DAILY PROFIT MAXIMIZATION USING LINEAR PROGRAMMING TECHNIQUES: SAPUGASKANDA OIL REFINERY STATION

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DECLARATION OF THE CANDIDATE

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any universities or other institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in this text.

Signature: Date:

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I have supervised and accepted this thesis for the submission of the degree.

Signature of the Supervisor: Date:

DEDICATION

I dedicate this research work to my family members

for their endless support and encouragement.

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ABSTRACT

The petroleum industry plays one of the most significant role in the energy market in Sri Lanka. The actual use of this source is limited by economical, technological and political reasons. Crude oil refining is an extremely complex and dynamic activity since the refinery itself works to maximize its profitability under the frame work of the organization.

To model the LP Problem to the Crude Oil Refinery station in Sapugaskanda, Sri Lanka, the primary data was collected. The data was modeled and the Linear Programming (LP) method was used to get the optimum solution. The refinery produces 12 major petroleum products together with 24 intermediate streams. The commonly used and most profitable products are Gasoline, SBP and Diesel. For above 36 streams, the flow rates in Metric Ton (MT) per day were considered as decision variables. To maximize the profit, the product values were considered as positive and the raw material costs and operating costs were considered as negative. The TORA software was used to generate the optimum solution. The optimum result obtained showed a notable profit compared to the existing situation in the Oil Refinery Station, Sapugaskanda. The operational difficulties, assumptions, suggestions and further recommendations were discussed.

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LIST OF ABBREVIATIONS

Abbreviation	Description
bbl	Barrels
b.p.s.d.	Barrels Per Stream Day
CEB	Ceylon Electricity Board
CEYPETCO	Ceylon Petroleum Cooperation
Codo	company owned dealer operated
CPSTL	Ceylon Petroleum Storage Terminals Limited
Cts.	cents
Dodo	dealer owned dealer operated
Kg	kilograms
LAUGFS	Lanka Auto Gas Filling Stations
LIOC	Lanka Indian Oil Company
LKR	Sri Lanka Rupees
LP	Linear Programming
LPG	Liquefied Petroleum Gas
LPP	Linear Programming Problem
Max	Maximum
Min	Minimum
MT	Metric Tones
R.H.S.	Right Hand Side
Rs.	Rupees
SBP	Special Boiling Point
sec.	Redwood Seconds
SOREM	Sapugaskanda Oil Refinery Expansion and Modernization
SPBM	Single Point Buoy Mooring

CHAPTER 1

INTRODUCTION

1.1 Petroleum Industry

The Ceylon Petroleum Corporation (CEYPETCO) was established in 1961 and entered importing, distributing and marketing of petroleum products throughout the island. It has been assigned to the Ministry of Petroleum Industries in 2010.The main objectives of the CEYPETCO are the following:

- To carry on business as an importer, exporter, seller, supplier and distributor of petroleum products.
- To carry on business of exploiting, producing and refining of petroleum.

The vision of the CEYPETCO is to be the premier customer driven, environmental friendly, enterprise in the petroleum and related industries in the region while contributing towards the prosperity of the nation. (Ceylon Petroleum Cooperation, n.d.)

The CEYPETCO offers agrochemical products, such as insecticides, weedicides and fungicides to control insects, weeds and fungi of crop cultivation. It also provides refueling services at the airports. The lubricant oil blending plant was installed at the Kolonnawa installation. Initially the Kolonnawa oil installation depot was used to store the imported petroleum products. To ensure regular supplies and conserve foreign exchange the corporation built a Sapugaskanda oil refinery station in 1968. It started operations in August 1969. First the capacity of the refiner was 38,000 barrels per day of Iranian light crude oil. Currently it can refine about 50,000 Iranian light crude oil barrels per day. This refinery consists of series of process units which transform materials into one another. Some materials may also be blended to make finished products. Normally the refinery produces Liquefied Petroleum Gas (LPG), Special Boiling Point (SBP) liquid, Chemical Naphtha, Gasoline, Avtur , Kerosene, Fuel Oil 800 sec. , Fuel Oil 1500 sec. ,Auto Diesel, High Sulfur Diesel, Heavy Fuel Oil and Blown Asphalt (Bitumen) as finished products. The Refinery flow Diagram is illustrated in Figure 1.1.

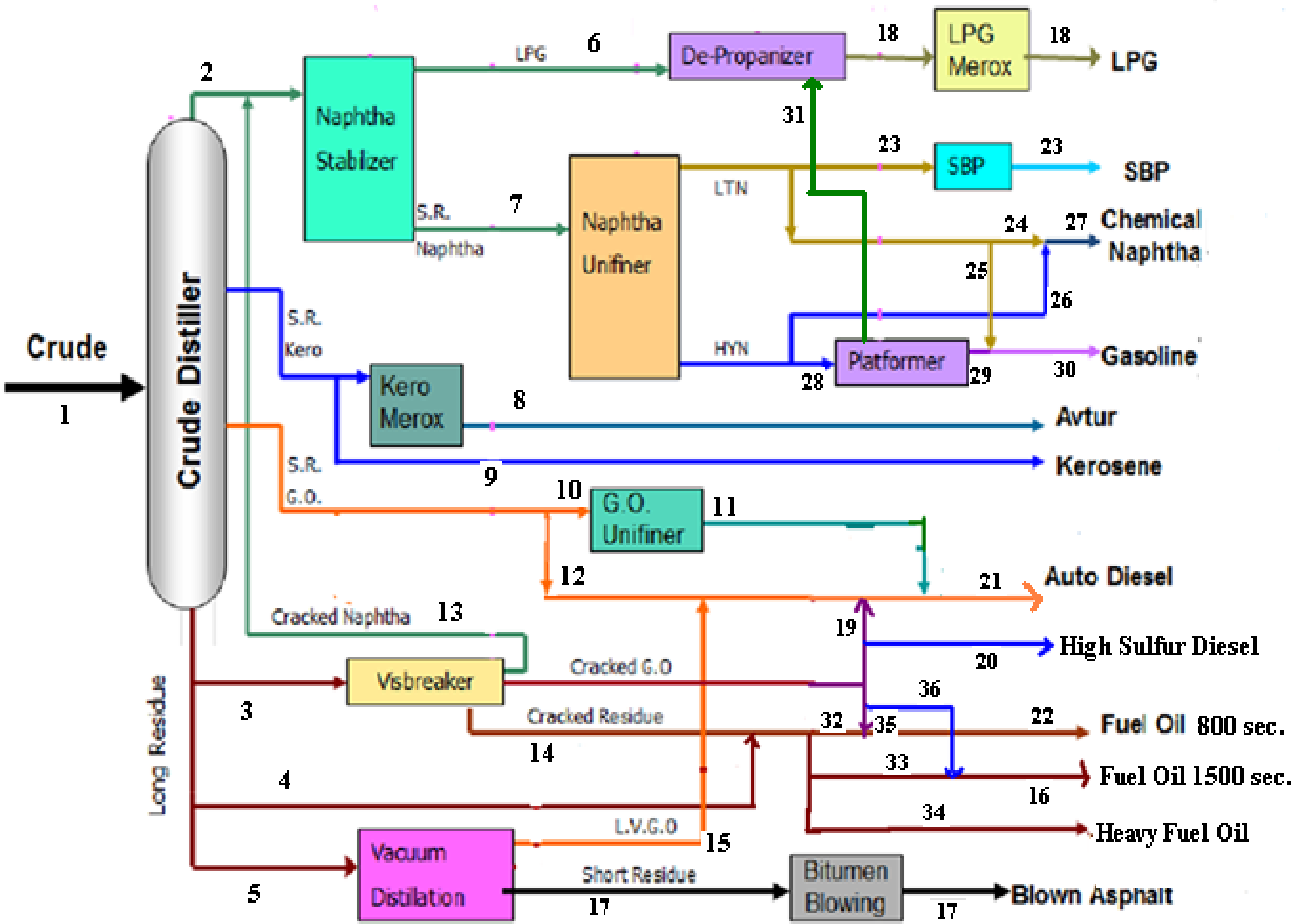

Figure 1.1: The Refinery flow Diagram

Source: Technical Services Division, Sapugaskanda Oil Refinery Station

In the above diagram there are 11 process units which carry out different processes as below,

- **Crude Distillation:** Crude oil is first heated and then put into a Crude Distillation Unit, also known as a still, where different fraction boil off and are recovered at different temperatures. All of the fractions are processed further in other refining units.
- **Vacuum Distillation:** Vacuum Distillation is a continuation of the crude oil distillation process. Long Residue from the Crude Distillation column is heated and distilled at sub atmospheric pressure to recover additional distillation and gas oil.
- **Visbreaking:** Visbreaking also known as Viscosity Breaking is a process that could be used to reduce the viscosity of residue to allow the products to meet fuel oil quality specifications.
- **Bitumen Blowing Unit:** Bitumen refining separates the lighter fractions from the residues. Several manufacturing methods are used to produce specification bitumen depending on the crude source and processing capabilities available.
- **Gas Oil Unifiner and Naphtha Unifiner:** These process units are used to remove sulfur and nitrogen compounds from the input streams.
- **Plat former:** Plat former is used to upgrade the low octane light naphtha to a high octane product.
- **Merox Unit:** The Merox process is an efficient and economical catalytic process developed for removal of sulfur present.
- **SBP Unit:** This is processed for Special Boiling Point Liquids.
- **De – Propanizer Unit:** This process unit is used to reduce the propane level.

