FEASIBILITY STUDY OF A SECOND OIL REFINERY IN BANGLADESH

PRODIP KUMER CHOWDHURY

MASTER OF ENGINEERING IN PETROLEUM ENGINEERING

DEPARTMENT OF PETROLEUM & MINERAL RESOURCES ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DHAKA-1000, BANGLADESH

APRIL, 2010

FEASIBILITY STUDY OF A SECOND OIL REFINERY IN BANGLADESH

A Thesis
Submitted to the Department of Petroleum & Mineral Resources Engineering in partial fulfillment of the requirements for the Degree of
MASTER OF ENGINEERING IN PETROLEUM ENGINEERING

By

PRODIP KUMER CHOWDHURY
ROLL NO: 040313012

DEPARTMENT OF PETROLEUM & MINERAL RESOURCES ENGINEERING
BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY
DHAKA-1000, BANGLADESH

APRIL, 2010

RECOMMRNDATION OF BOARD OF EXAMINERS

The project titled "FEASIBILITY STUDY OF A SECOND OIL REFINERY IN BANGLADESH" submitted by Prodip Kumer Chowdhury, Roll No : 040313012, Session : April 2003, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of MASTER OF ENGINEERING IN PETROLEUM ENGINEERING in April 24, 2010.

Chairman(Supervisor): ___________________________________

Mohammad Shorab Hossain
Assistant Professor
Department of Petroleum & Mineral Resources Engineering
BUET, Dhaka-1000.

Member : ___________________________________

Dr. Md. Mahbubur Rahman
Assistant Professor
Department of Petroleum & Mineral Resources Engineering
BUET, Dhaka-1000.

Member : ___________________________________

Dr. Waliuzzaman
Visiting Professor (Ex-chairman BCSIR)
Department of Chemical Engineering
BUET, Dhaka-1000.

Date: April 24,2010

ABSRACT

Eastern Refinery Limited is the only Petroleum Refining Company in Bangladesh which was established in 1968. Its installed capacity is 1.5 million MT. But now it can hardly process 1.3 million MT due to its aging effect. Total annual demand of petroleum products in Bangladesh is about 4 million MT and it is increasing day by day. Eastern Refinery Limited (ERL) can meet only 30 % of our demand. The rest 70 % is being imported by Bangladesh Petroleum Corporation (BPC).

It is seen from the demand/ supply situation of petroleum products in Bangladesh that the demand of diesel is higher than the all other petroleum products because of irrigation and transportation. It is important to point out that in the last five years kerosene demand has been falling and in 2006, it has recorded the biggest fall. The use of LPG in rural areas as cooking fuel and rural electrification help to decrease the demand of kerosene. Also it is seen from the analysis that kerosene demand is partially unmet and jet fuel demand is totally unmet. Since ERL cannot even meet the kerosene demand in the country, jet fuel which is basically kerosene must be imported to meet jet fuel demand. The demand of kerosene is not robust like diesel.

A cost analysis has shown that unit barrel imported refined product cost is higher than the refined cost of unit barrel crude and the difference of these two costs is increasing every year. As a result we are loosing large amount of money every year by not refining more crude oil in the country. Also profitability analysis has shown that crude/product price spread is an important factor for the profitability of this business.

Refinery is one of the trickiest businesses in the world. The first and foremost thing about refinery business is that prices are highly volatile. The business risks arise from the three major areas such as international, local and financial.

But counting the present economics and oil security instead of importing refined products establishment of a second oil refinery in Bangladesh has been found feasible. The second Refinery will meet the demands of all petroleum products except diesel because there is huge demand for diesel in Bangladesh. To run the plant uninterruptedly some surplus naphtha and furnace oil have to be exported.

ACKNOWLEDGEMENT

I would like to thank Mohammad Shorab Hossain, Assistant Professor, Department of Petroleum & Mineral Resources Engineering, for assigning such an important and practical topic on " Feasibility Study of a Second Refinery in Bangladesh" and for supervision and guidance throughout this study.

I am grateful to Dr. M. Tamim, Professor , Department of Petroleum & Mineral Resources Engineering, for his distinguished lectures and demonstration during class period that helped me to complete this work.

I would like to thank Dr. Mahbubur Rahman , Assistant Professor, Department of Petroleum & Mineral Resources Engineering, for his valuable lectures during our class period to understand the concept of petroleum engineering.

I also express my gratitude to the staff of Petroleum and Mineral Resources Engineering for their cooperation.

TABLE OF CONTENTS

CHAPTER

Chapter 1
INRODUCTION

Eastern Refinery Ltd.(ERL) is the only Petroleum Refinery in Bangladesh and a subsidiary organization of Bangladesh Petroleum Corporation (BPC). It was incorporated as a public limited company under companies Act,1913 in March,1963 and started commercial operation from May 7, 1968.

Eastern Refinery processes light crude from Middle Eastern countries namely, Murban Crude of Abu Dhabi and Arab Light Crude(ALC) of Saudi Arabia. Of these two crude oils, only ALC is suitable for Bitumen production because of higher viscosity of ALC residue which is produced from Atmospheric Distillation Unit. On the other hand, Murban Crude(MC) oil contains more valuable light distillates like LPG and Gasoline (Petrol & Octane) and middle distillates like Kerosene & Diesel. ERL also processes whatever natural gas condensates it receives from different gas fields of the country. ERL is a medium conversion refinery comprising the following processing units, such as 1. Atmospheric Distillation Unit 2.Pretreatment & Catalytic Reforming Unit. 3. Asphaltic Bitumen Unit 4. Long Residue Vis-breaker (LRV) unit. 5. Mild Hydro-cracking Unit

ERL has been playing the anchor role in catering to the needs of various petroleum products in the country without interruption since its inception and thereby playing a vital role in the national economy.

The idea of establishing second refinery in Bangladesh was discussed way back in the early eighties, but it never been materialized because of the following reasons. These are:

- Naphtha produced by ERL has no use in Bangladesh and excess furnace oil has to export in every few years.
- The profitability with low and controlled prices of finished products was never judged to be enough for a private investor.
- Most importantly, it could not find the funding for it.

All through nineties, several efforts to set up a second refinery were made by both the public and private sectors. But it did not find any fruitful solution because of the following reasons:

- Excess naphtha and furnace oil
- Insufficient refiner's margin
- Requirement of large working capital to purchase crude oil for the upward fluctuation of crude oil price.
- Requirement of large capital investment

Bangladesh's petroleum (oil) consumption is about 4 million tons per year. Yet it has only one refinery i.e. ERL built in 1968 having a capacity of 1.5 million tons. Because of the aging of units, it can hardly process more than 1.3 million tons per year.

ERL can meet only 30 % of our demand. Remaining 70 % is being imported as finished product by BPC (Bangladesh Petroleum Corporation).The demand of diesel is higher than all other petroleum products because of irrigation and transportation. The demand of diesel is about 2.3 Million tons out of total demand 4 million tons of finished products and it is increasing every year. The demand of other petroleum products such as LPG, Bitumen and JP-1 are also increasing day by day because of gas shortage and growth of socio-economic development.

With rising crude oil prices, refiner's margin, i.e., the difference between crude oil and refined products price has been increasing steadily. Clearly therefore, by not refining crude oil in Bangladesh, Government is losing a large amount of money. Since there is a necessity to save foreign currency, establishment of a second refinery is very important. Unlike the existing one, second refinery need to process medium crude to produce maximum of diesel to meet its increasing demand in Bangladesh.

This study analyzes the different types of refinery configurations and different types of crude oil. Also this study analyzes the economical viability to setup a second oil refinery in Bangladesh at present situation. Also it is seen from the profitability analysis that we are losing large amount of money not refining crude oil in our country. Since there is necessity to save foreign currency and also for maintaining the energy security , establishment of second oil refinery is very important.

Chapter2

DIFFERENT TYPES OF REFINERY

A refinery produces a wide variety of products. Some products such as HOBC(High Octane Blending Component) and Jet Fuel are derived using additional pieces of equipment from the outputs of the simple refinery, and products like JBO(Jute Batchig Oil), LDO(Light Diesel Oil), MTT(Mineral Terpentine), SBPS(Special Boiling Point Solvent) and lubricating oil are specialized cuts produced in low volume. Therefore, in the discussion the above products are excluded, and only the main products (LPG, Gasoline, Naphtha, Kerosene, Diesel, Furnace Oil, Bitumen) are dealt with. Naphtha and Gasoline are often lumped together because HOBC, which is blended with gasoline to increase its octane number, is obtained from reforming Naphtha. For the sake of convenience especially with respect to profitability analysis, it is customary to divide refinery products into the following three broad categories.

a. Light Distillates (LPG, Naphtha, MS, HOBC)

b. Middle Distillates (Kerosene, Jet Fuel, Diesel, LDO, Lubricating Oil)

c. Heavy Distillates (Heating Oils, Furnace Oil, Bitumen, Coke)

Since the Heavy Distillates have a value below the feedstock (crude oil), a refinery must try to minimize its production, but that depends on the crude oil quality and eventually on refining stages. This statement implies that with adequate investment, a refinery can minimize Heavy Distillates to any desired level. Of course, in some configurations the gas loss and/or investment may be so high that those may be ruled out. In refinery technology it is common to talk about the following three configurations.

2.1 Simple Refinery

2.2 Medium Conversion Refinery

2.3 Full Conversion Refinery

Both capital investment and profitability increase as one moves from simple to more complex configurations. The Simple refinery will of course have the lowest capital investment but must deal with a huge quantity of Naphtha and Furnace oil. The Medium conversion refinery can be used to convert Furnace oil into Bitumen. The Full conversion refinery will convert most of the furnace oil into more valuable products that can be sold within the country, but huge investments would be required.

2.1 Simple Refinery

The main item of the Simple refinery is an atmospheric distillation unit, which separates the feed crude oil into different fractions according to their boiling point ranges (Figure2.1.1). Certain fractions from an atmospheric distillation unit, i.e. Light & Heavy kerosene, Gas oil, and Atmospheric residue are marketed directly as Kerosene, Diesel and Furnace oil (Heavy fuel oil) respectively. The LPG fraction is washed with caustic solution before marketing. Light kerosene is treated (called sweetening operation) in a Merox unit and then marketed as jet kerosene. Heavy naphtha is hydro treated and catalytically converted in a Reforming unit to increase its octane number. The reformed Heavy naphtha is then blended with sweetened Light naphtha (i.e. Light naphtha treated in a Merox unit) and other High Octane Blending Compounds (imported) to produce motor gasoline.

Market demand of petroleum products in Bangladesh is such that a simple refinery using a typical available crude oil as feedstock will never be able to match the demand pattern. There will be deficit of Diesel and excess of Naphtha and Atmospheric residue (i.e. Heavy fuel oil). Product slate of the simple refinery using middle-eastern crude oil is shown in Table 2.1.1.

It is possible to convert all of the naphtha produced by a simple refinery into motor gasoline. But the market of motor gasoline in Bangladesh is small and a refinery of capacity 33,000 bbl/day will be able to market only one-third of its Gasoline/Naphtha stream within the country. The remaining two-third has to be exported as naphtha. A heavier product can be converted into lighter products using additional processing technologies and the cost of production.

The simple refinery will produce lots of furnace oil (heavy fuel oil),most of which has to be exported. Furnace oil can be processed further to produce marketable (within Bangladesh) products using additional processing plants .

Simple Refinery

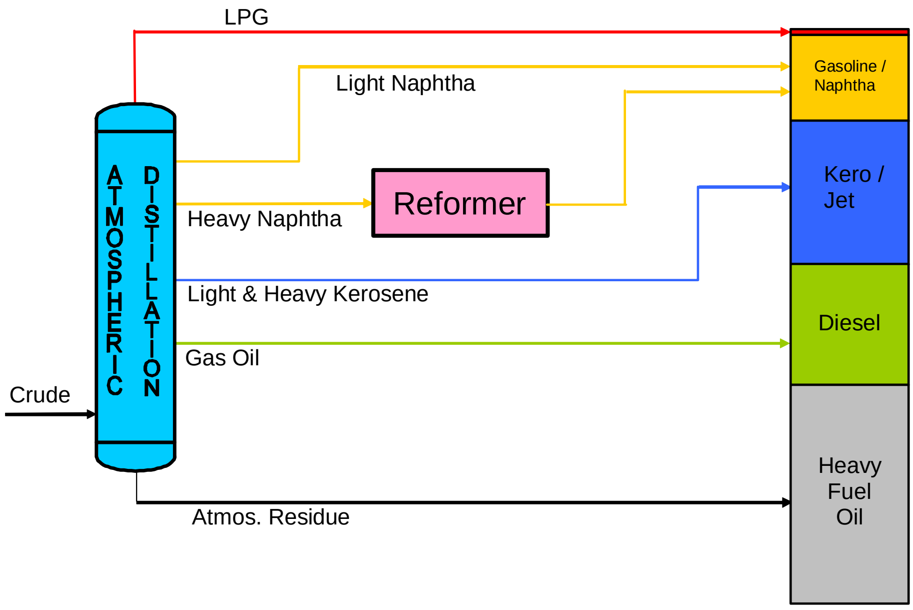

Figure 2.1.1: A simple refinery configuration

Table 2.1.1: Product Slate of simple refinery

Product	Finished Product (%)
LPG	1
Gasoline/Naphtha	15
Kerosene	25
Diesel	21
Furnace oil	38

2.1.1 Major Items / Equipment of Simple Refinery

A list of major items/equipment of the Simple refinery is shown below.

a. Atmospheric Crude Distillation Unit

b. Reforming Unit (with Hydrotreater)

c. Merox Sweetening Units (for gasoline and kerosene)

d. Tank farm (crude-oil and finished products)

e. Utilities (power, steam, process water, cooling water, compressed air)

f. On-site facilities (office building, workshop/stores, fire-fighting, waste treatment, etc.)

g. Crude-oil and Products handling facilities (jetty, pumping station, pipeline)

An Atmospheric Crude Distillation unit typically consists of three separate distillation towers, namely

(1) Main / Crude distillation tower,

(2) Stabilizer / Debutanizer tower, and

(3) Splitter tower

The main tower has several sub-units such as desalter, fired heater, heat exchangers, reflux unit, etc. The Debutanizer removes propane/butane from gasoline, while the Splitter Tower separates the gasoline steam into Light and Heavy Naphtha.

