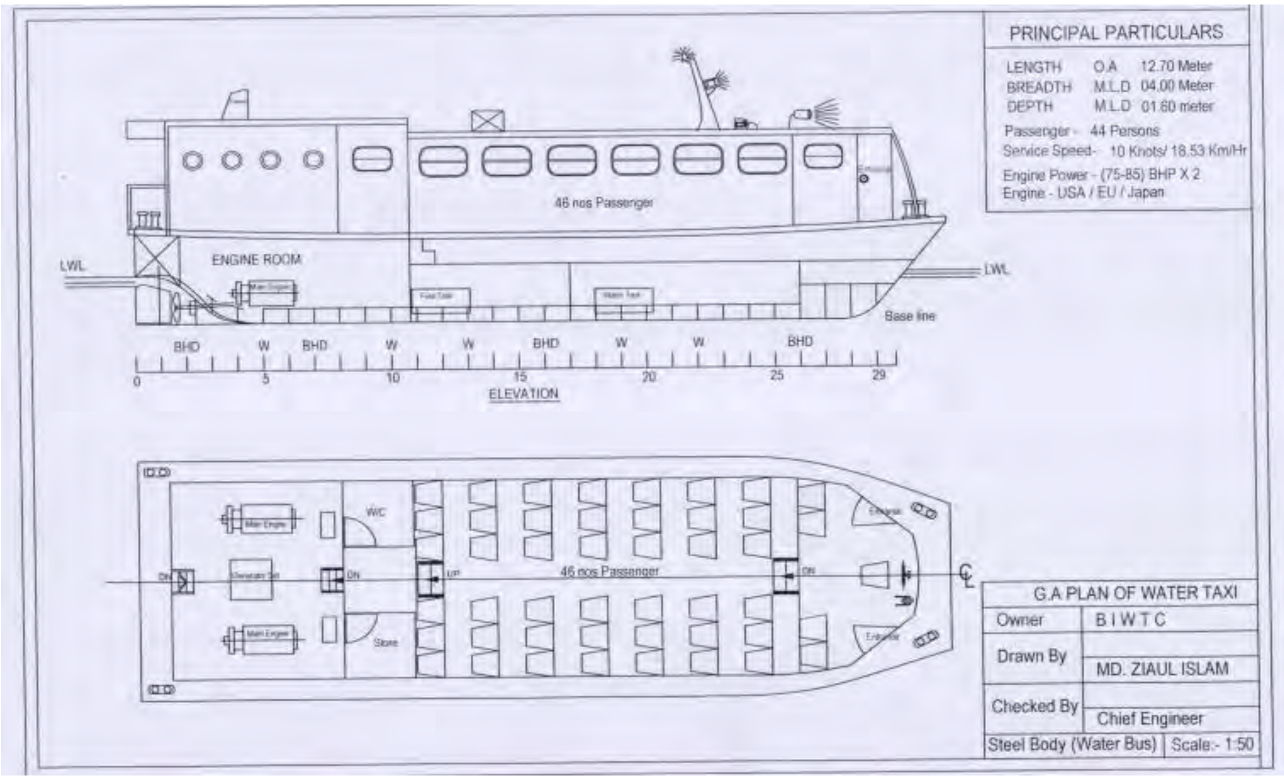

Figure A-D.13: G.A. Drawings of running another Water Bus

DIAGRAMS AND SKETCHES

SN ITEMS PAGE NO.

LIST OF TABLES

SN	TABLES & ITEMS	PAGE NO.