CEYPETCO purchases most of its crude oil requirement from the open market. Iran, Saudi Arabia, United Arab Emirates and Malaysia are the main suppliers. In this refinery, the commonly using crude types are Iranian Light, Arabian Light, Miri Light, Oman crude and Dubai crude. The refinery gets crude oil either directly from the Single Point Buoy Mooring (SPBM) facility installed about 10km offshore or from the crude oil storage tanks located in Orugodawatta. Part of the refinery products stored at sapugaskanda mini tank and the balance is pumped to the Kolonnawa storage facility. The production is supplied to the depot from the

Kolonnawa terminal through railway. Bowsers are used to distribute products from installation and depots to the sheds. Heavy Fuel Oil is directly transferred from the refinery to Sapugaskanda power plant (Annual Report 2011). The LPG production is delivered to the distributors Litro Gas Lanka Limited and Lanka Auto Gas Filling Stations (LAUGFS) Pvt. Ltd., since LPG supply is carried out by the aforesaid companies. CPSTL (Ceylon Petroleum Storage Terminals Limited) is responsible for storage and distribution of petroleum products. CEYPETCO distribute Gasoline, Diesel and Kerosene through dealers. There are two types of dealers named codo (company owned dealer operated) and dodo (dealer owned dealer operated). The most of the fuel stations provide 24 hour services. In addition to CEYPETCO, Lanka Indian Oil Company (LIOC) operates about 150 petrol and diesel stations in Sri Lanka. Petrol, diesel and Blown Asphalt are also imported and marketed by LIOC. Among the refinery productions Gasoline (petrol 92 octanes), Auto Diesel and Avtur are imported by CEYPETCO. Gasoline (petrol 95 octanes) and Super Diesel are imported totally. Lanka Super Diesel 4 STAR product has been introduced by reducing the sulfur content from that imported Super Diesel.

Small and medium scale energy conservation projects were implemented to make the refinery operation energy efficient. This Refinery consists of Utilities section which supplies electricity, water, steam, and instrument air, required for plant operations. In addition, 65 numbers of tanks are located within the refinery for crude oil, finished and intermediate products and four crude oil tanks at Orugodawatta tank farm.

The refinery has many strategic disadvantages in the competitive market due to its size. Number of employees compared to the size of the refinery is very high. It provides about one over third of the country requirements of fuel needs in Sri Lanka. That is the major challenge faced by the CEYPETCO. Another big challenge is the rapidly rising of overall demand. The refinery is facing with many challenges for its survival and growth. Emergency shutdown of the plant on account of technical failure is the main factor contributing to poor performance of the refinery. The project named Sapugaskanda Oil Refinery Expansion and Modernization (SOREM) has been started to meet the requirement of the petroleum products. On completion of the project will enable to save a substantial amount of foreign exchange to the country.

Petroleum products are useful materials derived from crude oil as it is processed in oil refineries. The Table 1.1 represents the some usages of petroleum products.

Table 1.1: The Usages of Petroleum Products

Petroleum Product	Uses
LPG	Cooking and industrial gas Motor fuel gas Synthetic fertilizer Alcohols Solvents and acetone Plasticizers Resins and fibers for plastics and textiles Paints and varnish
SBP	Industrial solvent Dry cleaning
Chemical Naphtha	Chemical industry feedstock
Gasoline	Fuel in petrol engines
Jet A1 (Avtur)	Fuel of aviation jet engines
Auto Diesel	Fuel in Diesel engines
Lanka Fuel Oil 800 sec.	Heating Fuel for some car engines
Lanka Fuel Oil 1500 sec.	Industry (for steaming)
Heavy Fuel Oil	Fuel in power plants
Blown Asphalt	Carpet backing Roofing and waterproofing industries Corrosion protection Manufacture of Paints
Kerosene	Lighting using Kerosene lamps Heating
HS Diesel	Re use in the refinery Fuel in power plants

Source: Sapugaskanda Oil Refinery Station

1.2 Significance of the Study

This study will be applied to Crude Oil Refinery Station in Sapugaskanda, Sri Lanka. Even if the crude oil refinery station produces these petroleum products they have no ability to meet country demand. Even if the refinery can earn high profit, they earn less. In this refinery they do not have profit maximization plan still. In the other countries most of the Research works have been done from the view of management and operational research knowledge. Most of the research works have been done by secondary data. Although some theoretical advancement has been made in this field, a gap between theory and application may exist. Practically it may not be feasible. In this refinery station we have 36 variables and eleven process units to be concerned. Hence this process is very complicated. Therefore the profit maximizing process is significant for Sapugaskanda Oil Refinery station.

1.3 Objectives of the Study

The main objective of this study is to apply LPP techniques for daily profit maximization in the Crude Oil refinery station, Sapugaskanda, Sri Lanka. The major objective is achieved through the following specific objectives,

- To study the existing maximization processes and the constraints (linear or nonlinear) of the crude oil refinery station.
- To formulate the LPP model to maximize the daily profit.
- To find out the best solving method to get the optimum solution.

1.4 Research Methodology

- **Selecting the portfolio for study:** This study will be applied to Sapugaskanda Oil Refinery Station.
- **Mapping existing process and data collection**: Process flow, capacities, operating costs for the refinery process units, revised prices for crude oil and other final products, minimum production requirements for each and every products, relative densities for relevant products, quality specifications such as octane number, sulfur contents, viscosity, need to be collected.

- **Formulate the problem for create refinery LP model**: Preparing objective function for maximize the profit and the resource constraints combine with above function need to be constructed.
- **Refinery model building:** After finalizing the data, it will be solved and optimum results will be taken by using the suitable LPP in Operational Research Techniques. Model will be checked for feasibility.

1.5 Content of Thesis

There are six chapters in the dissertation. Content of each chapter has been summarized as follows.

Chapter 1 - Introduction: The background of the study, the significance of this research and the brief report outline would be expressed in this chapter.

Chapter 2 - Literature Review: A survey of the literature on the fields which are relevant to this research problem would be discussed.

Chapter 3 - Methodology: In this chapter the different methods to solve this problem will be described.

Chapter 4- Analysis and Results: Using the methods in chapter 3, the objective function and the subjective constraints will be formulated with the aim of solving the problem. Further in this chapter the results will be presented, explained and summarized.

Chapter 5- Discussion: The discussion of the findings will be included in this chapter. Benefits of the derived model, difficulties, improvements, suggestions and assumptions will be discussed further.

Chapter 6- Conclusions and Recommendations: In this chapter the conclusion will be drawn based on the discussion. The implications of this research will be described further.

CHAPTER 2

LITERATURE REVIEW

Some literature regarding the process optimization in the field of Crude Oil Refinery was reviewed in this chapter.

Lorentsen and Roland developed a traditional simultaneous econometric model for the world oil market for the Norwegian Ministry for oil and energy. This model was developed in 1986 and used to trace crude oil price throughout the year 2000. The optimization model of a refinery Crude Distillation Unit in the context of total energy requirement was introduced by E.O.Okeke and A.A.Osakwe. This model (Okeke & Osakwe, 2003) has been applied to one of the refinery crude distillation unit owned by Nigerian National Petroleum Corporation. The main objective of this model was to optimize Gasoline production in the refinery. The reliable solution has been obtained by using Sequential Quadratic Programming. It has been assumed that this model can be applied to optimize the Crude Distillation Units in the other three refineries owned by Nigerian National Petroleum Corporation.

According to Bishnu Ram Boro, the profitability improvement in the role of oil refinery was introduced (Boro, 2004). A case study was accomplished to Bongaiyaon refinery and petrochemical limited. Possible solutions to the problem were developed and evaluated from managerial point of view. The Oil market model has been introduced by F.S.Manzano. The current supply chain practices were studied in the petroleum downstream industry. The main supply chain issues and challenges were described in the research work (Manzano, 2005).

Supply and demand plan was introduced by Beatrice N. Nnadili (Nnadili, 2005). Simple Linear Programming Model was introduced by Katie Pease (Pease, 2008). There were only two refinery products named jet fuel and gasoline as decision variables. The graphical method was used to maximize the profit. That was a Simple Linear Programming Model. Optimization model was introduced for operating conditions of Distillation Column by A.Fazlali, S.Hosseini, B.Yasini and A.Moghadassi (Fazlali, Hosseimi, Yasini, & Moghadassi, 2008). In this research work, the distillation unit of the Iran - Arak – Shazand petroleum refinery was subject to optimization effort. It was performed using a simulator with the aim to earn more overhead products.

A small model was introduced by Dr.Amidpour for the estimation of CO_2 emissions associated with operation of steam network as encountered in refineries. This model (Amidpour, 2008) has been used to calculate of the steam network of an existing refinery aiming at minimization total annualized cost with considering emission. It has been considered that CO_2 production taxes and other economic effects as the total annualized cost. This model has been performed in STAR software that licensed by energy system laboratory at K.N.Toosi University of Technology. This study was applied to the Southern Tehran Refinery in Iran.

Chris, Mandona and Adebusola developed a model to maximize the gross refinery margins. They have done strong work (Dunham, Luhila, & Odunga, 2009). It incorporates uncertainty into the demand of refinery products and the purchase price of crude oils. The aim of this project was to focus on production in refining. There were only 8 operating units in this refinery. Among those units the three units were modeled. In 2010 Sylvain Mouret has developed the mathematical models (Mouret, 2010) and algorithms for optimizing refinery crude oil operations using MINLP. This problem has been developed by the mathematical MOS and SOS models.

Oil production has been optimized for Marlim Field by Lamija and Andrea. (Dzubur & Langvik, 2012) They have achieved a strong outcome. The objective of the model was to maximize **total oil production** extracted from the reservoir. It was assumed that producing as much oil as possible is always economically preferable.