The Reformer converts Heavy Naphtha into high-octane gasoline, which in refinery terminology is called High Octane Blending Compound (HOBC). The addition of this unit therefore reduces the amount of naphtha produced by the atmospheric distillation tower.

The Merox sweetening unit removes sulfur from gasoline and kerosene. If the kerosene produced from the atmospheric unit meets other requirements, then, this unit will convert kerosene into Jet Fuel.

Tank Farm is an extremely important part of any refinery. Both crude oil and refined products in sufficient quantity must be stored in the refinery premises. These tanks are large vessels requiring a lot of space and can be expensive.

2.2 Medium Conversion Refinery

To extract more valuable products from the Atmospheric residue stream produced in a simple refinery, it is further distilled under reduced pressure in a unit called Vacuum distillation unit. The Medium conversion refinery (Figure2.2.1) will include the following in addition to everything in the Simple Refinery Configuration.

Vacuum distillation unit
Blowing tower
Vis-breaking unit

The vacuum distillation unit is also called Asphaltic Bitumen Plant, because the principal output of this plant is bitumen. In the process of vacuum distillation roughly 20% diesel is also produced, which is a very good thing for Bangladesh because of the high demand of diesel. The furnace oil from distillation columns is extremely difficult to handle because of its high viscosity characteristics. The vis-breaking unit makes heavy furnace oil more manageable, and in the process produces some diesel, which is a desirable feature for Bangladesh.

Economic benefit from the extra units and investment comes due to decrease in Furnace Oil, increase in Diesel, and production of Bitumen, which is a higher value product than furnace oil. Product slate of the Medium conversion refinery for Middle Eastern crude oil is shown in Table2.2.1.

Bitumen is marketed in standard size metal drums. Therefore a bitumen plant will include drum making and filling facilities. Also, storage tanks and pipelines for bitumen are insulated and fitted with steam coils.

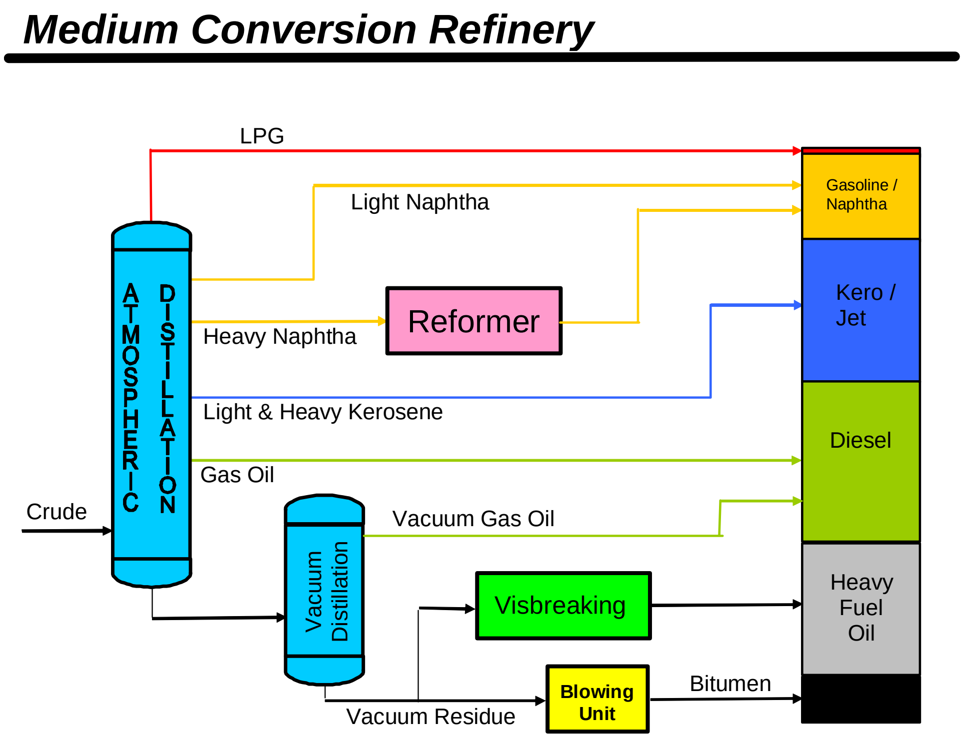

Figure 2.2.1: Medium conversion refinery configuration

Table2.2.1: Product Slate of Medium Conversion Refinery

Product	Finished Product (%)
LPG	1.5
Gasoline/Naphtha	15.5
Kerosene	25
Diesel	28
Furnace oil	22
Bitumen	8

2.2.1 Major Items / Equipment of Medium Conversion Refinery

Simple refinery

+

a. Vacuum Distillation Unit (with blowing tower)

b. Visbreaking Unit

c. Mild Hydrocracking Unit

d. Tank farm with heating coils for bitumen storage

e. Drum making & filling facility

The Vacuum distillation unit will separate Atmospheric residue into three streams; two Vacuum gas oil fractions and Vacuum residue. The lighter portion of Vacuum gas oil will be blended with Diesel and the heavier portion will blended with furnace oil. In future these streams can be further reprocessed (dewaxing, solvent extraction, etc.) to produce lubricating base oils.

A portion of the Vacuum residue will be blown with air in a Blowing tower to produce Bitumen. The quantity to be processed will be dictated by available market for road bitumen in Bangladesh and elsewhere.

The remaining portion of Vacuum residue will be processed in a Visbreaking unit. This is a mild thermal cracking process, which reduces the viscosity of the feed stream. This will make Vacuum residue suitable to be blended into furnace oil. Visbreaking unit will also produce small quantity of diesel oil.

A Mild Hydrocracker unit may also be included here. The latter unit will enhance the quality of the Diesel stream. Here specialized tanks with heating coils are required. A facility to make drums is also required.

2.3 Full Conversion Refinery

If it is desired that very little or no Furnace Oil should be produced, then one must opt for a Full conversion refinery. Apart from all the items mentioned for the simple and Medium Conversion Refinery, this refinery will also include a

a. Solvent Deasphalting unit, and a

b. Hydrocracker unit (including hydrogen generator)

In this configuration (Figure2.3.1), all of the residue produced by the Atmospheric distillation unit will be treated further either in the Vacuum distillation unit or in the Hydrocracker unit. Some quantity of petroleum coke will be produced in this refinery. If market cannot be found for this product, then it can be used as fuel within the refinery. Product slate of the Full conversion refinery is shown in Table2.3.1

Full Conversion configuration is very difficult to define because unlike the Medium Conversion Refinery, which consists of well-known and well-established units. Full conversion refineries come in a variety of shapes and sizes. Many refineries are custom made and tailored to process specific crude and meet specific market demands for refined products. Here, the most standard addition, i.e., the Hydrocracking Unit, which converts furnace oil into diesel, is considered. It should also be noted that even though this is being called a Full Conversion Refinery, it does not handle the excess Naphtha. To handle Naphtha, even more complex units called Naphtha crackers must be employed.

Full Conversion refinery is not only a highly investment intensive venture, but also it requires the capability to operate a complex chemical plant. As a refinery moves up from Medium Conversion to full conversion, the refinery begins to look more like a chemical plant rather than an oil refining plant.

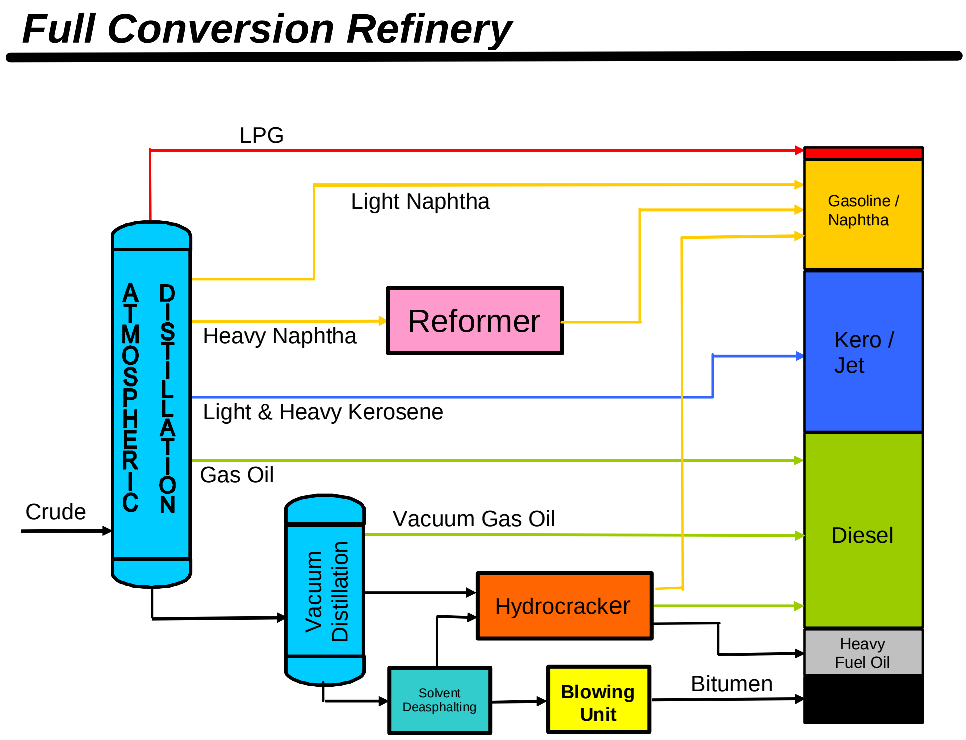

Figure 2.3.1 : Full conversion refinery configuration

Table2.3.1: Product slate for Full Conversion Refinery

Product	Finished Product (%)
LPG	2
Gasoline/Naphtha	19
Kerosene	28
Diesel	34
Furnace oil	8
Bitumen	8
Coke	1

2.3.1 Major Items / Equipment of Full Conversion Refinery

Medium conversion refinery

+

a. Solvent Deasphalting Unit

b. Hydrocracking Unit (with hydrogen generation system)

A Full conversion refinery is a complex set of units. For operational flexibility, this type of refinery includes many units some of which may remain idle at different times. The number and specific type of such units depend on financial decision and final design of the refinery. For example, the Full Conversion Refinery may include Thermal/Catalytic/Hydrocracking/FCC cracking unit.

In those countries where motor gasoline demand is very high, low demand of heavy products such as Atmospheric and Vacuum residues are thermally and catalytically cracked to produce gasoline. In Bangladesh, consumption of motor gasoline is low, and demand for diesel is very high. Therefore the proposed refinery should use a Hydrocracking unit to convert the residue streams into diesel oil. The Solvent deasphalting unit will remove asphalt from residue streams so that the deasphalted product stream can be processed in the Hydrocracking unit.

Hydrocracking is similar to catalytic cracking since it also uses a catalyst, but the reactions take place under a high pressure of hydrogen. The feed to the hydrocracking process is Vacuum Gas Oil (VGO). The large molecules in the VGO are cracked into smaller molecules by breaking carbon-carbon bonds and adding hydrogen atoms in their place. Other chemical changes also occur under hydrocracking conditions: the rings of some aromatic compounds are saturated, and most of the compounds containing sulfur and nitrogen heteroatoms are destroyed. The hydrocracking process yields a large percentage of product in the kerosene and diesel boiling ranges.

It is to be noted that even in the Full Conversion Refinery, some furnace oil is created, which may or may not be marketable in Bangladesh. In addition, Naphtha still remains in excess. There are processes under development that will be able to convert Naphtha into valuable LPG, for which there is plenty of demand in the country.

Chapter 3

EXISTING CRUDE PROCESSING PLANT IN BANGLADESH

3.1 Existing process plant

ERL is the only crude process plant in Bangladesh. ERL went on stream in 1968 with three main processing units (Crude distillation Unit, Catalytic Reforming Unit and Hydro-desulfurization Unit).Over the years, ERL has added several processing/ Treatment units like Asphaltic Bitumen plant, Long Residue Vis-breaker Unit, Merox Unit , Hydrogen plant etc . Existing processing units & their capacities are shown in the following Table 3.1

Table3.1: Existing processing units and their capacity

Sl. No	PROCESS UNIT	CAPACITY		Year of Commission
		Tons/Yr	BPSD	
1	Atmospheric Crude Distillation Unit	1,500,000	33,400	1968
2	i)Pre treatment for HG ii)Catalytic Reforming Unit	78,000 70,000	2000 1,800	1968
3	Asphaltic Bitumen Plant	70,000	1,300	1980
4	Long residue Visbreaker Unit	5,22,000	11,000	1994
5	Merox I (For LG)	65,000	1,900	1968
6	Merox II (For K1)	125,000	3,500	1968
7	LPG Sweetening Unit	24,000	400	1995
8	MHC Unit	57,000	1,300	1994
9	Hydrogen Plant	790	16	1994
10	Drum manufacturing and filling unit	1100 drum/day	-------	1980

Brief discussion of above mentioned four main units are described below with process flow diagram.

1. Atmospheric Crude distillation Unit:

atmospheric distillation Unit is the primary unit in crude oil fractionation. It is the starting point for the petroleum refinery. In this unit, crude oil is pumped directly from the crude oil storage tank by the feed pump and preheated in various heat exchangers and then it is introduced in a furnace. The flow rate of the feed is controlled by the control valve. In the furnace the feed (Crude) is heated up to around 370^0 C and so it is partially vaporized. This partially vaporized feed is then fed into distillation column, which is equipped with valve trays. The distillation column is operated slightly higher than atmospheric pressure and with two liquid reflux stream.

The straight run fractions obtained from the column are total gasoline, light kerosene, heavy kerosene, light gas oil, heavy gas oil and atmospheric residue. Lighter compounds (propane & butane) present in total gasoline are separated in a debutanizer unit and a part of it is converted as LPG (Lequefied Petroleum Gas). Rest of the propane and butane goes to refinery fuel gas system and is used in furnaces and boilers. De-butanized gasoline is then separated into a light gasoline and heavy gasoline stream in the re-distillation column. The straight run fractions need further processing and blending to make marketable products. A process flow diagram is given below.

2. Pretreatment and Catalytic reforming Unit

This unit is preceded by a hydro-treatment unit(pre-treatment) where heavy gasoline is desulfurised and hydrogenated to remove/reduce catalyst poisons e.g. sulfur, nitrogen, oxygen, arsenic etc from the feed. Desulfurised Naphtha thus produced is then mixed with a recycle gas rich in hydrogen and then the mixture is heated in the furnace to around 490 and then fed into a fixed bed reactor system , where the change is catalytically reformed over a catalyst containing precious metal platinum. Subsequent cooling ,separation and stabilization of the reactor effluents produce reformate of 80 to 89 RON (Research Octane Number)

Increase of octane number from 52 to 89 is mostly due to aromization of naphthenic hydrocarbon present in the feed. Reformate is used for production of HOBC and is also blended with LG(sweet) for augmenting octane number of motor sprit(MS) commonly known as petrol. Process flow diagram of Pretreatment and Catalytic reforming Unit is shown below.

3.1.3 Asphaltic Bitumen plant

In this unit Atmospheric residue of Arabian Light Crude (ALC) is further distilled under high vacuum to recover light and heavy vacuum gas oil. Vacuum residue is then oxidized by blowing air in Bitumen Blowing Tower to produce various grades of bitumen. Recovered light vacuum gas oil(LVGO) is blended with gas oils to increase production of diesel. Heavy Vacuum Gas Oil (HVGO) is a useful stock for furnace oil production. A process flow diagram of bitumen plant is shown below.

4. Long Residue Vis –breaker Unit

Long Residue Vis –breaker Unit is a mild thermal cracking process where heavy hydrocarbons (residue) are converted into comparatively lighter hydrocarbons and in the process viscosity of the residue is reduced considerably. Residue from the crude processing unit is preheated with hot product stream and finally heated in the vis-breaker furnace to around 480^0 C. At this high temperature and high pressure (20 Bar). thermal cracking takes place in the heater coil. Cracked products are separated in fractionating column as fuel gas, naphtha, gas oil and vis-broken residue. Fuel gas and sour gas removed from the process are burnt as fuel in the furnace. Gas oil and Vis-broken residue are taken into diesel and furnace oil pool respectively. Process flow diagram of Long Residue Vis –breaker Unit is shown below.

Chapter 4

PRODUCTS OUTPUT FROM DIFFERENT CRUDE AND UNIT

Eastern Refinery Ltd. is the only refinery in Bangladesh and capable of processing 33000 bbls/day . Its main feed is crude oil. It also processes gas condensates from different gas fields of Bangladesh. Two types of crude are used as main feed. Arabian Light Crude (ALC) from Saudi Arab and Murban from Abu Dhabi are used.

The outputs in percent from the two types of crude are in the following Table 4.1.

Table 4.1: Outputs of different types of crude

Outputs	ALC (%)	MURBAN (%)
Gasoline(Petrol& Octane)	12.00	18.20
Gas oil (Diesel)	21.10	20.90
Kerosene	22.00	26.00
LPG	1.00	1.00
Residue	41.10	31.10
G+L+C	2.80	2.80

The above comparative outputs from crude shows that Arabian light crude gives higher residue than Murban crude oil. In Bitumen unit Atmospheric residue of Arabian light crude is further distilled under high vacuum to recover light and heavy vacuum gas oil. Recovered light vacuum gas oil (LVGO) is blended with gas oil to increase production of High Speed Diesel (HSD) which is known as Diesel.

Also residue from Atmospheric Distillation Unit (For both ALC and Murban Crude) is further distilled in Long Residue Vis-breaker unit.

Outputs in percent of ERL’s Vis breaking and Bitumen unit are shown in Table 4.2.

Table 4.2 : Percent output of vis-breaking and bitumen Unit

Product	Bitumen unit (%)	LRV unit (%)
Naptha	--	5.00
Diesel	21.00	10.00
Bitumen	50.00	--
Furnace oil	29.00	85.00

The atmospheric column also produces significant quantity of Naphtha, which has no demand in Bangladesh. The reformer is used to convert some of the Naphtha into High Octane Blending Component (HOBC), which is used to raise the octane number of Gasoline from 68-70 to around 80. 100% Octane cannot be produced using only a simple reformer. For that, additional sophisticated and complicated equipment must be added. Therefore, 100% Octane has to import by Bangladesh Petroleum Corporation (BPC).

The two units, Vis breaking and vacuum Distillation, reduces 15 % of the total furnace oil (Residue).With a larger vacuum distillation unit further reduction of furnace oil is possible because of higher bitumen .

Chapter 5

PRODUCTION AND DEMAND SITUATION IN BANGLADESH

5.1 Production situation of Petroleum Products in Bangladesh

Eastern Refinery Limited is the only crude oil refining company in Bangladesh. It is the only source of finished petroleum products in Bangladesh. It can only supply 30 % of the total demand. The rest of the petroleum products (Finished) is imported by Bangladesh Petroleum Corporation (BPC). The annual production of petroleum products is shown in Table 5.1.1 and Table 5.1.2. Also graphical representation of annual production is shown in Figure 5.1.1 and Figure 5.1.2

Table5.1.1: Annual production of LPG, NAPHTHA, MS & HOBC

(Fig in M.Ton)

YEAR	LPG	NAPHTHA	MS(Petrol)	HOBC
1999-00	13071	59320	76322	78192
2000-01	13061	41402	91480	68479
2001-02	12409	37251	101162	40134
2002-03	15809	68804	98374	40791
2003-04	16029	73363	78761	43287
2004-05	14498	81029	59625	39327
2005-06	16083	121508	75714	20932
2006-07	12495	122667	66046	13046
2007-08	9986	138521	67046	13439

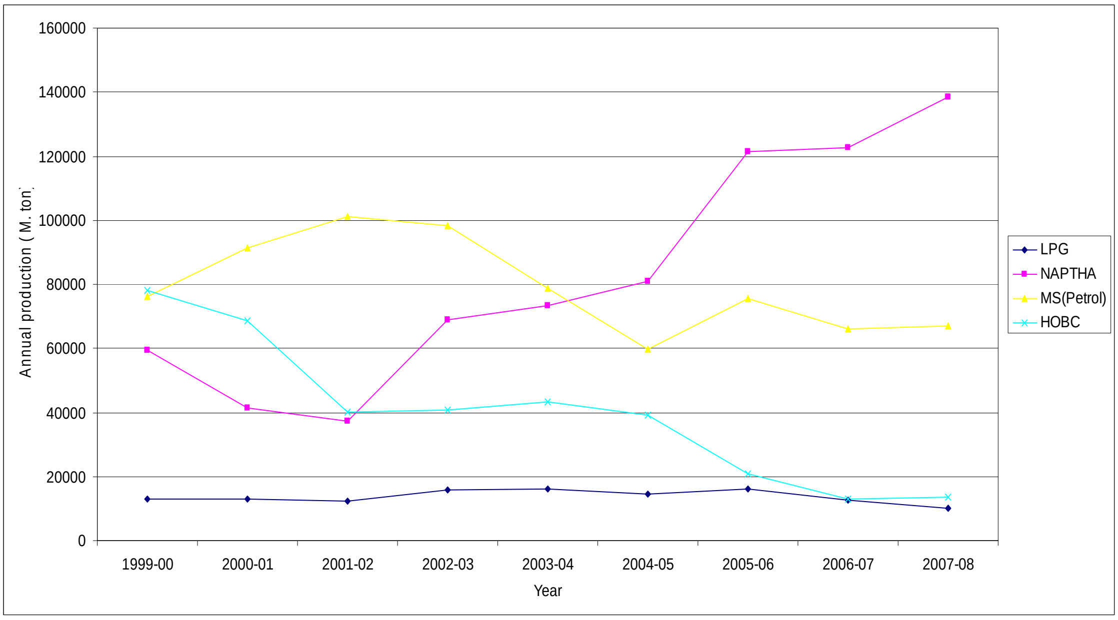

Figure 5.1.1 : Annual production of LPG, NAPHTHA, MS & HOBC

From the above figure 5.1.1 it is seen that naphtha production is increasing while the production of MS and HOBC is decreasing because the increased used of CNG in vehicles. MS and HOBC is produced from heavy naphtha.

Table5.1.2: Annual production of JP-1, SKO, HSD, HSFO & BITUMEN

(Fig in M.Ton)

YEAR	JP-1	SKO	HSD	HSFO	BITUMEN
1999-00	3834	321463	375104	339366	53190
2000-01	1124	339540	333629	346431	49245
2001-02	4578	306952	330448	281838	67744
2002-03	4550	358745	379024	382851	44359
2003-04	1585	338126	344507	322999	59600
2004-05	---	204864	396898	288614	50178
2005-06	5480	311524	383085	360878	59501
2006-07	---	315229	335714	273195	56379
2007-08	5678	262978	339131	290463	43722

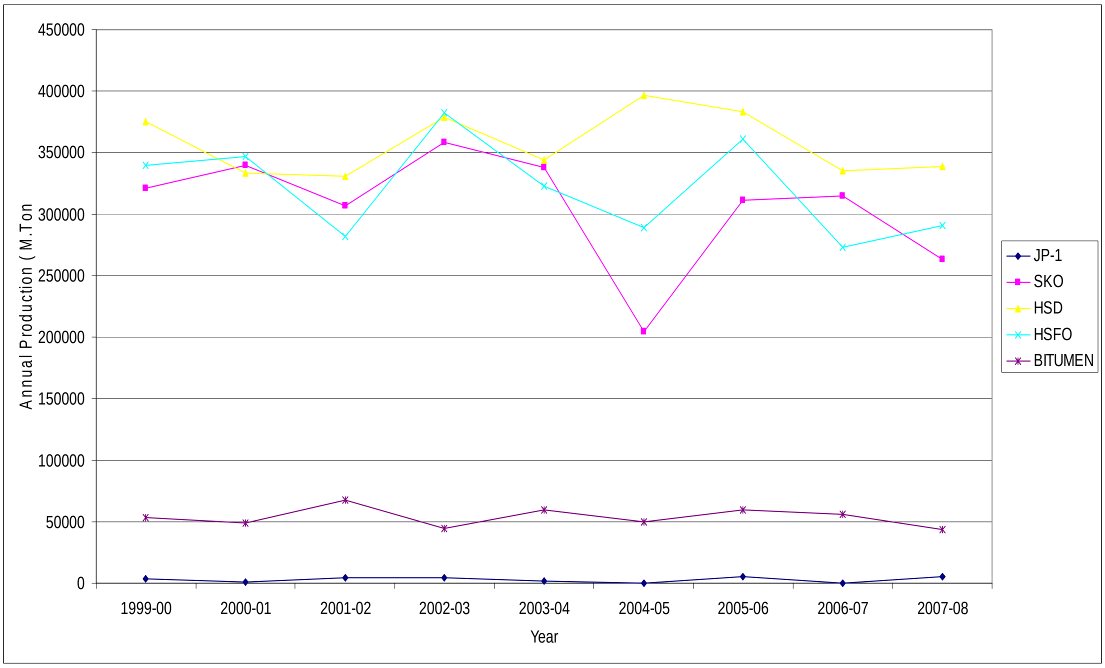

Figure 5.1.2: Annual production of JP-1, SKO, HSD,HSFO & BITUMEN

5.2 Demand situation of petroleum products in Bangladesh

We know that supply situation of petroleum products in Bangladesh is lower than the demand in Bangladesh. As a result we have to import finished petroleum products to meet the local demand. Annual demand of petroleum products is shown in Table 5.2.1 and Table 5.2.2. Also graphical representation of annual demand is shown Figure 5.2.1 , Figure 5.2.2 and Figure 5.2.3

Table5.2.1: Annual demand of MS, HOBC, JP-1, SKO & HSFO

(Fig in M.Ton)

YEAR	MS	HOBC	JP-1	SKO	HSFO
1999-00	194378	75838	142070	609402	338919
2000-01	197046	98458	169119	636098	308665
2001-02	187787	120454	175159	633755	223530
2002-03	164446	140251	197088	698486	271419
2003-04	151337	145588	226969	693638	309332
2004-05	143965	142450	253551	544478	309987
2005-06	153340	126315	238480	499207	333209
2006-07	129549	95376	225912	426357	255848
2007-08	124823	90021	277393	405101	290000

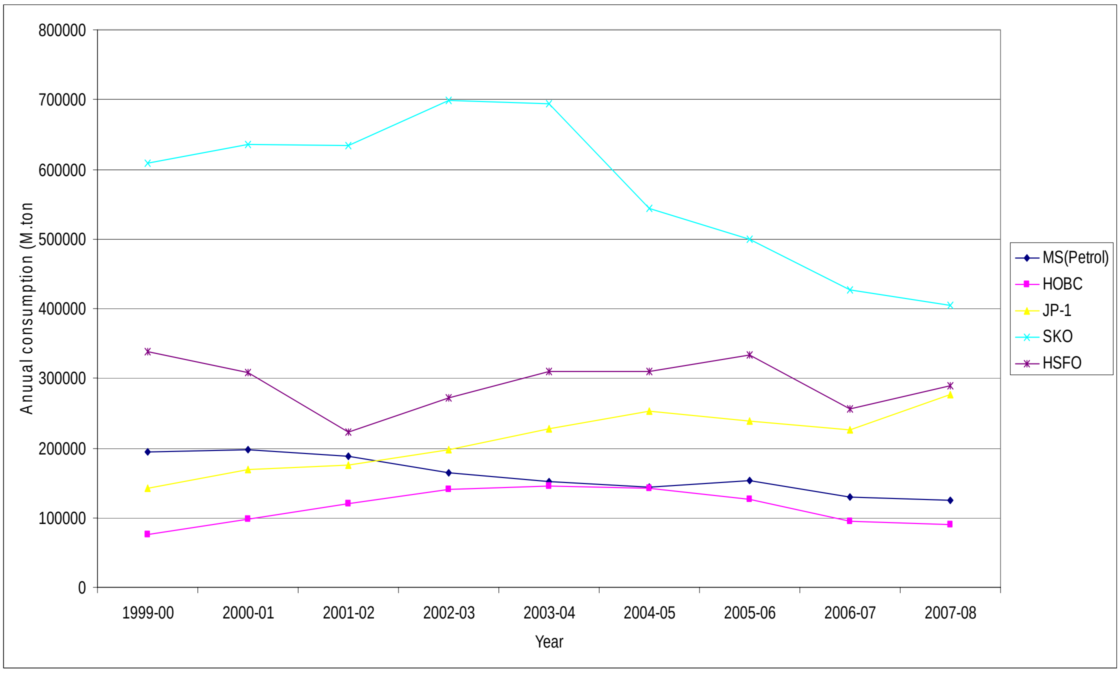

Figure 5.2.1: Annual demand of MS, HOBC, JP-1, SKO & HSFO

Table 5.2.2: Annual demand of HSD,LPG & BITUMEN

(Fig in M.Ton)