Profit maximization for the Crude Distillation Unit was modeled by S.Fali, N.Yusoff, S.Ganguli, M.Z.Abidin and K.Siraj in Malaysia (Ali, Yusoff, Ganguly, Abidin, & Siraj, 2013).A weekly decision has been made. Operational optimization was carried out to maximize the net profit within the acceptable limit of temperatures. A profit function was considered as an objective function while material and energy balance, vapor and liquid summation and equilibrium equations were considered as constrains. Model has been optimized by using sequential quadratic programming algorithm. This has advancement since energy balance has been considered.

An optimization framework was developed for existing refinery distillation process (Gadalla, Jobson, & Smith). This process was optimized by changing key operating parameters, while concurrently accounting for hydraulic limitations, the design and the performance of the existing heat exchanger network. The high operating cost need to be paid if there is no less energy consumption. A case study of this research showed that a reduction in energy consumption and operating costs of over 25% could be achieved. This was a significant reduction in the energy consumption and operating cost of an existing crude oil distillation column.

Most of the models aimed towards the less energy consumptions. Any heat recovered from the distillation process reduces the operating cost for that. If the operating cost was taken relate to the less energy consumption and then we need not pay attention at energy constraint. This paper presents a profit maximization approach using LPP by considering the operating cost associated with less energy consumptions for distillation unit.

CHAPTER 3

METHODOLOGY

3.1 Linear Programming

The linear programming technique can be said to have a linear objective function which is to be optimized subject to a set of linear constraints. This constrains can be considered as equalities or inequalities. The term linear describes the proportional relationship of two or more decision variables. Thus a given change in one variable will always cause a resulting proportional change in another variable.

3.2 The Graphical Method

The LP Problem involving two variables can be solved by using the Graphical Method. Consider the following steps to solve the problem by this method.

Step I: Sketch the region to the system of constraints. The points are called feasible solution if those are inside or on the boundary of the region.

Step II: From that region find the corresponding vertices.

Step III: Test the objective function at each of the vertices and select values of the variables that optimize the objective function.

3.3 Linear Programming Problem

Formally any LP problem can be written in the following form.

Z = max $\ {}_{i=1}^{n} C_i \, X_i$

Subject to,

${}_{i=1}^{n} a_{ji} \, X_i \ \leq \ b_j$ for all j { 1,….,m}

$X_i \ \geq 0$ for all i {1,….,n}

This is the standard form to the LP Problem. Any LP Problem can be converted in to the standard form.

After adding the slack variables above problem can be written as,

$Z = \max \sum_{i=1}^{n} C_i X_i + 0 \sum_{j=1}^{m} S_j$

Subject to,

$a_{11}X_1 + a_{12}X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + a_{1n}X_n + S_1 = b_1$

$a_{21}X_1 + a_{22}X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + a_{2n}X_n + S_2 = b_2$

$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$

$a_{m1}X_1 + a_{m2}X_2 + \ldots\ldots\ldots\ldots\ldots\ldots + a_{mn}X_n + S_m = b_m$

Where $S_j \geq 0$

The variables that are nonzero are called basic variables. The basic solution for which all variables are nonnegative is called a basic feasible solution.

Constraints may have ≤, ≥ and = signs. By considering the state the slack, surplus and artificial variables can be used. The artificial variables have no physical meaning in the original model. It should be abandoned once the mission has been accomplished. A logical way to achieve this objective is to penalize the artificial variable in the objective function. This can be done by using two methods.

3.4 The Big M - Method (Method of Penalty)

Use the following steps.

Step I: Problem need to be expressed in the standard form.

Step II: For ≥ or = type constraints, add artificial variables to the L.H.S.

These variables should not be appeared in the ultimate solution. This can be achieved by assigning a very large penalty (-M for maximization and +M for minimization) in the objective function.

Step III: Solve the modified LPP by Simplex method until anyone of the following cases may occur.

Optimality: If there are no artificial variables with non zero value in the optimal solution.

No Feasible Solution: The original problem has no feasible solution, if any artificial variable is in the basis with nonzero value at the optimal solution

3.5 The Two Phase Method

In this techniques although the artificial variables are added in the same manner employed in the Big M – Technique, the use of the constant M is eliminated by solving the problem in Two Phase (Vinary, n.d.) .These two Phases are as follows,

Phase I:

Construct a new objective function r that seeks the minimization of sum of the artificial variables subject to the constraints of the original problem. Always the sum of the artificial variables should be minimized. If minimum value of the sum is positive, the problem has no feasible solution which ends the process. If the minimum value of the new objective function is zero then proceed to phase II.

Phase II:

Use the optimum basic feasible solution of phase I as a starting solution for the original problem. Assign actual values to the variable in the objective function and zero value to every artificial variable in the basis at zero level. Delete the column of the artificial variable from the table which is eliminated from the basis in phase I. The modified table obtained from end of the phase I should be solved by simplex method. This should be done until an optimum basic feasible is obtained or until there is an indication of unbounded solution.

3.6 The Sensitivity Analysis

The Sensitivity Analysis is a systematic study of how sensitive solutions are to change in the parameters. This gives a model a dynamic characteristic which allows the analyst to study the behavior of the optimal solution as result of making changes in the model's parameter. The ultimate objective of the analysis is to obtain information about possible new optimum solutions with minimal additional computations.

Sensitivity analysis supports answer questions about how the optimal solution changes given various changes of inputs,

- Objective function coefficients
- RHS constants
- Addition or deletion of constraints

3.6.1 Changes in the Objective Coefficients

The objective function coefficients can be changed within limits without affecting the optimum value of the variables. Any changes in the coefficients of the objective function will affect only the objective equation in the optimum tableau. The range of variation for the objective coefficients should be determined for which the current optimum remain unchanged. There are two cases to be considered.

Case I: Change in a Basic Variable

Any changes in the original coefficients of the optimal basic variables will affect all the non basic coefficients in the objective row of the optimum tableau. Such a change may thus affect the current optimum because one or more of its non basic variables may become eligible to enter the basic solution.

Case II: Change in a Non Basic Variable

The changes in original objective coefficients of the non basic variables can affect only their z – equation coefficient and nothing else. This follows because the corresponding column is not pivoted as in a basic column.

Reduced Cost: The objective function coefficients for the non basic variables at the optimum are usually called the reduced costs. It represents the amount that the variable is overpriced in minimization problems or underpriced in maximization problems. The reduced cost represents the net difference between the cost of the resources used to produce one unit of input and it's per unit revenue.

3.6.2 Changes in RHS Constants of Constraints

Any change in the RHS of a binding constraint will change the optimal solution. Any changes in the RHS of a nonbinding constraint that is less than its slack or surplus, will not change the optimal solution.

Shadow Prices: The objective function coefficients for the slack and surplus variables at the optimum are called the Shadow Prices. It is also called the dual prices. This represents the change in the objective function value per one unit increase in the RHS of the constraint.

If the changes in the RHS value are within the acceptable range, then:

- The shadow price does not change
- The change in objective function value = (shadow price) x (RHS change)

If the change of RHS goes beyond the allowable range, then the shadow price will change.

3.6.3 Addition or deletion of constraints

Adding a new constraint has two possibilities.

- A redundant constraint, no impact on optimal solution
- If new constraint cuts out the optimal solution point from the original feasible solution area, the new optimal solution needs to be calculated.

Deleting an old constraint also has two possibilities.

- If it's slack = 0, then the problem need to be resolved.
- If it's slack > 0, then it has no impact on the optimal solution.

CHAPTER 4

ANALYSIS AND RESULTS

4.1 Data Collection

The Crude oil refinery station, sapugaskanda was visited to get more detailed information about Crude Oil Refinery processes. The relevant officers in the division of Technical Services, Economic and Scheduling and Finance were met to obtain the primary data. This data collection was also done over the telephone. The data for this thesis work is the primary data obtained from the Oil Refinery Station in Sapugaskanda, Sri Lanka. The collected data was summarized below.

The Minimum production requirement: The Table 4.1 shares minimum daily production requirement from MT for refinery products.

Table 4.1: The minimum daily production requirements for refinery products

Products	**Min. (MT/day)**
LPG	0
SBP	6
Chemical Naphtha	0
Gasoline	500
Jet A1 (Avtur)	0
Auto Diesel	1460
Lanka Fuel Oil 800 sec.	=250 (fixed)
Lanka Fuel Oil 1500 sec.	0
Heavy Fuel Oil	=750 (fixed)
Blown Asphalt	50
Kerosene	265
HS Diesel	0

Source: Technical Services Division, Sapugaskanda Oil Refinery Station

Capacities of the process units: Table 4.2 illustrates the capacity of the process units in the Crude oil refinery. The refinery is capable of an overall crude oil processing rate of 50,000 bbl per day. All the other process units have the relevant capacities. Using these primary data in third column, capacities were calculated in MT per day and the fourth column is made up for that.

Table 4.2: Refinery process Units and Capacities

No. of the Process Unit	Process Unit	Capacity (b.p.s.d.)	Capacity (MT/day)
01	Crude Distillation Unit	50,000	6757.5000
02	Naphtha Unifiner Unit	9,100	1027.2990
04& 07	Gas Oil Unifiner Unit (with Hydro treating Unit)	9,300	1249.5000
03	Platformer Unit	5,400	643.9500
05	Visbreaker Unit	12,500	1878.1800
15	Kerosene Merox Treater	8,050	998.3610
06	L.P.G. Merox Treater	700	61.2150
14	SBP Unit	950	101.2035
08	Vacuum Distillation Unit	2,360	242.0298
09	Bitumen Blowing Unit	50,000 MT/Year	142.8500
13	De- Propanizer Unit	130 MT/day	130.0000

Source: Technical Services Division, Sapugaskanda Oil Refinery Station

Prices for petroleum products: Table 4.3 shares current prices for Petroleum products which effect from 22nd midnight of February 2013. The first column is made up of the product name and the second column is made up of the revised price per liter. Using these primary data Revised prices per MT were calculated and the third column was made up for that. The capacity of the one barrel is equal to 159 liters. It has been considered that 1US$ = 130.19 LKR (Sri Lanka Rupees).

Table 4.3: The current prices for Petroleum Products

Product	Revised Price Per Liter Rs. Cts.	Revised Price Per MT Rs. Cts.
Gasoline (Lanka Petrol 92 Octane)	162.00	217,449.66
Lanka Auto Diesel	121.00	143,195.27
High Sulfur Diesel	121.00	142,688.68
Lanka Kerosene	106.00	133,333.33
Lanka Fuel Oil 800 sec.	92.20	99,139.78
Lanka Fuel Oil 1500 sec.	90.00	96,153.84
Lanka Fuel Oil 3500 sec. (Heavy Fuel Oil)	90.00	97,297.29
SBP	160.00	245,022.97
Chemical Naphtha	90.00	137,825.42
Avtur (Jet- A1)	106.00	133,333.33
LPG	127.64 (Per kg)	127,640.00
Blown Asphalt	105.80 (Per kg)	105,800.00
Iranian Crude	109.00(US$ Per bbl)	104,385.04

Source: Economic and Scheduling Division, Sapugaskanda Oil Refinery Station

Density of petroleum products: The densities were obtained from the refinery station and Table 4.4 represent those densities. These data was used to calculate the refinery capacities in MT per day as well as Prices of petroleum products in LKR per MT.

Table 4.4: The Densities of the petroleum products.

Product	Specific Gravity	Density (kg m^{-3})
Iranian Crude	0.855	855
Gasoline	0.775	775
Lanka Auto Diesel	0.845	845
High Sulfur Diesel	0.848	848
Lanka Kerosene	0.790	790
Lanka Fuel Oil 800 sec.	0.930	930
Lanka Fuel Oil 1500 sec.	0.936	936
Lanka Fuel Oil 3500 sec. (Heavy Fuel Oil)	0.925	925
SBP	0.653	653
Chemical Naphtha	0.653	653
Avtur	0.795	795
LPG	0.540	540
Blown Asphalt (Bitumen)	1.000	1000
S R Naphtha	0.699	699
L T Naphtha	0.653	653
Heavy Naphtha	0.734	734
Platformate	0.745	745
S R Kerosene	0.795	795
S R Gas Oil	0.845	845
Super Diesel	0.830	830
Cracked Gas Oil	0.830	830
H.V. Gas Oil	0.930	930

Source: Economic and Scheduling Division, Sapugaskanda Oil Refinery Station

Budget Amount: The annual budget amount was obtained for each and every process units. This can be considered as the refinery expenses. The total overhead expenses were included in this budget amount. Power insurance, Staff remunerations, Upkeep of assets, Administrative expenses and financial expenses can be considered as total overhead cost. Table 4.5 illustrates those budget values. Considering that the refinery is working 350 days per year, the daily budget amount can be calculated.

Table 4.5: Annual Budget Amount for each and every process units.

Process Unit	Direct cost per MT (Rs.)
Crude Distillation Unit (1)	1799.00
Naphtha Unifiner Unit (2)	3347.42
Gas Oil Unifiner Unit (4& 7)	7512.28
Platformer Unit (3)	5940.21
Visbreaker Unit (5)	3023.62
Kerosene Merox Treater (15)	490.36
L.P.G. Merox Treater (6)	1337.62
S.B.P. Unit (14)	1578.53
Vacuum Distillation Unit (8)	5713.96
Bitumen Blowing Unit (9)	4425.18
De- Propanizer Unit (13)	3773.87

Source: Sapugaskanda Oil Refinery Station

In addition to above budget amount, the following expenditure needs to be made. Terminal charge, Normal loss in depot, Selling and distributing cost, Administrative cost, Selling tax and Dealers' discount can be considered as the expenditure. The Table 4.6 shares CEYPETCO cost for petroleum products. The first column was made up of the product name and the second column was made up of the Terminal charge. CPSTL is the receiver of these terminal charges. The third column was made up of the Normal loss in depot. Petroleum loss can be occurred due to vaporization. There are two types of dealers named codo and dodo. They are provided per liter discounts. CEYPETCO is providing 2.25% for codo and 2.50% for dodo. Without knowing sales details, the total dealers' discount value for given product cannot be determined. Since the codo dealers' sales are greater than the sales of the dodo, the average discount 2.375% was considered as dealers' discount. The seventh column was made up of the Dealers' discount. Using all the data, total cost per MT was calculated and the ninth column was made up for that.

Table 4.6: The CEYPETCO costs for Petroleum Products

Product	Terminal Charge (Per Liter) Rs. cts.	Normal loss in depot (Per Liter) Rs. cts.	Selling & distributing cost (Per Liter) Rs. cts.	Administrative cost (Per Liter) Rs. cts	Selling Tax (Per Liter) Rs. cts	**(2.375%)** Dealers' discount (Per Liter) Rs. cts	Total cost (Per Liter) Rs. cts	Total cost (Per MT) Rs.
Gasoline (Lanka Petrol 92 Octane)	2.39	0.19	1.08	0. 85	29. 00	3.85	37.36	50148
Lanka Auto Diesel	2. 09	0.15	1.08	0. 85	3. 00	2.87	10.04	11882
Lanka Kerosene	1.99	0.50	1.08	0. 85	—	2.52	6.94	8730
Lanka Fuel Oil 800 sec.	2.09	—	—	0. 85	—	—	2.94	3161
Lanka Fuel Oil 1500 sec.	2.09	—	—	0. 85	—	—	2.94	3141
Lanka Fuel Oil 3500 sec. (Heavy Fuel Oil)	—	—	—	0. 85	—	—	0.85	919
SBP	2.39	—	—	0. 85	—	—	3.24	4962
Chemical Naphtha	1.30	—	—	0. 85	—	—	2.15	3292
Avtur	1.83	0.50	1.08	0. 85	—	—	4.26	5358
LPG	—	—	—	0. 85	—	—	0.85	1574
Blown Asphalt	—	—	—	0. 85	—	—	0.85	850

Source: CEYPETCO (up to sixth column)

Quality Specifications and Physical Properties: This type of information has been illustrated in Table 4.7. Column 1 is made up of the Petroleum product. The second, third and fourth columns are made up of the Sulfur content, viscosity and Octane number.

Table 4.7: Quality Specifications and Physical Properties for relevant petroleum products.

Stream	**Sulfur Content %**	**Viscosity**	**Octane Number**
Gasoline	-	-	92
Light Naphtha	-	-	65
Platformate	-	-	94
S R Gas Oil	1.00	-	-
LV Gas Oil	1.80	-	-
Cracked Gas Oil	1.50	13.0	-
Super Diesel	0.15	-	-
Auto Diesel	0.30	-	-
Lanka Fuel Oil 800 sec.	-	29.3	-
Lanka Fuel Oil 1500 sec.	-	30.9	-
Fuel Oil to be blended	-	32.0	-

Source: Technical Services Division, Sapugaskanda Oil Refinery Station

4.2 Data Analysis

The Primary data were processed by considering the following steps.

Step 1: By considering the refinery flow diagram (see figure 1.1), the process streams were considered as the variables and those streams were assigned variable names. It has been represented in Table 4.8.

Step 2: The capacities of the process units were calculated into MT per day, since it has been given by the volume.

Step 3: By using the data of Table 4.5, the daily operating cost per MT was calculated for each process units. Input and output streams were analyzed. Table 4.9 represents the analyzed data for step 2 and 3.

Step 4: Revised price per MT for each petroleum product were calculated. Table 4.3 shares those prices. These values, operating costs and head office costs formed the coefficient of the objective function.

This information has been illustrated in the tables below.

Table 4.8: Daily production of the process streams in MT, as a Decision variable X_i , i = 1,2,3,4,……,36

No	**Decision variable (X_i)**	**Name**	**Flow Rates (MT per day)**
1	X_1	CRUDE	Crude oil flow rate to the unit 01
2	X_2	SRN	Straight – run Naphtha flow rate from unit 01
3	X_3	LR VB	Long Residue flow rate for unit 05
4	X_4	LRO	Long Residue flow rate for Oil making
5	X_5	LRVD	Long Residue flow rate to unit 08
6	X_6	LPG DP	LPG flow rate to the unit 13
7	X_7	SRN NU	S.R. Naphtha flow rate to the unit 02
8	X_8	SRK KM	S.R. Kerosene feed rate to the unit 15 or
		AVT	Avtur flow rate
9	X_9	KERO	Kerosene flow rate
10	X_{10}	SRGO GOU	S.R. Gas Oil feed rate to the unit 04
11	X_{11}	SD	Super Diesel flow rate for blend 03
12	X_{12}	SRGO b3	S.R. Gas Oil flow rate for blend 03
13	X_{13}	VB CN	Cracked Naphtha flow rate from unit 05
14	X_{14}	VB CR O	Cracked Residue flow rate for Oil making
15	X_{15}	VD LVGO	Light Vacuum Gas Oil flow rate for blend 03