YEAR	HSD	LPG	BITUMEN
1999-00	1743251	14845	44170
2000-01	1846239	29432	63113
2001-02	1838266	20167	65405
2002-03	1815159	22275	45651
2003-04	2004402	23144	60191
2004-05	2264843	20513	45720
2005-06	2298677	22298	64584
2006-07	2294223	16770	52333
2007-08	2333597	14802	48295

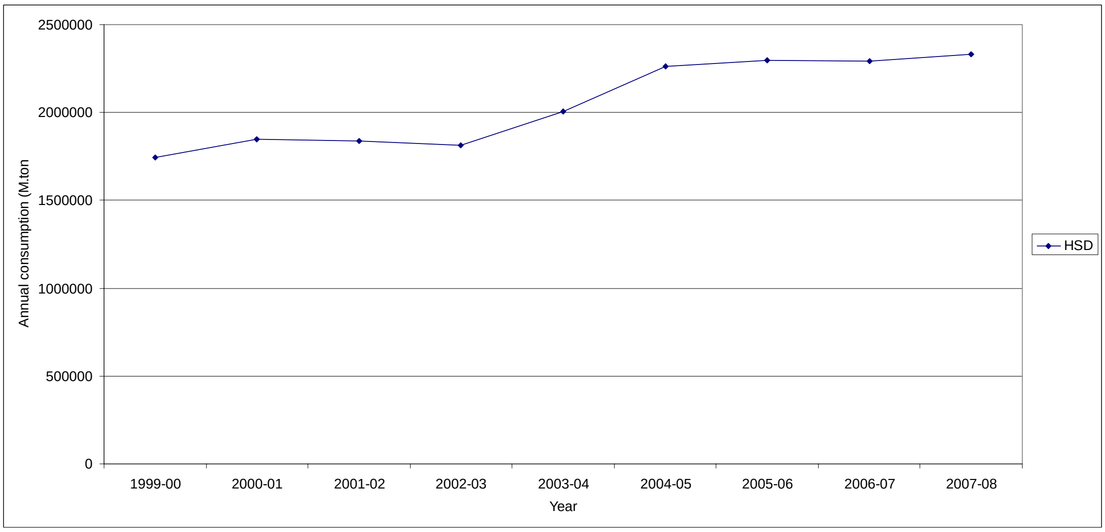

Figure 5.2.2 : Annual demand of HSD

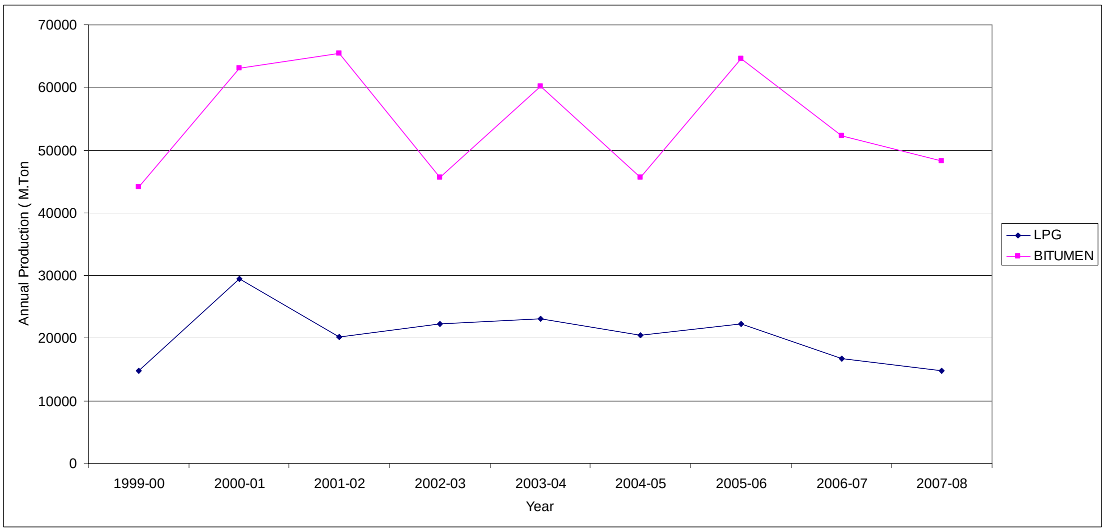

Figure 5.2.3: Annual demand of LPG & BITUMEN (Excluding private sector sales)

5.3 Comparative analysis of supply and demand of petroleum products in Bangladesh.

The demand of petroleum products is increasing day by day because of industrial growth and infrastructural development. The shortfall/excess of different petroleum products are shown in Table 5.3.1. Also graphical representation of shortfall/excess is shown in Figure 5.3.1

Table 5.3.1 : Shortfall/excess of different petroleum products in Bangladesh

(All figures are in M. Ton)

Products	Demand (2007-2008)	ERL production (Average for 3 years)	Shortage(-) /excess(+)
LPG	14802	12854	(-)1948
NAPTHA	---	127565	(+) 127565
MS	124823	69602	(-) 55221
HOBC	90021	15805	(-) 74216
JP-1	277393	3719	(-) 27367
SKO	405101	296577	(-) 108524
HSD	2333597	352643	(-) 1980954
HSFO	290000	308178	(+) 18178
BITUMEN	180000	53200	(-) 126800

Note: LPG shortage will be more than the above value because of the exclusion of private sector. But Bitumen demand value is actual demand (including of private sales).

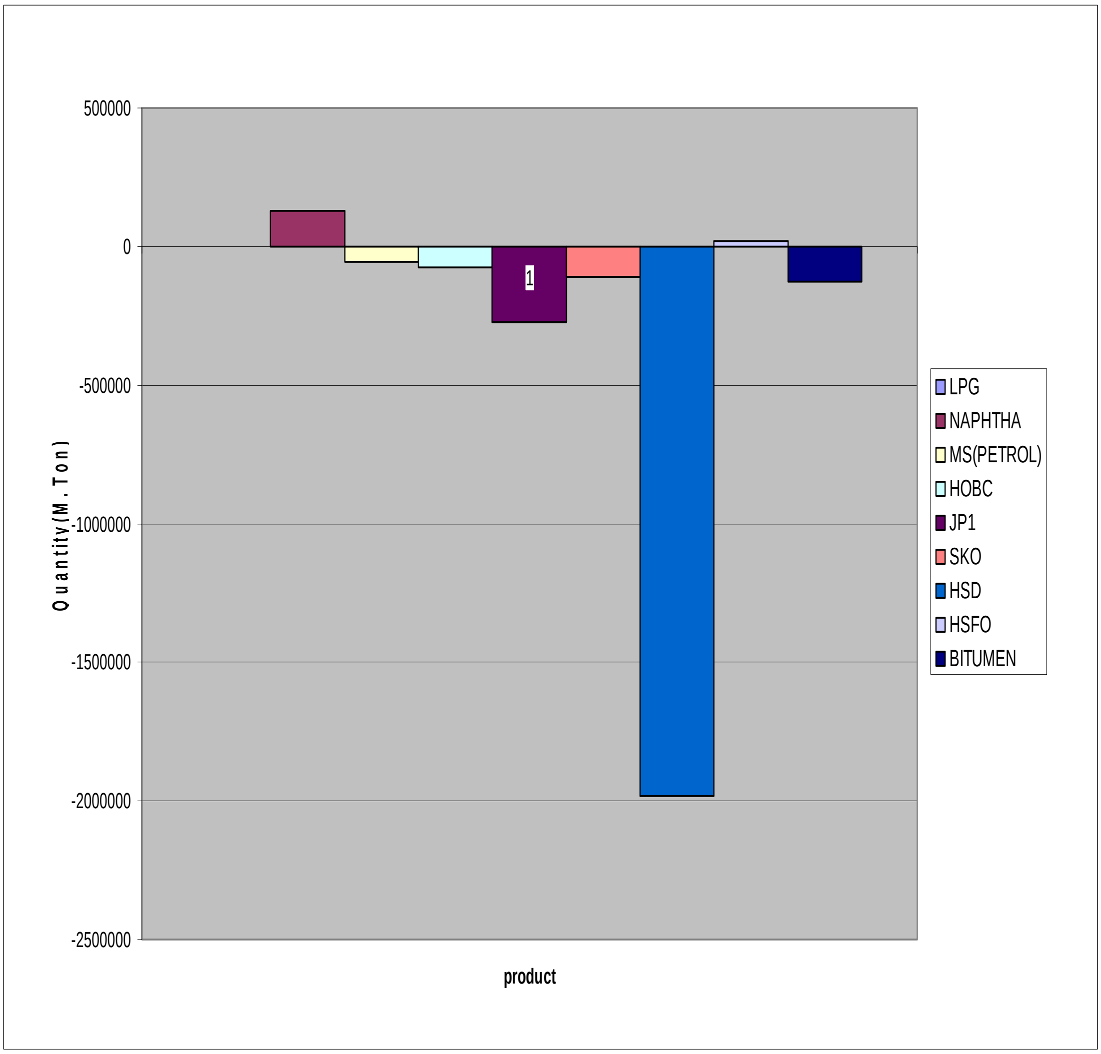

Figure 5.3.1 : Shortfall/excess of different petroleum products in Bangladesh

Table 5.1.1 and Table 5.1.2 show annual production of refined petroleum products of Bangladesh. Eastern Refinery Limited (ERL) is the only crude refining company in Bangladesh. It is to be noted that the ERL production shown in Table 5.1.1 and Table 5.1.2 is the final production, i.e., after processing in all four major units listed in chapter 3.

Table 5.2.1 and Table 5.2.2 show the annual demand of petroleum product within the country. From the tables it is clear that the demand pattern of petroleum products in Bangladesh is heavily dependent on middle distillate i.e.,SKO and HSD. It is important to point out that in the last five years the kerosene demand has been falling and in 2006, it has recoded the biggest fall. Kerosene is mainly used for lighting and cooking purpose in rural areas. The use of LPG in rural areas as cooking fuel and rural electrification help to decrease the demand of kerosene. It is clearly seen that there is huge demand of diesel in our country. The reason for huge demand of diesel is irrigation and transportation.

The shortfall, consumption minus ERL's production, is also presented in Table 5.3.1. The consumption data from the Bangladesh Petroleum Corporation (BPC) is for the latest year, while production of ERL is averaged over three years. The reason behind averaging ERL's data is that, the production of the different products can vary considerably from one year to the other. ERL produces several other products in small volumes such as LDO (Light Diesel Oil), JBO(Jute Batching Oil), MTT(Mineral Turpentine) and SBPS(Special Boiling Point Solvent). These have been excluded from the Tables and also the discussion because of their small volume production and hence treated insignificance.

It is also seen from the Table 5.3.1, kerosene demand is partially unmet and the jet fuel demand is totally unmet. Since ERL cannot even meet the kerosene demand in the country, jet fuel, which is basically kerosene must be imported to meet jet fuel demand. The demand for kerosene is not robust like that of diesel. The specifications of jet fuel is extremely stringent, and very careful processing and considerable upgrading may be required to meet the requirements of jet fuel.

The 100% Octane demand is difficult to meet with an ordinary configuration refinery. Therefore, Naphtha surplus must be dealt with. There are processes under development that will convert naphtha into LPG, which has a huge demand in Bangladesh. Complicated options like naphtha cracker, isomerisation and alklylation may be considered. Since, there is excess naphtha at ERL, a joint effort should be undertaken to deal with it. A polymer manufacturing industry can be considered.

The furnace oil demand is very difficult to guess. The present high demand is the result of Bangladesh Power Development Board (BPDB) running all its furnace oil generators to cope with the huge shortages of electricity in Bangladesh. These furnace oil generators are very old, and are expected to be retired very soon. In this case the shipping industry will remain the only significant user. At present the supply of natural gas is decreasing day by day. As a result the gas based power stations are shut now or not producing their full capacity. So furnace oil based power station should be established to meet the electricity demand and hence it will increase the demand of furnace oil in future. Also the demand for furnace oil can be increased if it is made available at competitive prices.

From process point of view addition of hydro-cracking unit may be considered as first option because it will convert furnace oil into diesel and jet fuel (basically kerosene). Otherwise, the second refinery must be prepared to export furnace oil along with naphtha.

Chapter 6

EXPECTED DEMAND OF PETROLEUM PRODUCTS IN BANGLADESH

6.1 Expected petroleum products demand

The future projections of petroleum products demand is estimated on the basis of previous petroleum products demand. This approach may be very simplistic and may not reflect the actual demand pattern of future.

The future demand of petroleum products is shown in Table 6.1.1.