16	X_{16}	FOHV	1500” Fuel Oil flow rate
17	X_{17}	VD SR	Short Residue feed rate to the unit 09 or
		BA	Blown Asphalt flow rate
18	X_{18}	LPG LM	LPG flow rate to the unit 06 or
		LPG	LPG flow rate
19	X_{19}	VB CGO b3	Cracked Gas Oil flow rate for blend 03
20	X_{20}	HSD	High Sulfur Diesel flow rate
21	X_{21}	AD	Auto Diesel flow rate
22	X_{22}	FOLV	800” Fuel Oil flow rate
23	X_{23}	NU LTN SBP	Light Naphtha feed rate to the unit 14 or
		SBP	SBP flow rate
24	X_{24}	NU LTN b1	LTN flow rate for blend 01
25	X_{25}	NU LTN b2	LTN flow rate for blend 02
26	X_{26}	NU HYN b1	Heavy Naphtha flow rate for blend 01
27	X_{27}	CN	Chemical Naphtha flow rate
28	X_{28}	NU HYN PF	HYN feed rate to the unit 03
29	X_{29}	PF PT b2	Platform ate flow rate for blend 02
30	X_{30}	G	Gasoline flow rate
31	X_{31}	LPG PT	LPG flow rate from unit 03
32	X_{32}	FOLVb4	Fuel Oil flow rate for blend 04
33	X_{33}	FOHVb5	Fuel Oil flow rate for blend 05
34	X_{34}	HFO	Heavy Fuel Oil flow rate
35	X_{35}	VBCGOb4	Cracked Gas Oil flow rate for blend 04
36	X_{36}	VBCGOb5	Cracked Gas Oil flow rate for blend 05

Table 4.9: The Capacities, Operating costs, Mass Yields for the Refinery Process Units

Unit	Capacity (MT/day)	Operating Cost (Rs./ MT)	Input	Output	Mass Yield of Output Stream (MT/MT)%
Crude Distiller (Unit 01)	6757.50	5.14	CRUDE	SRN	16
				SRK KM (=AVT) KERO	14
				SRGO GOU SRGO b3	25
				LR VB LRO LRVD	44
Naphtha Unifiner (Unit 02)	1027.30	9.56	SRN NU	NU LTN SBP (=SBP) NU LTN b1 NU LTN b2	36
				NU HYN b1 NU HYN PF	60
Kero Merox Unit (Unit 15)	998.40	1.41	SRK KM (=AVT)	AVT	100
G.O. Unifiner (Unit 04 & 07)	1249.50	21.46	SRGO GOU	SD	98
Visbreaker (Unit 05)	1878.18	8.64	LR VB	VB CN	1
				VB CGO b3 HSD VBCGOb4 VBCGOb5	12
				VB CR O	85
Vacuum Distillation (Unit 08)	242.03	16.32	LRVD	VD LVGO	15
				VD SR (=BA)	40

Bitumen Blowing (Unit 09)	142.85	12.64	VD SR (=BA)	BA	100
Platformer (Unit 03)	643.95	16.97	NU HYN PF	LPG PT	6
				PF PT b2	82
De- propanizer (Unit 13)	130.00	10.78	LPG DP LPG PT	LPG LM (=LPG)	70
LPG Merox (Unit 06)	61.22	3.82	LPG LM (=LPG)	LPG	100
SBP (Unit 14)	101.21	4.51	NU LTN SBP (=SBP)	SBP	100

Source: Sapugaskanda Oil Refinery Station

4.2.1 Formulation of Objective Function

This Refinery plant includes 11 process units. It refines crude oil to produce Gasoline, Lanka Auto Diesel, High Sulfur Diesel, Lanka Kerosene, Lanka Fuel Oil 800 sec., Lanka Fuel Oil 1500 sec., Heavy Fuel Oil, SBP, Chemical Naphtha, Avtur (Jet – A1) and LPG.

The objective is to maximize the daily profit. The Refinery station has to purchase crude oil. Each and every process units have operating costs which affect the negative contribution to the profit. The crude cost has been combined with the operating cost of the Unit 01. In addition to the operating costs head office cost contributes negatively to the profit. The station can earn profit by selling major products throughout the country. There is no cost associated with blending. The sales prices were shown as positive and the costs were shown as negative.

The Objective function was obtained by considering data of column 3 and 4 in Table 4.9, together with column 3 in Table 4.3 and column 9 of Table 4.6.

The Objective function Z can be formulated as,

Max Z = - (104385.04 + 5.14) CRUDE – (9.56) SRN NU– (1.40) AV – (21.41) SRGO GOU

- (8.64) LR VB - (16.32) LRVD – (12.64) BA – (16.97) NU HYN PF

- (10.78) LPG DP - (10.78) LPG PT - (3.82) LPG - (4.51) SBP

(the refinery cost)

- (1574) LPG - (4962) SBP - (3292) CN - (50148) G - (5358) AVT - (8730) KERO

- (11882) AD - (3161) FOLV - (3141) FOHV - (919) HFO - (850) BA

(the head office cost)

+ (127640) LPG + (245 022) SBP + (137825) CN + (217449) G + (133333) AVT

+ (133333) KERO + (143195) AD + (142688) HSD + (99139) FOLV

+ (96153) FOHV+ (97297) HFO + (105800) BA (the profit)

Max Z = - (104390.18) CRUDE– (9.56) SRN NU– (21.41) SRGO GOU - (8.64) LR VB

- (16.32) LRVD– (16.97) NU HYN PF– (10.78) LPG DP- (10.78) LPG PT

+ (126062) LPG+ (240055) SBP + (134533) CN+ (167301) G+ (127973) AVT

+ (124603) KERO+ (131313) AD + (142688) HSD + (95978) FOLV

+ (93012) FOHV+ (96378) HFO + (104937) BA

4.2.2 Formulation of Constraints

First set of constraints: Since each process unit has maximum capacity and mass yields, below conditions should be satisfied. (Capacities and mass yields can be found in Table 4.9)

Crude Distiller Unit (Unit 01)

CRUDE ≤ 6757.5 (Maximum Capacity for Unit 01) (Redundant Constraint)

$(\frac{16}{100})$CRUDE = SRN (For 100MT of crude, it produces 16 MT of SRN)

Therefore,

(0.16) CRUDE = SRN

Also the following constraints can be developed by considering the relevant mass yields.

(0.14) CRUDE = AVT + KERO

(0.25) CRUDE = SRGO GOU + SRGO b3

(0.44) CRUDE = LR VB + LRO + LRVD

Naphtha Unifiner Unit (Unit 02)

SRN NU ≤ 1027.30

(0.36) SRN NU = SBP + NU LTN b1 + NU LTN b2

(0.60) SRN NU = NU HYN b1 + NU HYN PF

Kerosene Merox Unit (Unit 15)

AVT ≤ 998.40

Gas Oil Unifiner Unit (04 and 07)

SRGO GOU ≤ 1249.50

(0.98) SRGO GOU = SD

Visbreaker Unit (Unit 05)

LR VB ≤ 1878.18

(0.01) LR VB = VB CN

(0.12) LR VB = VB CGO b3 + HSD + VBCGOb4 + VBCGOb5

(0.85) LR VB = VB CR O

Vacuum Distillation Unit (Unit 08)

$LRVD \leq 242.03$

$(0.15)\ LRVD = VD\ LVGO$

$(0.40)\ LRVD = BA$

Bitumen Blowing Unit (Unit 09)

$BA \leq 142.85$

Platformer Unit (Unit 03)

$NU\ HYN\ PF \leq 643.95$

$(0.82)\ NU\ HYN\ PF = PF\ PT\ b2$

$(0.06)\ NU\ HYN\ PF = LPG\ PT$

De- propanizer Unit (Unit 13)

$LPG\ DP + LPG\ PT \leq 130$

$(0.70)\ (LPG\ DP + LPG\ PT) = LPG$

LPG Merox Unit (Unit 06)

$LPG \leq 61.22$

SBP Unit (Unit 14)

$SBP \leq 101.21$

Second set of constraints: Since each blending process has quantity and quality specifications, below conditions should be satisfied. (Quantities and qualities can be found in Table 4.7).The Material Balance constraint state that the sum of the input streams for blender must equal to sum of the output streams. Sum of mass of each component weighted by its sulfur specification or viscosity must meet the quality of the blending output. Sum of volume of each component weighted by its Octane rating must meet the quality of the blending output. Volume was calculated by dividing the mass of the relevant process stream by its density. The Figure 4.1 shows corresponding blending numbers and associated figures. It can be found in appendix A. All the quality constraints use linear blending.

Blending 01

Material Balance NU LTN b1 + NU HYN b1 = CN

Blending 02

Material Balance NU LTN b2 + PF PT b2 = G

Octane Rating $(65)\left(\frac{10^3}{653}\right)$ NU LTN b2 + $(94)\left(\frac{10^3}{745}\right)$ PF PT b2 = $(92)\left(\frac{10^3}{775}\right)$ G

⇨ (99.54) NU LTN b2 + (126.17) PF PT b2 = (118.71) G

Blending 03

Material Balance SD + SRGO b3 + VD LVGO + VB CGO b3 = AD

Sulfur Specification

$\left(\frac{0.15}{100}\right)$ SD + $\left(\frac{1}{100}\right)$ SRGO b3+ $\left(\frac{1.8}{100}\right)$ VD LVGO + $\left(\frac{1.5}{100}\right)$ VB CGO b3 = $\left(\frac{0.3}{100}\right)$ AD

Blending 04

Material Balance FOLVb4 + VBCGOb4 = FOLV

Viscosity (32) FOLVb4 + (13) VBCGOb4 = (29.3) FOLV

Blending 05

Material Balance FOHVb5 + VBCGOb5 = FOHV

Viscosity (32) FOHVb5 + (13) VBCGOb5 = (30.9) FOHV

Third set of constraints: Since there should be material balance around stream splits, below conditions should be satisfied. (See figure 1.1)

LRO + VB CR O = FOLVb4 + FOHVb5 + HFO

Naphtha Stabilizer

From the Naphtha Stabilizer 1.4% of LPG DP and 98.6% of SRN NU are produced. By considering these mass yields the following constraints can be developed.

(0.014) (SRN + VB CN) = LPG DP

(0.986) (SRN + VB CN) = SRN NU

Fourth set of constraints: Since there is crude availability and each product has minimum production state, below conditions should be satisfied. (Minimum production can be found in Table 4.1)

Crude Availability,

$CRUDE \leq 6500$	Limiting the refinery to 6500MT Crude per day.

Minimum Production,

$LPG \geq 0$	
$SBP \geq 6$	Refinery must produce at least 6MT/day of SBP to meet the company marketing division requirements.
$CN \geq 0$	
$G \geq 500$	
$AVT \geq 0$	
$KERO \geq 265$	
$AD \geq 1460$	
$FOLV = 250$	
$FOHV \geq 0$	
$HFO = 750$	
$BA \geq 50$	
$HSD \geq 0$	

Modified LP Problem: From the column 2 and 3 of Table 4.8 the above decision variables can be brought up in short form (X_i). The modified LP problem is as follows,

Max Z = - (104390.18) X_1 - (8.64) X_3- (16.32) X_5– (10.78) X_6– (9.56) X_7+ (127973) X_8+ (124603) X_9– (21.41) X_{10} + (93012) X_{16}+ (104937) X_{17}+ (126062) X_{18}+ (142688) X_{20} + (131313) X_{21}+ (95978) X_{22}+ (240055) X_{23}+ (134533) X_{27}–(16.97) X_{28}+ (167301) X_{30} - (10.78) X_{31}+ (96378) X_{34}

Subject to,

$X_1 \leq 6757.5$ Redundant Constraint

(0.16) $X_1 - X_2 = 0$

(0.14) $X_1 - X_8 - X_9 = 0$

(0.25) $X_1 - X_{10} - X_{12} = 0$

(0.44) $X_1 - X_3 - X_4 - X_5 = 0$

$X_7 \leq 1027.30$

(0.36) $X_7 - X_{23} - X_{24} - X_{25} = 0$

(0.60) $X_7 - X_{26} - X_{28} = 0$

$X_8 \leq 998.40$

$X_{10} \leq 1249.50$

(0.98) $X_{10} - X_{11} = 0$

$X_3 \leq 1878.18$

(0.01) $X_3 - X_{13} = 0$

(0.12) $X_3 - X_{19} - X_{20} - X_{35} - X_{36} = 0$

(0.85) $X_3 - X_{14} = 0$

$X_5 \leq 242.03$

$(0.15)\ X_5 \ - X_{15} = 0$

$(0.40)\ X_5 \ - X_{17} = 0$

$X_{17} \leq 142.85$

$X_{28} \leq 643.95$

$(0.82)\ X_{28} - X_{29} = 0$

$(0.06)\ X_{28} - X_{31} = 0$

$X_6 + X_{31} \leq 130$

$(0.70)\ X_6 + (0.70)\ X_{31} - X_{18} = 0$
$X_{18} \leq 61.22$
$X_{23} \leq 101.21$

$X_{24} + X_{26} - X_{27} = 0$

$X_{25} + X_{29} - X_{30} = 0$

$(99.54)\ X_{25} + (126.17)\ X_{29} - (118.71)\ X_{30} = 0$

$X_{11} + X_{12} + X_{15} + X_{19} - X_{21} = 0$

$(0.15) X_{11} + (1) X_{12} + (1.8)\ X_{15} + (1.5) X_{19} - (0.3)\ X_{21} = 0$

$X_{32} + X_{35} - X_{22} = 0$

$(32)\ X_{32} + (13)\ X_{35} - (29.3)\ X_{22} = 0$

$X_{33} + X_{36} - X_{16} = 0$

$(32)\ X_{33} + (13)\ X_{36} - (30.9)\ X_{16} = 0$

$X_4 + X_{14} - X_{32} - X_{33} - X_{34} = 0$

$(0.014)\ X_2 + (0.014)\ X_{13} - X_6 = 0$

$(0.986)\ X_2 + (0.986)\ X_{13} - X_7 = 0$

$X_1 \leq 6500$

$X_{23} \geq 6$

$X_{30} \geq 500$

$X_9 \geq$ 265

$X_{21} \geq 1460$

X_{22} = 250

X_{34} = 750

$X_{17} \geq 50$

$X_i \geq 0$; i = 1,2,3,……, 36

The above LP Problem can be expressed in standard form by assigning S_j Slack, Surplus variables and A_k Artificial variables. Here $S_j \geq 0$; j = 1,2,3,……, 16 and $A_k \geq 0$; k = 1,2,3,…, 34.

4.2.3 The Big M - Method to solve the Problem

By considering the above LP problem, we can penalize the artificial variables $A_{1,} A_2, A_3, A_4, \ldots\ldots, A_{34}$ in the objective function by assigning them very large negative coefficients in the objective function. Let - M < 0 be a very large constant. Then the objective function in above LP problem becomes,

Max Z = - (104390.18) X_1 - (8.64) X_3 - (16.32) X_5– (10.78) X_6– (9.56) X_7+ (127973) X_8+ (124603) X_9– (21.41) X_{10} + (93012) X_{16}+ (104937) X_{17}+ (126062) X_{18}+ (142688) X_{20} + (131313) X_{21}+ (95978) X_{22}+ (240055) X_{23}+ (134533) X_{27}–(16.97) X_{28}+ (167301) X_{30} - (10.78) X_{31}+ (96378) X_{34} - M $\,^{34}_{j=1} A_j$

Constraints are remaining same as the original. Constraint equations can be used to substitute out A_1 , $A_2, A_3, A_4,, \ldots\ldots, A_{34}$ in the objective function. The value of M should be sufficiently large. By considering the coefficients of the objective function, the problem was solved by assigning 4, 000,000 for M. Then the starting tableau becomes,

Table 4.10: The Initial Tableau of Big M- Method

Basic	X_1	..	X_{21}	..	X_{29}	X_{32}	S_{11}	Solution
Z	-3855609.82	..	1068687	..	-504680000	-128000000	0	-13124000000
A_1	0.16	..	0	..	0	0	0	0
A_2	0.14	..	0	..	0	0	0	0
:	:	..	:	..	:	:	:	:
A_{17}	0	..	0	..	1	0	0	0
:	:	..	:	..	:	:	:	:
S_{11}	1	..	0	..	0	0	1	6500

The complete form of the table can be found in the TORA software provided with this. This tableau is not optimum since it has negative coefficients in the objective raw. This modified LPP was solved by simplex method. Upon applying the optimality condition, X_{29} has the most negative coefficient in the Z- equation and hence is selected as the entering variable. According to the feasibility condition A_{17} must leave the solution. (See the TORA output) Then the new tableau becomes,

Table 4.11: Iteration 2 of Big M- Method

Basic	X_1	..	X_{21}	..	X_{29}	..	X_{32}	..	S_{11}	Solution
Z	-3855609.82	..	1068687	..	0	..	-128000000	..	0	-13124000000
A_1	0.16	..	0	..	0	..	0	..	0	0
A_2	0.14	..	0	..	0		0		0	0
:	:	..	:	..	..	..	:	..	:	:
X_{29}	0	..	0	..	1	..	0	..	0	0
:	:	..	:	..	..	..	:	..	:	:
S_{11}	1	..	0	..	0	..	0	..	1	6500

The complete form of the table can be found in the TORA software provided with this. Above tableau is not optimal since it has negative coefficients in the objective raw. The optimum tableau was obtained in 45 iterations and is given by,

Table 4.12: The Optimum Tableau of Big M- Method

Basic	X_1	..	X_{19}	..	X_{24}	..	X_{26}	..	S_1	Solution
Z	0	..	67932.25	..	0	..	18387.17	..	0	65358650.61
X_1	1	..	6.86	..	0	..	0	..	0	5886.87
X_2	0	..	1.10	..	0		0		0	941.90
X_9	0	..	0	..	0	..	0	..	0	265
:	:	..	:	..	:	..	:	..	:	:
X_{30}	0	..	0.74	..	0	..	1.14	..	0	647.40
:	:	..	:	..	:	..	:	..	:	:
X_{21}	0	..	0.71	..	0	..	0	..	0	1465.48

This tableau is optimal since all the non basic coefficients in the Z – equation are non negative. Solution is feasible since solution values are non negative. The complete form of the table can be found in the TORA software provided with this.

4.2.4 The Two Phase Method to solve the Problem

Phase I

All artificial variables are to be driven to zero. Auxiliary Objective function r needs to be considered.

Min r = Sum of all the artificial variables

Min r = $\sum_{j=1}^{34} A_j$ The starting tableau thus becomes,

Table 4.13: The initial Tableau of Phase I

Basic	X_1	X_2	X_3	..	X_{29}	..	S_{13}	..	S_{16}	A_1	..	A_{34}	Solution
r	0.99	0	-0.02	..	126.17	..	-1	..	-1	0	..	0	3281
A_1	0.16	-1	0	..	0	..	0	..	0	1	..	0	0
A_2	0.14	0	0	..	0	..	0	..	0	0	..	0	0
:	:	:	:	..	:	..	:	..	:	:	..	:	:
S_1	0	0	0	..	0	..	0	..	0	0	..	0	1027.30
:	:	:	:	..	:	..	:	..	:	:	..	:	:
A_{17}	0	0	0	..	1	..	0		0	0		0	0
:	:	:	:	..	:	..	:	..	:	:	..	:	:
A_{34}	0	0	0	..	0	..	0	..	-1	0	..	1	50

The complete form of the table can be found in the TORA software provided with this. This tableau is not optimum since it has positive coefficients in the objective raw. This modified LPP was solved by simplex method. The Optimum tableau was obtained in 41 iterations and is given by Table 4.14.