Table 6.1.1: Future demand of petroleum products

Year	Product (M. Ton)					
	JP-1	HOBC	MS	SKO	HSD	HSFO
2008-09	293537	84295	119368	386061	2356932	288434
2009-10	310620	78934	114151	367916	2380502	286876
2010-11	328698	73944	109163	350624	2404307	285327
2011-12	347828	69213	104392	334144	2428350	283786
2012-13	368071	68811	99830	318439	2452633	282254
2013-14	389493	60689	95468	303473	2477160	280729
2014-15	412162	56829	91296	289210	2501931	279213
2015-16	436149	53215	87306	275617	2526951	277706
2016-17	461533	49830	83491	262663	2552220	276206
2017-18	488395	46661	79842	250317	2577742	274715
2018-19	516819	43693	76353	238553	2603520	273231
2019-20	546898	40914	73016	227341	2629555	271756
2020-21	578728	38312	69826	216656	2655851	270288
2021-22	612410	35875	66774	206473	2682409	268829
2022-23	648052	33594	63856	196768	2709233	267377
2023-24	685769	31457	61066	187520	2736326	265933
2024-25	725680	29456	58397	178707	2763689	264497
2025-26	767915	27583	55845	170308	2791326	263069
2026-27	812608	25829	53405	162303	2819239	261648
2027-28	859901	24186	51071	154675	2847431	260235

(All the Calculations are shown in APPENDIX –A)

It may be noted that bitumen and LPG became open for private sector from the year 1998 and 2000 respectively. So future demand cannot be estimated because of non availability of private sector sales data.

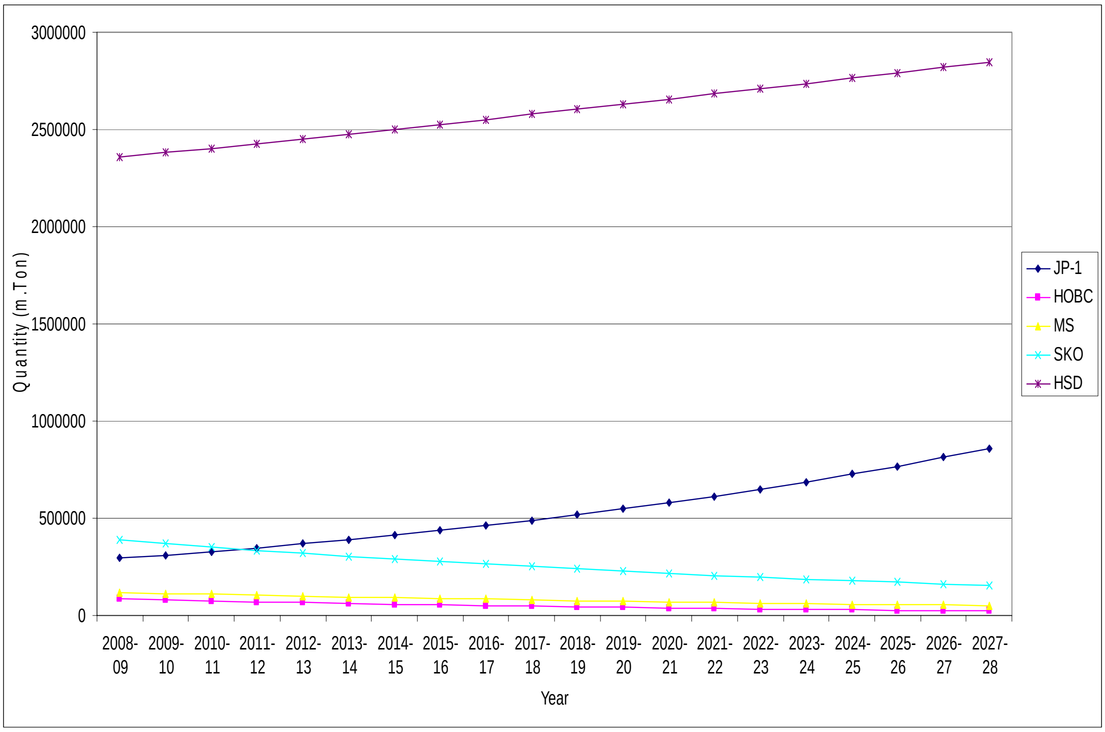

Figure6.1.1 : Expected future demand of JP-1, HOBC,MS , SKO & HSD

Chapter 7

IMPORT QUANTITY OF CRUDE OIL AND PETROLEUM PRODUCTS IN BANGLADESH AND THEIR COST

Eastern Refinery Limited (ERL) is the only refinery in Bangladesh. ERL can meet 30 % of our demand. The rest is being imported by Bangladesh Petroleum Corporation (BPC).

The quantity (Difference between demand and production) of imported petroleum products are shown in Table 7.1.1

Table 7.1.1: Imported petroleum products in Bangladesh (All figures are in M.ton)

Year	HSD	HOBC/MS	SKO	JP-1
1999-00	1310200	107367	268250	137583
2000-01	1501562	113009	283760	170582
2001-02	1421791	146078	334342	170089
2002-03	1505207	140080	362590	211883
2003-04	1546713	147795	347717	220123
2004-05	1888775	166735	340403	254848
2005-06	1793067	165979	174676	250016
2006-07	1958509	145833	111128	225912
2007-08	1776433	116767	120073	269800

Table 7.1.1 shows the quantity of imported petroleum products in Bangladesh. From the table is seen that huge amount of Diesel has to import every year to meet the local demand.

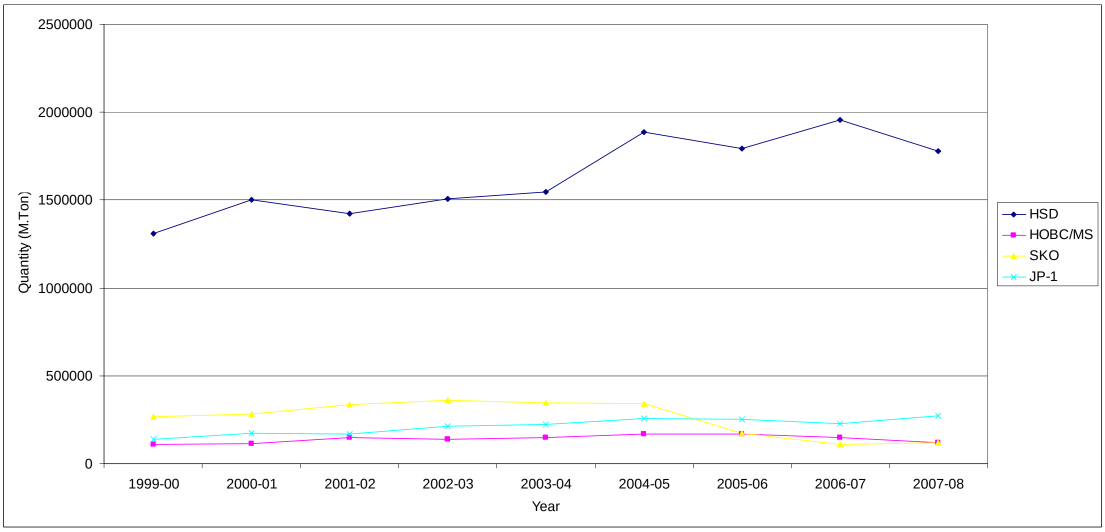

Figure 7.1.1: Imported petroleum products in Bangladesh

Import cost of crude oil and refined products is shown in table 7.1.2

Table 7.1.2 : Import cost of crude oil and refined products

Year	Import cost of crude oil		Import cost of refined products	
	Qty(M.ton)	Cost(Corer Tk)	Qty(M.ton)	Cost(Corer Tk)
1999-00	1236049	1110.96	1823400	2021.43
2000-01	1337121	1598.60	2068913	2999.20
2001-02	1224707	1277.78	2072300	2535.62
2002-03	1335114	1693.03	2219760	3315.35
2003-04	1252424	1848.43	2262348	4015.81
2004-05	1060927	2261.98	2690620	7213.88
2005-06	1250819	3750.69	2383738	9382.77
2006-07	1253000	3985.02	2441382	10443.02
2007-08	1140190	5659.81	2283073	16821.22

From the above table it is clearly seen that the cost of crude oil and refined products is increasing every year. Import cost of crude oil and refined products is shown in figure 7.1.2.

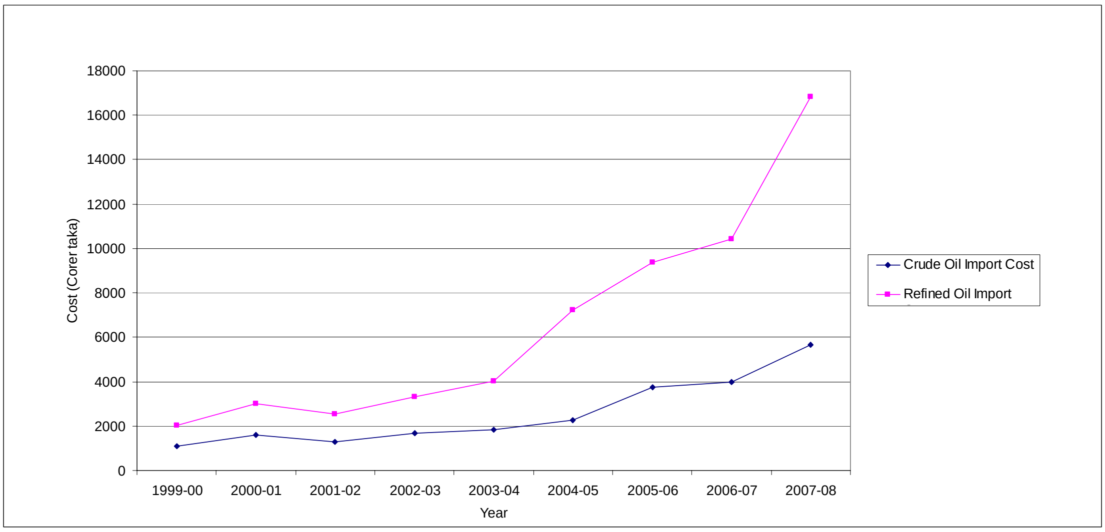

Figure 7.1.2: Import cost of crude oil and refined products

Import cost of crude and refined products depends on the price of crude oil price. Import cost of Unit barrel for crude and refined products is shown in the following table 7.1.3.

Table 7.1.3: Unit barrel cost for crude and refined products

Year	C& F Crude price/bbl (Taka)	C & F Imported Refined product price/bbl (Taka)
1999-00	1193.30	1394.47
2000-01	1587.29	1823.45
2001-02	1385.20	1539.09
2002-03	1683.58	1878.69
2003-04	1959.48	2232.78
2004-05	2830.69	3372.48
2005-06	3981.13	4952.14
2006-07	4222.49	5169.56
2007-08	6590.43	9262.67

(All the Calculations are shown in APPENDIX –A)

From the above table we can see that unit barrel refined product price is higher than the unit barrel crude price.

Now the operating cost for unit barrel of crude oil is shown in table 8.1.4. The data is taken from the existing refinery.

Table 7.1.4 : Total Operating cost for crude oil processed

Year	Processing cost (Lac Tk)	Administrative Cost(Lac Tk)	Total Operating cost (Lac Tk)
1999-00	5660.44	4071.30	9731.74
2000-01	5769.78	3980.10	9749.88
2001-02	5999.26	3644.31	9643.57
2002-03	7032.42	3464.86	10497.28
2003-04	6818.81	2991.51	9810.32
2004-05	7120.12	1992.83	9112.95
2005-06	6939.91	1965.77	8905.68
2006-07	7368.40	1837.17	9205.57
2007-08	7447.90	1719.20	9167.10

Table 7.1.5 : Total amount of crude oil processed and output of products form that crude

Year	Crude Processing Amount (M.ton)	Process Loss (%)	Product Amount after process Loss (M.Ton)	Product Amount after Process Loss (bbl)
1999-00	1377600	1.71	1354043.04	10913586.90
2000-01	1350420	1.58	1329083.36	10712411.88
2001-02	1249240	1.73	1227628.14	9894682.80
2002-03	1455000	1.74	1429683.00	11523244.98
2003-04	1351600	1.75	1292577.00	10418170.62
2004-05	1226000	1.75	1204545.00	9708632.70
2005-06	1405000	1.74	1380553.00	11127257.18
2006-07	1269400	1.74	1247312.44	10053338.27
2007-08	1213800	1.73	1192801.26	9613978.15

Table 7.1.6: Operating cost per barrel of product

Year	Total Operating cost (Lac Tk)	Product Amount after Process Loss (M.Ton)	Product Amount after Process Loss (bbl)	Operating Cost (Tk / bbl)
1999-00	9731.74	1354043.04	10913586.90	89.17
2000-01	9749.88	1329083.36	10712411.88	91.01
2001-02	9643.57	1227628.14	9894682.80	97.46
2002-03	10497.28	1429683.00	11523244.98	91.09
2003-04	9810.32	1292577.00	10418170.62	94.16
2004-05	9112.95	1204545.00	9708632.70	93.86
2005-06	8905.68	1380553.00	11127257.18	80.03
2006-07	9205.57	1247312.44	10053338.27	91.56
2007-08	9167.10	1192801.26	9613978.15	95.35

(All the Calculations are shown in APPENDIX –A)

Cost of Production per barrel = Cost of crude per barrel +Operating cost per barrel

Table 7.1.7: Cost of production per barrel

Year	Cost of crude per barrel (Tk)	Operating cost per barrel (Tk)	**Cost of Production per barrel (Tk)**
1999-00	1193.30	89.17	1282.47
2000-01	1587.29	91.01	1678.3
2001-02	1385.20	97.46	1482.66
2002-03	1683.58	91.09	1774.67
2003-04	1959.48	94.16	2053.64
2004-05	2830.69	93.86	2924.55
2005-06	3981.13	80.03	4061.16
2006-07	4222.49	91.56	4314.05
2007-08	6590.43	95.35	6685.78

Loss calculation (Loss due to import of refined products):

Loss for the import of unit barrel refined petroleum product

= Cost of imported refined petroleum products per barrel – Cost of production per barrel

Losses are shown in the following table

Table:7.1.8 : Loss for the import of unit barrel refined petroleum product

Year	Imported refined products cost (Tk/Bbl)	Production cost (Tk/Bbl)	**Loss due to import of refined products (Tk/Bbl)**
1999-00	1394.47	1282.47	112.00
2000-01	1823.45	1678.3	145.15
2001-02	1539.09	1482.66	56.43
2002-03	1878.69	1774.67	104.02
2003-04	2232.78	2053.64	179.14
2004-05	3372.48	2924.55	447.93
2005-06	4952.14	4061.16	890.98
2006-07	5169.56	4314.05	855.51
2007-08	9262.67	6685.78	2576.89

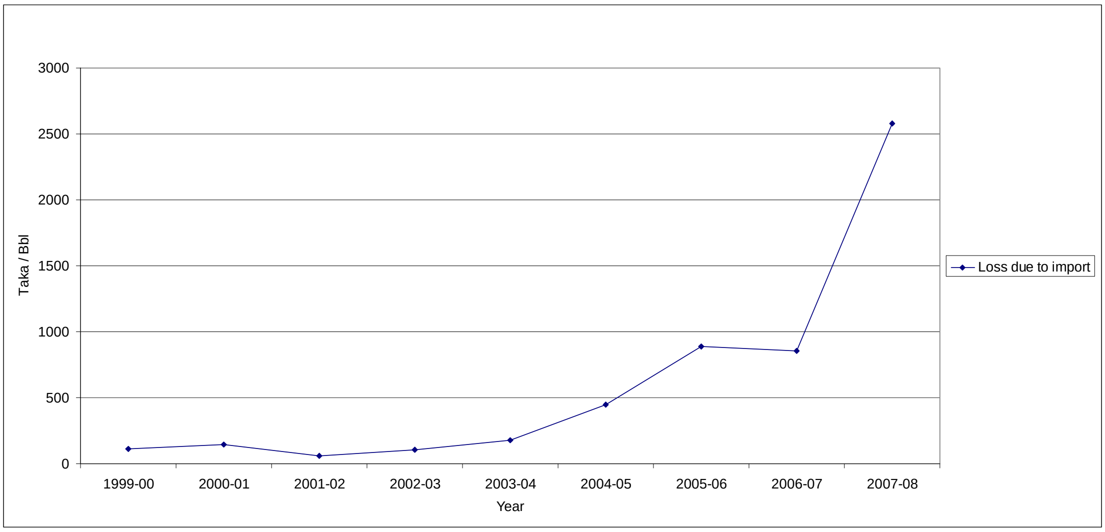

Figure 7.1.8: Loss for importing refined petroleum products

From the figure7.1.8 it is clearly seen that loss amount is increasing every year. This is because of high crude price and product price and their difference. If new refinery is installed we can save large amount of money by refining in the country.

The above data shows that refined cost for the petroleum products is lower than the import cost. As result we are loosing large amount of money every year by not refining crude oil in country.

The above calculations are carried out by using the operating cost of existing refinery which is about forty years old. The operating cost for the new refinery would be higher than the existing operating cost. Three different scenarios are analyzed below by increasing existing operating cost to some extent.

Scenario I: Increasing existing operating cost by 50%

Existing operating cost = 10497.28 Lac Taka (Taking the Highest value)

Operating cost for new refinery = 10497.28 + 10497.28 × 0.5 Lac Taka

= 15745.92Lac Taka

= 15745.92 × 10^5 Taka

Processing capacity = 1500000 MT / Year

Process loss = 1.74 % (Taking highest value)

Process amount after loss = 1473900 MT

= 11101414.8 bbl

Operating cost per unit barrel = 15745.92 × 10^5 Taka / 11101414.8 Bbl

= 141.83 Taka/ Bbl

Cost of crude = $ 77/Bbl

= 5390 Taka/Bbl ($ 1 = 70 Taka)

Cost of production = Cost of crude + Operating cost

= (5390 + 141.83) Taka / Bbl

= 5531.83 Taka/Bbl

Average Cost of refined product (Which are imported) = $ 85 /Bbl

= 5950 Taka /Bbl

Loss due to import of refined finished petroleum products

= (5950 – 5531.83) Taka/Bbl

= 418.17 Taka / Bbl

Scenario II: Increasing existing operating cost by 100%

Existing operating cost = 10497.28 Lac Taka (Taking the Highest value)

Operating cost for new refinery = 10497.28 + 10497.28 Lac Taka

= 20994.56 Lac Taka

= 20994.56×10^5 Taka

Processing capacity = 1500000 MT / Year

Process loss = 1.74 % (Taking highest value)

Process amount after loss = 1473900 MT

= 11101414.8 bbl

Operating cost per unit barrel = 20994.56×10^5 Taka / 11101414.8 Bbl

= 189.11 Taka/ Bbl

Cost of crude = $ 77/Bbl

= 5390 Taka/Bbl ($ 1 = 70 Taka)

Cost of production = Cost of crude + Operating cost

= (5390 + 189.11) Taka / Bbl

= 5579.11 Taka / Bbl

Average Cost of refined product (Which are imported) = $ 85 /Bbl

= 5950 Taka /Bbl

Loss due to import of refined finished petroleum products

= (5950 - 5579.11) Taka/Bbl

= 370.89 Taka / Bbl

Scenario III: Increasing existing operating cost by 200%

Existing operating cost = 10497.28 Lac Taka (Taking the Highest value)

Operating cost for new refinery = 10497.28 + 10497.28 × 2 Lac Taka

= 31491.84 Lac Taka

= 31491.84×10^5 Taka

Processing capacity = 1500000 MT / Year

Process loss = 1.74 % (Taking highest value)

Process amount after loss = 1473900 MT

= 11101414.8 bbl

Operating cost per unit barrel = 31491.84×10^5 Taka / 11101414.8 Bbl

= 283.64 Taka/ Bbl

Cost of crude = $ 77/Bbl

= 5390 Taka/Bbl ($ 1 = 70 Taka)

Cost of production = Cost of crude + Operating cost

= 5390+ 283.64

= 5673.64 Taka / Bbl

Average Cost of refined product (Which are imported) = $ 85 /Bbl

= 5950 Taka /Bbl

Loss due to import of refined finished petroleum products

= (5950 - 5673.64) Taka/Bbl

= 276.36 Taka / Bbl

The three above scenarios also show that refined cost for the petroleum products is lower than the import cost. So the second refinery will minimize the loss from importing finished petroleum products.

Chapter 8

SELECTION OF SECOND OIL REFINERY

From previous the table 6.1.1 it is seen that the demand of HOBC, MS. SKO and HSFO is decreasing every year and the demand of JP-1 and HSD is increasing every year. ERL is a medium conversion refinery. To keep the refinery business simple and still make reasonable profit, the medium conversion refinery is ideal. Therefore, it is proposed that at least to start off, the second refinery in Bangladesh should also be of the ERL configuration except that it should take advantage of the unfulfilled bitumen demand by expanding the capacity of the vacuum distillation unit.

Existing product yield pattern is shown in Table 8.1.1.

Table 8.1.1 : Product yield pattern of ERL (Capacity 33000 bbl/day)

Product	Average Production / Day (M.ton)	Production /year (M. ton)
LPG	45	14850
NAPHTHA	50	16500
SBPS	05	1650
MS(PETROL)	300	99000
HOBC	150	49500
MTT	150	49500
JP-1	150	49500
SKO	1000	330000
HSD	1015	334950
LDO	30	9900
JBO	75	24750
HSFO	1250	412500
BITUMEN	200	66000

If refinery like ERL having capacity 33000 bbl/day is selected, it will meet the future demand of HOBC, MS, SKO, & HSFO fully. It is seen from the table 6.1.1 that the demand of SKO is decreasing every year where JP-1 is increasing every year. JP-1 is produced from the kerosene maintaining some parameters. The surplus kerosene can be converted into JP-1 which will meet the demand almost fully. It is clearly seen, there is a huge demand for Diesel. Therefore, the second refinery must be designed for diesel maximization. In theory that is possible, but most existing refineries around the world are designed to maximize MS (gasoline). Indian refineries, however, are designed to yield higher quantities of diesel. It is only recently with the huge demand for diesel in countries like China and India that diesel maximizing refineries are being built.

Since the demand of MS and HOBC is decreasing every year, naphtha production will increase according to the decrease rate of MS and HOBC.

From the demand table 5.2.2 it is seen that the demand of bitumen is decreasing which is not the actual condition because of non availability of private sector sales. Actually the demand of bitumen is increasing every year for infrastructural development. To meet the increasing demand of bitumen the second refinery must be designed with larger bitumen plant.

Outputs of second refinery and shortfall at present condition are shown in table 8.1.1

Table 8.1.2: Short fall at present condition and outputs of second refinery

Product	Shortfall (M. ton)	2nd Refinery outputs (M.ton)	Remark
LPG	>2000	148500	Shortfall of LPG will be higher than mentioned value because of non availability of private sales.
MS	~60000	99000	OK
HOBC	~80000	49500	Can produce more
NAPHTHA	----	16500	It will increase because of lower demand of MS & HOBC. It has to export because of no use.
JP-1	~275000	49500	Surplus SKO can be converted into JP-1 to meet the demand
SKO	>100000	330000	OK
HSD	~2000000	344950	Large gap will exist. and has to import to meet demand
HSFO	No shortfall	412500	Has to export
BITUMENS	>125000	66000	To be balanced by design

From the table 8.1.2 it is clearly seen that LPG, MS, HOBC & HSFO demand can be met fully. Since kerosene demand is lower than the output of second refinery, the surplus kerosene can be converted into JP-1 to meet the demand of JP-1. Also there is deficit in bitumen demand. But this amount of deficit can be balanced by design and by the import quantity of private sector.

Considering future demand shortfall and outputs of second refinery are shown in table 8.1.3.

Table 8.1.3 : short fall (Considering future demand) and outputs of second refinery

Product	Shortfall	2nd Refinery outputs	Remark
MS	No shortfall (+47929)	99000	Excess Ms has to export.
HOBC	No shortfall (+25314)	49500	Excess HOBC has to export.
NAPHTHA	----	16500	Naphtha production will increase due to lower demand of MS and HOBC. It has to export.
JP-1	810401	49500	Surplus SKO can be converted into JP-1 and some quantity has to import
SKO	No shortfall (+175325)	330000	OK
HSD	>2500000	3344950	Large gap will exist
HSFO	No shortfall (+152265)	412500	Has to export

From the table 7.1.3 it is clearly seen that excess MS, HOBC , Naphtha and Furnace oil has to export. The surplus SKO can be converted into JP-1. But this will not meet the demand of JP-1 fully. So some quantity of JP-1 and Large amount of diesel has to import to meet the demand.

It may be noted that future estimation of LPG and Bitumen cannot be done for non availability of private sector sales. But it may be assumed that the demand of LPG and Bitumen will increase in future because of shortage of gas and infrastrucral development respectively.

If higher capacity than the existing refinery is selected large amount of Naphtha and Furnace oil will be produced which will create problem for storage and hence for the operation. Also higher capacity refinery will not meet the diesel demand of our country. It also requires large amount of investment. After considering all the above issues the refinery having 33000b/d (1500000 M.ton / Year) would be the best choice for second refinery. The second refinery will have some more units than the existing refinery to process higher specific gravity crude because the stock of lighter crude is decreasing day by day.

Chapter 9

BENEFITS OF A SECOND REFINERY

With rising crude oil prices, refiners' margin, i.e., the difference between crude oil and refined products, has been increasing steadily. Of course refiners have to sell some products (furnace oil, bitumen and coke) at prices below crude oil prices. No doubt, if refining was done in the country, naphtha and furnace oil may have to exported at prices below international ones because of the low volumes of export involved, but the savings on the premium products (HOBC, jet fuel, diesel and kerosene) would more than offset the losses. Since there is bound to be some savings for the country by opting for a second refinery, the Government should be proactive in promoting it either in the public or private sector.

Therefore, we can see from the previous chapter by not refining crude oil in Bangladesh, the Government is losing a large amount of money every year.

There are other benefits of possessing domestic refining capacity. Firstly, the second refinery will always hold a certain stock of refined products, which the Government can access easily in the event of supply disruption or unusual demand within the country. Secondly, it is easier to have crude buffer than to have storage for several refined products.

From an energy security point of view, the second refinery justifies itself even if the costs for both options (refining vs. importing) are equal. A private refinery will relive the Government of considerable financial pressures.

Chapter 10

FACTORS AFFECT THE REFINERY ECONOMICS

10.1 Refinery Economics (International)

Refined product prices are determined by a variety of factors such as the economy, weather and competition between retailers and from other fuels. Feedstock prices (crude oil) are influenced by the above demand factors, actions by OPEC and governmental regulations. Refinery margins (the difference between raw material costs + processing cost and product revenues expressed on a per barrel of crude basis) can vary depending on the complexity of the refinery. The more complicated the refinery, the higher the operating costs, but the greater the ability to make higher-valued products like gasoline and diesel.

Earnings and cash flow from refining and marketing are primarily affected by Refinery margins. The cost to acquire feed stocks and the price of the refined products that is ultimately sold depend on numerous factors beyond the refiner's control, including the supply of, and demand for, crude oil, gasoline and other refined products which, in turn, depend on, among other factors, changes in domestic and foreign economies, weather conditions, domestic and foreign political affairs, production levels, the availability of imports, the marketing of competitive fuels and government regulation. While sales and operating revenues fluctuate significantly with movements in crude oil and refined product prices, it is the spread between crude oil and refined product prices, and not necessarily fluctuations in those prices that affects the earnings.

10.2 Refinery Economics (Bangladesh)

The three key factors for the refinery business in international market are equally applicable in Bangladesh. Crude slate, configuration and product slate are the lifeline of refinery business. Any refinery in Bangladesh is mainly configured to meet the local market demand. As an input to a new refinery, the technology, oil type, oil price is linked to the international market and availability whereas the local product market is priced by an unregulated arbitrary artificial system. Combining the two modality of pricing through an executable commercial framework would be the biggest challenge for setting up a local refinery.