Table 4.14: The Optimum Tableau of Phase I

Basic	X_1	..	X_{19}	..	S_{12}	..	S_3	..	A_1	..	A_{33}	A_{34}	Solution
r	0	..	0	..	0	..	0	..	-1	..	-1	-1	0
X_1	1	..	1.50	..	0	..	-4.09	..	0	..	0	0	5845.79
X_2	0	..	0.24	..	0	..	-0.65	..	-1		0	0	935.33
:		..		..		..		..		..			
S_2	0	..	- 0.21	..	0	..	0.57	..	0	..	0	0	444.99
:		..		..		..		..		..			
S_{16}	0		1.67		0		2.78		0		0	-1	12.78
:		..		..		..		..		..			
X_{17}	0	..	1.67	..	0	..	2.78	..	0	..	0	0	62.78

The complete form of the table can be found in software provided with this. Since the min r=0, the problem has a feasible solution. It can be moved to Phase II.

Phase II

The artificial variables have served their purpose. Thus the starting tableau for Phase II becomes,

Table 4.15: The Starting Tableau of Phase II

Basic	X_1	..	X_{19}	:	S_{12}	S_{15}	S_{16}	:	S_3	Solution
Z	0	..	-142942.39	:	-105522	-235220.22	0	:	-246095.13	47280703.45
X_1	1	..	1.50	:	0	-7.50	0	:	-4.09	5845.79
X_2	0		0.24		0	-1.20	0		-0.65	935.3
:	:	..	:	:	:	:	..	:	:	:
S_2	0	..	-0.21	:	0	1.05	0	:	0.57	444.49
:	:	..	:	:	:	:	..	:	:	:
S_{16}	0		1.67		0	2.33	1		2.78	12.78
:	:	..	:	:	:	:	..	:	:	:
X_{17}	0	..	1.67	:	0	2.33	0	:	2.78	62.78

The complete form of the table can be found in the TORA software provided with this. This tableau is not optimal since it has negative coefficients in the objective raw. This modified LPP was solved by simplex method. The optimum tableau was obtained in 47 iterations. It was same as the optimum tableau obtained by Big M method. (See table 4.12)

4.3 Results

4.3.1 Optimum Solution of the model

According to the optimum output obtained in above, the maximum daily profit was Rs. 65,358,650.61. The total amount that each stream contributes in arriving at the optimum solution is shown below. It shows that all the decision variables up to X_{36} except X_{19} and X_{26} are recommended.

Table 4.16: The total amount that each stream contributes in arriving at the maximum profit

Decision variable(X_i)	Optimum Solution (MT per day)	Flow Rates
X_1	5886.87	Crude oil flow rate to the unit 01
X_2	941.90	Straight – run Naphtha flow rate from unit 01
X_3	1878.18	Long Residue flow rate for unit 05
X_4	587.04	Long Residue flow rate for Oil making
X_5	125.00	Long Residue flow rate to unit 08
X_6	13.45	LPG flow rate to the unit 13
X_7	947.23	S.R. Naphtha flow rate to the unit 02
X_8	559.16	S.R. Kerosene feed rate to the unit 15 or Avtur flow rate
X_9	265.00	Kerosene flow rate
X_{10}	1249.50	S.R. Gas Oil feed rate to the unit 04
X_{11}	1224.51	Super Diesel flow rate from for blend 03
X_{12}	222.22	S.R. Gas Oil flow rate for blend 03
X_{13}	18.78	Cracked Naphtha flow rate from unit 05
X_{14}	1596.45	Cracked Residue flow rate for Oil making
X_{15}	18.75	Light Vacuum Gas Oil flow rate for blend 03

X_{16}	1293.93	1500" Fuel Oil flow rate
X_{17}	50.00	Short Residue feed rate to the unit 09 or
		Blown Asphalt flow rate
X_{18}	33.28	LPG flow rate to the unit 06 or
		LPG flow rate
X_{19}	0.00	Cracked Gas Oil flow rate for blend 03
X_{20}	114.94	High Sulfur Diesel flow rate
X_{21}	1465.48	Auto Diesel flow rate
X_{22}	250.00	800" Fuel Oil flow rate
X_{23}	101.21	Light Naphtha feed rate to the unit 14 or
		SBP flow rate
X_{24}	58.43	LTN flow rate for blend 01
X_{25}	181.36	LTN flow rate for blend 02
X_{26}	0.00	Heavy Naphtha flow rate for blend 01
X_{27}	58.43	Chemical Naphtha flow rate
X_{28}	568.34	HYN feed rate to the unit 03
X_{29}	466.04	Platform ate flow rate for blend 02
X_{30}	647.40	Gasoline flow rate
X_{31}	34.10	LPG flow rate from unit 03
X_{32}	214.47	Fuel Oil flow rate for blend 04
X_{33}	1219.02	Fuel Oil flow rate for blend 05
X_{34}	750.00	Heavy Fuel Oil flow rate
X_{35}	35.53	Cracked Gas Oil flow rate for blend 04
X_{36}	74.91	Cracked Gas Oil flow rate for blend 05

Table 4.17 which showing the result descriptively, can be found in appendix B. The maximum daily profit that was based upon this research work is greater than the present available profit in the refinery station. The current daily profit cannot be mentioned here under the company regulations.

4.3.2 Status of Resources

The description of slack and surplus variables associated with each constraint is shown in Table 4.18. A zero slack indicates that the entire amount of the resource is consumed by the activities of the model. It is considered as scarce. The slack value means that the resource is not used completely, thus is abundant. The surplus means that the resource is overused.

Table 4.18: Slack and surplus variables

Constraint	RHS	Slack-/Surplus+
1 (=)	0.00	0.00
2 (=)	0.00	0.00
3 (=)	0.00	0.00
4 (=)	0.00	0.00
5 (<)	1027.30	80.07-
6 (=)	0.00	0.00
7 (=)	0.00	0.00
8 (<)	998.40	439.24-
9 (<)	1249.50	0.00
10 (=)	0.00	0.00
11 (<)	1878.18	0.00
12 (=)	0.00	0.00
13 (=)	0.00	0.00
14 (=)	0.00	0.00
15 (<)	242.03	117.03-
16 (=)	0.00	0.00
17 (=)	0.00	0.00
18 (<)	142.85	92.85-
19 (<)	643.95	75.61-
20 (=)	0.00	0.00
21 (=)	0.00	0.00
22 (<)	130.00	82.45-
23 (=)	0.00	0.00
24 (<)	61.22	27.94-
25 (<)	101.21	0.00
26 (=)	0.00	0.00
27 (=)	0.00	0.00
28 (=)	0.00	0.00
29 (=)	0.00	0.00
30 (=)	0.00	0.00
31 (=)	0.00	0.00
32 (=)	0.00	0.00
33 (=)	0.00	0.00
34 (=)	0.00	0.00
35 (=)	0.00	0.00
36 (=)	0.00	0.00
37 (=)	0.00	0.00
38 (<)	6500.00	613.13-
39 (>)	6.00	95.21+
40 (>)	500.00	147.40+
41 (>)	265.00	0.00
42 (>)	1460.00	5.48+
43 (=)	250.00	0.00
44 (=)	750.00	0.00
45 (>)	50.00	0.00

In the above table fifth constraint has 80.07 slack value. It's mean even if the Naphtha Unifiner Unit has 1027.30 MT as daily capacity, 80.07 MT has been unused. The fortieth constraint represents 147.40 as surplus value. Daily production of Gasoline has been exceeded its minimum requirement by 147.40 MT.

4.3.3 Sensitivity Analysis of the Objective Coefficients and RHS Values

Table 4.19: Output for the sensitivity analysis of the objective coefficients

Sensitivity Analysis

Variable	Current Obj Coeff	Min Obj Coeff	Max Obj Coeff	Reduced Cost
x1:	-104390.18	-112091.07	infinity	0.00
x2:	0.00	-48130.59	infinity	0.00
x3:	-8.64	-5023.14	infinity	0.00
x4:	0.00	-17502.03	5014.50	0.00
x5:	-16.32	-infinity	38892.02	0.00
x6:	-10.78	-infinity	infinity	0.00
x7:	-9.56	-48823.54	infinity	0.00
x8:	127973.00	124603.00	infinity	0.00
x9:	124603.00	-infinity	127973.00	0.00
x10:	-21.41	-37293.74	infinity	0.00
x11:	0.00	-38032.99	infinity	0.00
x12:	0.00	-39627.15	infinity	0.00
x13:	0.00	-501449.96	infinity	0.00
x14:	0.00	-5899.41	infinity	0.00
x15:	0.00	-infinity	259388.93	0.00
x16:	93012.00	76523.24	124506.58	0.00
x17:	104937.00	-infinity	202207.85	0.00
x18:	126062.00	-311727.68	infinity	0.00
x19:	0.00	-infinity	67932.25	67932.25
x20:	142688.00	103881.45	427493.78	0.00
x21:	131313.00	99991.72	infinity	0.00
x22:	95978.00	-infinity	infinity	0.00
x23:	240055.00	134533.00	infinity	0.00
x24:	0.00	-289631.31	57621.46	0.00
x25:	0.00	-57621.46	infinity	0.00
x26:	0.00	-infinity	18387.17	18387.17
x27:	134533.00	-155098.31	148472.15	0.00
x28:	-16.97	-18404.14	infinity	0.00
x29:	0.00	-22423.37	infinity	0.00
x30:	167301.00	151159.20	infinity	0.00
x31:	-10.78	-306463.56	infinity	0.00
x32:	0.00	-infinity	infinity	0.00
x33:	0.00	-17502.03	33430.00	0.00
x34:	96378.00	-infinity	infinity	0.00
x35:	0.00	-infinity	infinity	0.00
x36:	0.00	-284805.78	543997.23	0.00