Chapter 11

FINANCIAL ANALYSIS

Two cases have been analyzed. Case I uses C&F value for both crude and refined products, while case II uses a fixed refiners' margin to be paid by the Government to process the crude irrespective of its international price. In the latter case, the mechanism for crude import will have to be negotiated between the two parties.

11.1 C&F Crude and Product price Analysis

Cost summary (Unit Wise): Cost summary is shown in the following Table

Table 11.1.1: Cost summary(Unit Wise)[11]

Description	**Cost (US $)**
Crude Distillation Unit	35106309
Vacuum Distillation Unit	27858044
Diesel Hydro-desulfurizer Unit	49744043
Naphtha Hydrotreater	8334672
Amine & Sour water Stripper Unit	12250906
UOP Platforming Process Unit	9544593
Asphalt Blowing Unit	16965264
Sulfur Recovery Unit	32804557
LPG Merox	1712612
Light Naphtha Merox	2952126
Heavy Naphtha Merox	3330604
Kero Merox	3860473
Tankage & Product Transfer System	10396250
Roads & Buildings	8000000
Power Generation System	75520000
Cooling Water System	1340000
Instrument Air System	400000
Laboratory Equipment	2000000
TOTAL	**302120453**

Eastern Refinery Limited is a medium conversion refinery with a rated capacity of 1.5 million tons. On the average, at 92 to 95% capacity utilization, it processes about 33,000 bbl/day. For a refinery of similar capacity and with the addition of some new equipment, the investment requirement would be about 302 million dollars. ERL cannot meet the bitumen demand. The second refinery will have the provision to meet bitumen demand per year. The product slate of the new refinery would be:

Light	16%
Middle	56%
Heavy	28%

Under this scenario, C &F crude oil price of $77 (Average C&F crude price for the last three years) per barrel has been used and also the product price $ 96/bbl.The average heavy distillate price is $ 70/bbl. Since Bangladesh has to export heavy distillate lower than international price $60/bbl instead of $70 because of low volume. The other input data financial analysis are shown in the below.

Price coefficient for Light Distillate	= Product price / Crude price
	= 96 / 77
	= 1.246
Price coefficient for Middle Distillate	= 96/77
	= 1.246
Price coefficient for Heavy distillate	= 60/77
	= 0.779

Investment	$302 million
Corporate tax	35%
Depreciation	10%
Discount rate	10%
O&M cost	$1.5 per bbl (Average Operating Cost of last three years)

Under this scenario, the project is favorable with an IRR of 17 % and NPV of $158 million. If operating and maintenance cost of $4 per barrel is assumed, IRR and NPV becomes 12% and $ 35 million. This has been kept on the higher side compensating for the cost of Working Capital and also due to the refurbished nature of the refinery. Efficient business keeping operating cost at a minimum is very important for the profitability of the refinery. Sensitivity analysis is shown below.

Table 11.1.2: Performance Sensitivity of Operating Cost

Operating Cost ($/bbl)	**NPV (million $)**	**IRR (%)**
1.5 (actual case)	158	17
2.0	133	16
3.0 (Considering base case)	84	14
4.0	35	12

(All the calculations are shown in APPENDIX- B)

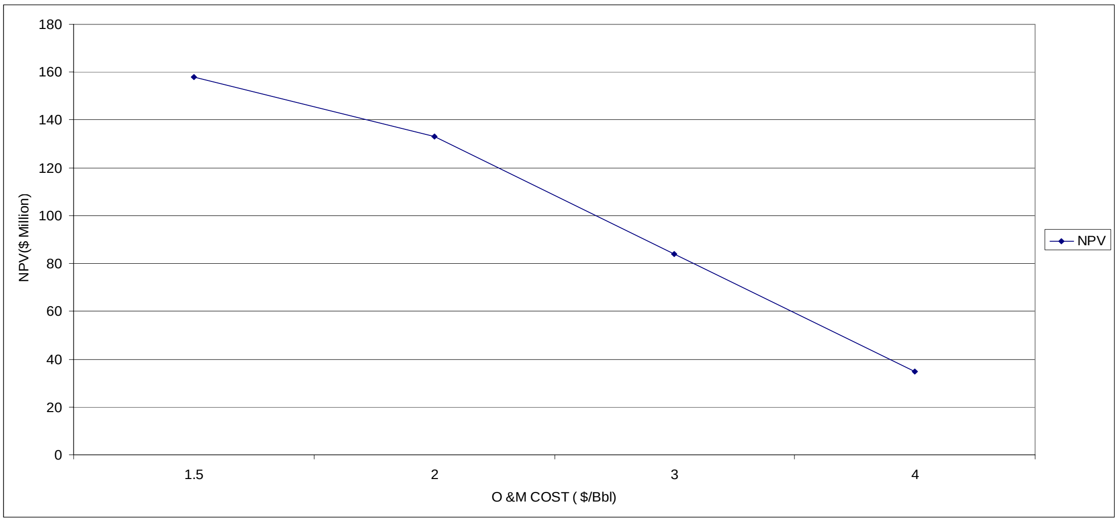

Figure 11.1.2.1: NPV vs. O&M COST

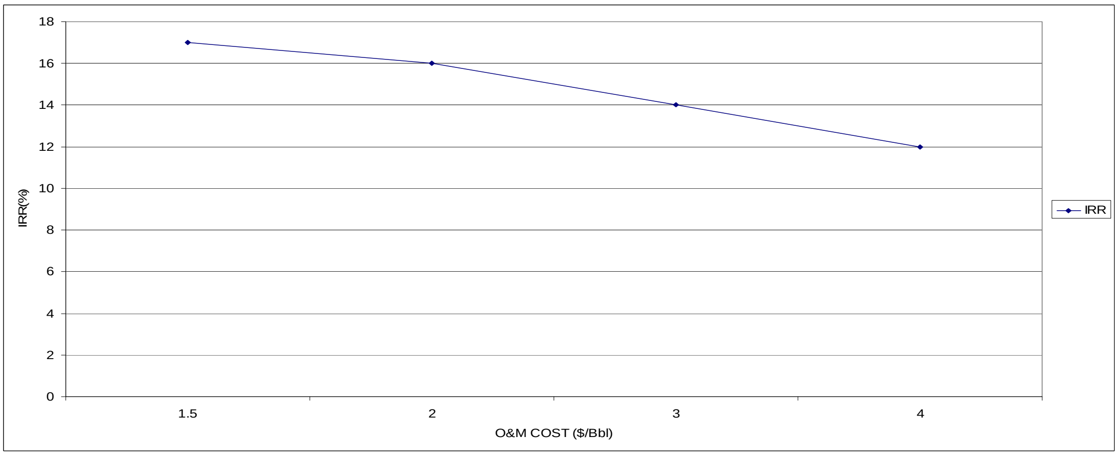

Figure 11.1.2.1: IRR vs. O&M COST

For the viability of the project, the spread between the crude and product price is most critical. The spread (price difference between crude and average of various products) is largely sensitive to product demand. If there is an increased product demand that exceeds refinery capacity, as is the case now, the refineries cannot supply enough products driving the price down. As a netback process, the crude price goes up but not at the same rate. As a result, the spread is higher at higher oil price and shrinks when the price is low. Presently, the refiners are going through a golden age enjoying record spread. At lower oil price, on many occasions, the average products price may be even lower than crude price. Various other market forces are responsible for this situation. This was the situation in mid to late nineties when there was worldwide refinery over capacity and the oil price hit as low as $ 10 per barrel. Tens of refineries closed down and generally refiners across the board lost money. This is the greatest risk in refining business. A sensitivity analysis was performed to demonstrate the vulnerability of refinery business to unpredictable and highly fluctuating oil price. Using the present crude/product spot price ratio, for an oil price of $60, the average product price comes to be $66.91. Using these input data in the otherwise unchanged base case scenario, it shows that the same refinery would lose money. An intermediate oil price ($70/bbl) gives a better profitability with only little increased margin

Table 11.1.3:Performance sensitivity of crude-product price spread (base case0

Crude – Product Spread	**NPV (million $)**	**IRR (%)**
$60 - $66.91/bbl	-11	9
$70 - $78.06/bbl	44	12
$80 - $89.21/bbl	101	15

(All the calculations are shown in APPENDIX-B)

From the above results it can be seen that if the crude product price spread is high, the project is rather risk free for a wide range of operating/fixed expenses.

The oil price is the most fluctuating and volatile among all the operating parameters. Under the base case scenario, an eight-dollar refiner’s margin is a minimum to maintain profitability. Even a small change in any other parameter will result in loss.

There is also uncertainty in project investment. Depending on the availability of different units in the refurbished market, the investors may have to procure new components. Moreover delays in installation, procurement, land preparation, etc may drive the estimate up, and therefore, a higher investment scenario have also been considered

Table11.1.4: Performance sensitivity of investment

Investment (million $)	**NPV (million $)**	**IRR (in %)**
302	84	14
325	69	13
350	52	12
400	18	11

(All the calculations are shown in APPENDIX-B)

11.2 Fixed Refiner's Margin

In this case, it considered as a long-term utility service infrastructure investment (like gas pipeline, electric transmission line, highways etc.) where payment will be made on a per barrel processing fee (margin) basis. This fee would be determined on the basis of investment, fixed and operating expenses. A typical rate of return would be in the range of 12 to 15%. After the initial fixation, mandatory review every three to five years of the fee can be built into the contract. In case of extraordinary situations (i.e. mid term investment for upgrading, expansion), the operator can apply for special review thoroughly presenting their case. A minimum processing volume for take or pay clause need to be determined as well.

Under both financial arrangement, the two stage refinery seems to be profitable but with elements of risk regarding crude/product price spread and operating cost.

Chapter 12
RISK ANALYSIS

Refinery is one of the trickiest businesses in the world. The first and foremost thing about refinery business is that prices are highly volatile. Therefore, unless the refinery operates on a commission basis for the Government, it will have to manage all risks and uncertainties associated with the international oil refining business. Refinery businesses in small-demand countries are extremely troublesome because all products cannot be consumed within the country. Even in large countries, refineries sometimes have to deal with excess of some products. In a particular year, a refinery can lose money. Refineries compensate such losses by trying to capture windfall profits as is occurring now. Refinery business is therefore, a long term business. The business risks arise from the following three major areas.

11.1 International

11.2 Local

11.3 Financial

11.1 International

The predominant risk is the price of oil. Both high and low prices of oil are risky. With declining crude oil prices, refiners' margin also shrinks. In some cases this can actually send the refinery into the red " not an accepted version" . In the USA, refiners' margin in the nineties was so low that the return on investment during that decade was around 4%.

The high price of oil is risky in two ways. First, a large working capital is required to procure crude oil. Second, during the time the oil is ordered, shipped and refined, if the price falls drastically, and if other international refiners are able to respond quickly, the Government may refuse to buy refined products at the old rate leading to potential huge losses.

Procurement of crude oil is also not easy especially when small volumes are ordered. Being a private refinery, no concessionary or favorable terms will be available, as is usually given to procurement on a Government level. Since prices of oil changes on a daily basis, when exactly to buy oil is a big issue. For this, special departments may need to be created. For the national refinery, ERL, this is not really an issue because Bangladesh often receives crude oil at monthly average rates, and sometimes even at concessionary ones. Moreover, the purchases are often on a Government-to-Government basis.

11.2 Local Risks

The local risks of crude oil refining business are mainly with the initial negotiation with BPC and to what extent BPC honors the negotiated contract. The right to get energy is becoming a big issue in Bangladesh. High inflation in recent years has eroded the purchasing power of consumers. This has led to severe resistances to Government's efforts to increase prices of diesel and kerosene. Recent data show that high kerosene prices have already forced a downward trend in its demand. People have now started resisting even justified increases in oil prices. Therefore, the Government may be forced to continue with the diesel and kerosene subsidy for a long time. This will invariably lead to BPC's financial position to become critical. It is obvious that doing business with an organization that for all practical purposes is bankrupt, and must depend on periodic handouts from the Government, obviously carries a considerable amount of risks.

11.3 Financial Risks

The financial risks are difficult to ascertain without knowing the type of purchase agreement that the refinery will have with BPC. If for example the contract is such that the Government assumes all risks, then the refinery will operate on a low level of profit. The existing power purchase agreements with the IPPs are contracts of that nature. If however, the new refinery shoulders all risks (international, local and financial), then very high profit margin must be maintained to manage uncertainties. To what extent BPC will allow a new refinery to make profit under a negotiated purchase agreement is not known. The high profit scenario is also very dangerous from public perception point of view. In Bangladesh, people's perception of high profits regardless of how much risk a private company undertakes is always very negative. It is likely that some formula, which is in between the two extremes, would have to be worked out. The other financial risk of the project is the initial investment cost. Refurbished refineries can vary in price from being one-fifth to half that of new refineries. The operating and maintenance costs are also difficult to judge. The profitability analysis presented is therefore indicative, and the low IRR values are very risky.

Chapter 13
CONCLUSIONS

Refinery economics are largely a function of supply and demand. Product prices are determined by a variety of factors such as the economy, weather and competition between retailers and from other fuels. Feedstock prices (crude oil) are influenced by the above demand factors, actions by OPEC and governmental regulations. Refinery margins (the difference between raw material costs and product revenues expressed on a per barrel of crude basis) can vary depending on the complexity of the refinery. The more complicated the refinery, the higher the operating costs, but the greater the ability to make higher-valued products like gasoline and diesel.

Total demand of petroleum products is increasing day by day. Eastern Refinery Limited Can meet 30 % of our demand. The rest 70 % is being imported by Bangladesh Petroleum Corporation as finished products. By importing finished products government is loosing large amount of money every year. The demand of Diesel is huge in Bangladesh because of irrigation and transportation. By installing second refinery in Bangladesh we can minimize import quantity of finished products and hence we can save considerable amount of money for the country.

Due to aging effect the capacity of existing refinery is decreasing and maintenance cost is in creasing every year. Now it is time to think seriously for establishing a Second Oil Refinery in Bangladesh

Second refinery will also give energy security in this fluctuating oil price situation. The oil price is the most fluctuating and volatile among all the operating parameters. A Six-dollar refiner’s margin is a minimum to maintain profitability. From technical analysis medium type refinery with hydro cracker unit is best option in our country for second refinery.

Chapter 14
RECOMMENDATION

- Form earlier analysis two stage refinery can be considered for Bangladesh depending on the availability of fund. The second refinery might have the provision to process heavier crude because the availability of lighter crude is decreasing day by day.
- At present there is no use of naphtha in Bangladesh. Naphtha and excess furnace oil have to export timely.
- Capacity enhancement of the existing plant can be considered. For that a detail study is recommended.
- FO (Furnace oil) Based power plant may be considered to minimize the pressure on Natural Gas.

REFERENCES

[1] Annual Report 2008, Eastern Refinery Limited

[2] Sullivan,W.G., Bontadelli, J.A., and Wicks, E.M., (2009): Engineering Economy, Published by Addison Wesley Longman (Singapore) Pte. Ltd., Delhi

[3] Nelson, W.L., (1987): Petroleum Refinery Engineering, McGraw Hill International Edition, Singapore.

[4] Annual Diary 2009, Bangladesh Petroleum Corporation

[5] Annual Report 2005, Bangladesh Petroleum Corporation

[6] Annual Report 2002, Bangladesh Petroleum Corporation

[7] Annual Report 1999, Bangladesh Petroleum Corporation

[8] Max S. Peters and Klaus D. Timmerhaus (1991) : Plant design and economics for chemical Engineering , McGraw Hill International Edition, Sigapore.

[9] Allen,F.H and Seba, R.D (1993) : Economics of Worldwide Petroleum Production , OGCI Publication, Oil & Gas consultants international, inc,Tulsa, Oklahoma,USA.

[10] Thompson,R.S and Wright,J.D (1984) : Oil Property Evaluation , Thomson Wright Associates, Golden , Colorado 80402

[11] Bankable Feasibility Study Report by ADB(2009)

APPENDIX-A

Calculation for Expected demand :

Growth rate/Decrease rate for demand
= {(Present demand-Previous demand)/Previous demand}}×100

JP-1:

2004-05 = {(253551-226969)/226969}×100 = 11.71 %
2005-06 = {(238480-253551)/253551}×100 = -5.94 %
2006-07 = {(225912-238480)/238480 }×100 = - 5.27 %
2007-08 = {(277393-225912)/2259912}×100 = 22.78 %

Average growth rate: 5.82 %

Expected demand for 2008-09 = 277393 ×5.82 % = 293537
2009-10 = 293537 ×5.82 % = 310620
and so on.

Calculation for unit barrel crude cost:

Crude Specific Gravity:

ALC Crude = 0.85
MURBAN Crude = 0.82

Average Specific Gravity = 0.835

1 ton crude =1000 kg
= (1000 / 0.835) Lt.
= 1197.60 Lt.
= (1197.60/159) bbl [l bbl =159 Lt.]

1 ton crude =7.532 bbl.

1999-00

Crude quantity =1236049 ton.
=1236049 × 7.532 bbl [1ton= 7.532 bbl]
=9309921.068 bbl.

Total Cost of crude = 1110.96 Core Taka
=1110.96×10^7 Taka

Per barrel cost of crude =Total cost of crude in Taka / Total quantity of crude in barrel
=1110.96×10^7 Taka/9309921.068 bbl
=1193.30 Taka/bbl

2000-01

Crude quantity =1337121 ton.
=(1337121 × 7.532) bbl [1ton= 7.532 bbl]
=10071195.37 bbl.

Total Cost of crude = 1598.60 Core Taka
=1598.60×10^7 Taka

Per barrel cost of crude=Total cost of crude in Taka/Total quantity of crude in bbl
=1598.60×10^7 Taka/10071195.37 bbl
=1587.29 Taka/bbl

2001-02

Crude quantity =1224707 ton.
=1224707 × 7.532 bbl [1ton= 7.532 bbl]
=9224493.12 bbl.

Total Cost of crude = 1277.78 Core Taka
=1277.78×10^7 Taka

Per barrel cost of crude =Total cost of crude in Taka / Total quantity of crude in barrel
=1277.78×10^7 Taka/9224493.12 bbl
=1385.20 Taka/bbl

2002-03

Crude quantity =1335114 ton.
=1335114 × 7.532 bbl [1ton= 7.532 bbl
=10056078.65 bbl.

Total Cost of crude = 1693.03 Core Taka
=1693.03×10^7 Taka

Per barrel cost of crude =Total cost of crude in Taka / Total quantity of crude in barrel
=1693.03×10^7 Taka/10056078.65 bbl
=1683.58 Taka/bbl

2003-04

Crude quantity =1252424 ton.
=1252424 × 7.532 bbl [1ton= 7.532 bbl]
=9433257.57 bbl.

Total Cost of crude = 1848.43 Core Taka
=1848.43×10^7 Taka

Per barrel cost of crude =Total cost of crude in Taka / Total quantity of crude in barrel
=1848.43×10^7 Taka/9433257.57 bbl
=1959.48 Taka/bbl

2004-05

Crude quantity =1060927 ton.
=1060927 × 7.532 bbl [1ton= 7.532 bbl]
=7990902.16 bbl.

Total Cost of crude = 2261.98 Core Taka
=2261.98×10^7 Taka

Per barrel cost of crude =Total cost of crude in Taka / Total quantity of crude in barrel
=2261.98×10^7 Taka/ 7990902.16 bbl
=2830.69 Taka/bbl

2005-06

Crude quantity =1250818 ton.
=1250819 × 7.532 bbl [1ton= 7.532 bbl]
=9421168.708 bbl.

Total Cost of crude = 3750.69 Core Taka
=3750.69×10^7 Taka

Per barrel cost of crude =Total cost of crude in Taka / Total quantity of crude in barrel
=3750.69×10^7 Taka / 9421168.708 bbl
=3981.13 Taka/bbl

2006-07

Crude quantity =1253000 ton.
=1253000 × 7.532 bbl [1ton= 7.532 bbl]
=9437596 bbl.

Total Cost of crude = 3985.02 Core Taka
=3985.02×10^7 Taka

Per barrel cost of crude =Total cost of crude in Taka / Total quantity of crude in barrel
=3985.02×10^7 Taka/9437596 bbl
= 4222.49 Taka/bbl

2007-08

Crude quantity =1140190 ton.
=1140190 × 7.532 bbl [1ton= 7.532 bbl]
=8587911.08 bbl.

Total Cost of crude = 5659.81 Core Taka
=5659.81×10^7 Taka

Per barrel cost of crude =Total cost of crude in Taka / Total quantity of crude in barrel
=5659.81×10^7 Taka / 8587911.08 bbl
= 6590.43 Taka/bbl

Calculation for unit barrel refined product cost

Refined product specific gravity:

HSD = 0.855
MS = 0.76
HOBC = 0.76
SKO = 0.80
JP-1 = 0.78

Average specific gravity: 0.791

1 ton refined product	= 1000 kg
	= (1000/0.791) Lt
	= 1264.22 Lt
	= (1264.22/159) bbl [1 bbl = 159 Lt)
	= 7.95 bbl

1999-00

Imported Refined product Quantity	= 1823400 ton
	= 1823400 × 7.95 bbl
	= 14496030 bbl
Import cost of refined product	= 2021.43 corer Taka
	= 2021.43×10^7 Taka
Refined product cost per barrel	= (2021.43×10^7 Taka / 14496030 bbl)
	= 1394.47 Taka / bbl

2000-01

Imported Refined product Quantity	= 2068913 ton
	= 2068913 × 7.95 bbl
	= 16447858.35 bbl
Import cost of refined product	= 2999.20 corer Taka
	= 2999.20×10^7 Taka
Refined product cost per barrel	= (2999.20×10^7 Taka / 16447858.35 bbl)
	= 1823.45 Taka / bbl

and so on.

Calculation for operating cost of unit barrel product output:

Specific gravity of product:

LPG	= 0.55
LG	= 0.68
HG	= 0.75
K1	= 0.80
K2	= 0.82
LGO	= 0.84
HGO	= 0.87
Residue	= 0.945

Average specific gravity = 0.78

1 ton product = 1000 kg
= 1000/ 0.78 Lt
= 1282.05 Lt
= 1282.05 / 159 bbl
= 8.06 bbl

1999-00

Total operating cost = Processing expenses + Administrative& Financial expenses
= 5660.44 +4071.30 Lac taka
= 9731.44 Lac Taka
= 9731.44×10^5 Taka

Crude processing amount = 1377600 ton
Process loss = 1.71 %
Total amount of product = 1377600 – (1377600/1.71) ×100
= 1354043.04 ton
= 1354043.04 × 8.06 bbl [1 ton = 8.06 bbl]
= 10913586.9 bbl

Operating cost per unit barrel of product output

= (9731.44×10^5 Taka / 10913586.9 bbl
= 89.17 Taka/bbl

2000-01

Total operating cost = Processing expenses + Administrative& Financial expenses
= 5769.78 +3980.10 Lac taka
= 9749.88 Lac Taka
= 9749.88×10^5 Taka

Crude processing amount = 1350420 ton
Process loss = 1.58 %
Total amount of product = 1350420 – (1350420/1.58) ×100
= 1329083.36 ton
= 1329083.36× 8.06 bbl [1 ton = 8.06 bbl]
= 10712411.91 bbl

Operating cost per unit barrel of product output

= (9749.88×10^5 Taka / 10712411.91 bbl
= 91.01 Taka/bbl
and so on.

APPENDIX-B

The product slate of the new refinery :

Light	16%
Middle	56%
Heavy	28%

Light Distillate	= 0.16 Share / Barrel
Middle Distillate	= 0.56 Share / Barrel
Heavy Distillate	= 0.28 Share / Barrel

C &F crude oil price = $77 /Bbl

(Average C&F crude price for the last three years)

Product price for Light Distillate	= $ 96/Bbl
Product price for Middle Distillate	= $ 96/Bbl
Product price for Heavy Distillate	= $ 60 /Bbl
Price coefficient for Light Distillate	= Product price / Crude price
	= 96 / 77
	= 1.246
Price coefficient for Middle Distillate	= 96/77
	= 1.246
Price coefficient for Heavy distillate	= 60/77
	= 0.779
Capacity	= 33000 b/d
First year of production	= 70 % of the capacity
Project implementation year	= 3 years
Total Investment	= $302 million

Investment was done in three different percents which are mention below:

Investment on 1^{st} year of project implementation = 15 % of total investment

Investment on 2^{nd} year of project implementation = 50 % of total investment

Investment on 3^{rd} year of project implementation = 35 % of total investment

Corporate tax	= 35%
Depreciation	= 10%
Discount rate	= 10%
O&M cost	= $1.5 per bbl (Average Operating Cost of last three years)

Sensitivity analysis on O & M cost is carried out keeping other parameters unchanged. Detail calculations are shown below.

DD&A (Depreciation, Depletion & Amortization)

= Depreciation { Investment – SUM (Previous year DDA)}

Investment = $ 302 Million
Depreciation = 10 %

Year	Investment	DDA	
0	302	30.2 $ Million	
After one year	0	0.1 {302 – 30.2)	= 27.18 $ Million
After two year	0	0.1 {302 – (30.2+27.18)}	= 24.46 $ Million

and so on.

Revenue

= Average Product Price × capacity (bbl/day) × 0.000365 $ Million

0 year (Production Starting year):

= 85.87348 ×23100 × 0.000365 $ Million
=724.04 $ Million

After One year of production:

= 85.87348 ×33000 × 0.000365 $ Million
= 1034.35 $ Million and so on.

O & M Cost

= Operating cost × capacity × 0.000365 $ Million [When O & M Cost = $ 1.5 /Bbl]

0 year (Production Starting year):

= 1.5 ×23100 ×0.000365
= 12.65 $ Million

After One year of production:

=1.5 ×33000 ×0.000365
= 18.07 $ Million and so on.

Cost of crude
= Crude price × capacity × 0.000365 $ Million

0 year (Production Starting year):
= 77× 23100 × 0.000365 $ Million
= 649.23 $ Million

After One year of production and the rest of years
= Crude price × capacity × 0.000365 $ Million
= 77× 33000 × 0.000365 $ Million
= 927.47 $ Million and so on.

Net revenue
= Revenue – O &M cost – cost of crude oil

0 year (Production Starting year):
= 724.04 – 12.65 - 649.23
=62.17 $ Million

After One year of production:
= 1034.35 - 18.7 - 927.47
= 88.81 $ Million and so on.

Taxable income
= Net revenue – DD&A
0 year (Production Starting year):
=62.17-30.2
= 31.97 $ Million
After One year of production:
= 88.81 – 27.18
= 61.63 $ Million and so on.

Tax
= Taxable income ×Tax rate
0 year (Production Starting year):
= 31.97 × 0.3 5
= 11.19 $ Million
After One year of production:
=58.61 × 0.35
=21.57 $ Million and so on.

Income after tax
= Taxable income – Tax
0 year (Production Starting year):
= 31.97 - 11.19
= 20.78 $ Million
After One year of production:
=61.63 - 21.57
=40.06 $ Million and so on.

Cash Flow

= Income after tax – Investment + DDA

1st year of Project Implementation:

Cash flow= - 45.30 $ Million (15 % of total investment)

2nd year of Project Implementation:

Cash flow = -151.00 $ Million (50 % of total investment)

3rd year of Project Implementation:

Cash flow = -105.70 $ Million (50 % of total investment)

0 year (Production Starting year):

Cash flow = 20.78 – 0 +30.20 = 50.98 $ Million

After One year of production:

Cash flow = 40.06 – 0 +27.18 = 67.24 $ Million

And so on.

then NPV and IRR are calculated using these cash flows in Excel sheet.

Sensitivity analysis is done on crude-product price spread and investment keeping other parameters unchanged.