Table 4.20: Sensitivity analysis of the RHS Values

Constraint	Current RHS	Min RHS	Max RHS	Dual Price
1 (=)	0.00	-81.21	218.72	-139447.23
2 (=)	0.00	-439.24	559.16	-127973.00
3 (=)	0.00	-333.55	126.88	-98321.27
4 (=)	0.00	-1870.44	587.04	-89959.28
5 (<)	1027.30	947.23	infinity	0.00
6 (=)	0.00	-infinity	58.43	-134533.00
7 (=)	0.00	-75.61	129.40	-152920.17
8 (<)	998.40	559.16	infinity	0.00
9 (<)	1249.50	1244.90	1354.36	37272.33
10 (=)	0.00	-592.13	4.51	-138382.66
11 (<)	1878.18	988.65	2465.22	5014.50
12 (=)	0.00	-81.21	18.78	-139447.23
13 (=)	0.00	-infinity	114.94	-142688.00
14 (=)	0.00	-1870.44	1219.02	-89959.28
15 (<)	242.03	125.00	infinity	0.00
16 (=)	0.00	-4.79	18.75	-60616.43
17 (=)	0.00	-50.00	12.78	-202207.85
18 (<)	142.85	50.00	infinity	0.00
19 (<)	643.95	568.34	infinity	0.00
20 (=)	0.00	-150.16	106.11	-180052.66
21 (=)	0.00	-39.91	34.10	-88232.62
22 (<)	130.00	47.55	infinity	0.00
23 (=)	0.00	-27.94	33.28	-126062.00
24 (<)	61.22	33.28	infinity	0.00
25 (<)	101.21	6.00	159.64	105522.00
26 (=)	0.00	-infinity	58.43	-134533.00
27 (=)	0.00	-28.39	9.44	35614.46
28 (=)	0.00	-1120.19	2825.58	-1709.34
29 (=)	0.00	-296.06	3.83	-145452.31
30 (=)	0.00	-3.83	88.82	47131.05
31 (=)	0.00	-21.09	66.59	-178765.54
32 (=)	0.00	-2057.49	675.00	2775.20
33 (=)	0.00	-43.40	66.59	-178765.54
34 (=)	0.00	-2057.49	1340.92	2775.20
35 (=)	0.00	-1870.44	1219.02	-89959.28
36 (=)	0.00	-39.91	13.45	-88232.62
37 (=)	0.00	-80.07	215.66	-140174.42
38 (<)	6500.00	5886.87	infinity	0.00
39 (>)	6.00	-infinity	101.21	0.00
40 (>)	500.00	-infinity	647.40	0.00
41 (>)	265.00	0.00	824.16	-3370.00
42 (>)	1460.00	-infinity	1465.48	0.00
43 (=)	250.00	0.00	1535.93	-1474.31
44 (=)	750.00	0.00	1969.02	6418.72
45 (>)	50.00	0.00	62.78	-97270.85

Reduced Cost: Cracked Gas Oil flow rate for blend 03 (X_{19}) and Heavy Naphtha flow rate for blend 01(X_{26}) are non basic in the optimum tableau. That is because their reduced costs have non zero values. Table 4.20 gives output for the sensitivity analysis of the objective coefficient.

Since the reduced cost for Cracked Gas Oil flow rate for blend 03 (X_{19}) is 67,932.25, the profitability of the variable X_{19} must be increased by 67,932.25 in order for the variable to be just profitable. Also for Heavy Naphtha flow rate for blend 01 (X_{26}) the reduced cost is 18,387.17.The profitability of the variable X_{26} must be increased by 18,387.17 in order for the variable to be just profitable.

Current objective coefficient for X_1 is – 104390.18. The current optimum objective value will remain optimal as long as the coefficient of X_1 lies in the range [– 112091.07, ∞]. For each and every products selling prices and associated costs can be forecasted by using above results. Table 4.19 shows the ranges for each objective coefficient.

Shadow Prices: Table 4.20 gives output for the sensitivity analysis of the RHS Values. For an example the 25th constraint shows that an increase of 1 MT of SBP will increase the net profit from Rs.105 522.00. If the RHS lies in between the range (6, 159.64) then the optimality will not be changed. This result is useful to prepare future action plans.

4.3.4 Comparison of Results

The results obtained using LPP model and actual result was compared and shown in the Table 4.21. Comparison was done with the actual daily average material balance. Crude intake obtained in this model was greater than the actual value. Column 5 was made up for indicate the production differences. A positive value means that there is an increment and a negative value means that there is a decrement in production. All the production amounts have been increased except LPG, Auto Diesel and Chemical Naphtha. Therefore it can be clearly seen, there are comparatively high production for highly profitable products such as Gasoline (petrol) and SBP. This is significance saving for the company.

Table 4.21: The Results Comparison

Decision variable (X_i)	Actual Daily Result (year 2014) (MT per day)	Optimum Solution From LPP (MT per day)	Crude Intake and Finished Products	Comparison of Optimum Result (Increment + / decrement–) (MT per day)
X_1	5536.30	5886.87	Crude oil	350.57 +
X_8	473.60	559.16	Avtur	85.56 +
X_9	236.80	265.00	Kerosene	28.20 +
X_{17}	0.00	50.00	Blown Asphalt (Bitumen)	50.00 +
X_{18}	86.70	33.28	LPG	53.42 -
X_{20}	0.00	114.94	High Sulfur Diesel	114.94 +
X_{21}	1735.40	1465.48	Auto Diesel	269.92 -
X_{16}	2048.50	1293.93	Fuel Oil 1500 sec.	245.43 +
X_{22}		250.00	Fuel Oil 800 sec.	
X_{34}		750.00	Heavy Fuel Oil	
X_{23}	100.00	101.21	SBP	01.21 +
X_{27}	432.60	58.43	Chemical Naphtha	374.17 -
X_{30}	503.90	647.40	Gasoline	143.50 +

4.3.5 Chapter Summary

Table 4.22: The refinery daily process summary.

01 UNIT		MT
Crude Intake		5886.87
SR Naphtha	to blend	941.90
SR Kerosene	to 15 unit	800.00
	Product-kerosene	24.16
SR Gas Oil	to 04&7 unit	1249.50
	to blend	222.22
Long Residue	to 05 unit	1878.18
	to 08 unit	125.00
	to blend	587.04

02 UNIT		MT
Feed	Ex 01 unit	947.23
Light Naphtha	to Blend 01	58.43
	to Blend 02	181.36
	to 14 unit	101.21
Heavy Naphtha	to 03 unit	568.34
	to Blend 01	0.00

03 UNIT		MT
Feed	Ex 02 unit	568.34
LPG		34.10
Platformate		466.04

04 & 07 UNIT		MT
Feed	Ex 01 unit	1249.50
SD to Blend 03		1224.51

05 UNIT		MT
Feed	Ex 01 unit	1878.18
Cracked Naphtha	to Blend	18.78
Cracked Gas Oil	to AD Blend	0.00
	to Storage(HS)	114.94
	to Blend 04	35.53
	to Blend 05	74.91
Cracked Residue	to Blend	1596.45

06 UNIT		MT
Feed	Ex 13 unit	33.28
Product	LPG	33.28

08 UNIT		MT
Feed	Ex 01 unit	125.00
Light Vacuum Gas Oil		18.75
Short Residue		50.00

09 UNIT		MT
Feed	Ex 08 unit	50.00
Product	Blown Asphalt	50.00

13 UNIT		MT
Feed	Ex 01 unit	13.45
	Ex 03 unit	34.10
	Total	47.55
LPG to storage		33.28

14 UNIT		MT
Feed	Ex 02 unit	101.21
Product	SBP	101.21

15 UNIT		MT
Feed	Ex 01 unit	800.00
Product	Avtur	800.00

FINISHED PRODUCTS	MT
LPG	33.28
SBP	101.21
Chemical Naphtha	58.43
Gasoline	647.40
Jet A1 (Avtur)	559.16
Auto Diesel	1465.48
Fuel Oil 800sec.	250.00
Fuel Oil 1500 sec.	1293.93
Heavy Fuel Oil	750.00
Blown Asphalt	50.00
Kerosene	265.00
HS Diesel	114.94

INTERMEDIATE STREAMS	MT
SR Naphtha	941.90
SR Kerosene	824.16
SR Gas Oil	1471.72
Long Residue	2590.22
Short Residue	50.00
LVGO	18.75
Cr. Residue	1596.45
Cr. Gas Oil	225.38
Cr. Naphtha	18.78
Light Naphtha	341.00
Heavy Naphtha	568.34
SD for Blend	1224.51
LPG flow rate to unit 13	13.45
SR Naphtha flow rate to unit 02	947.23
Platformate	466.04

CHAPTER 5

DISCUSSION

5.1 Benefits of the Derived Model

The optimum solution was provided in this model. As per the derived model it can be seen that about Rs.65 358 650.61 can be saved in daily. This profit is only for refinery productions. The production has been maximized for most profitable products such as Gasoline (petrol) and SBP. The amount of the crude oil intake can be derived without wasting time and money. This model is responsive when values such as selling prices, production cost, mass yields, process unit capacities, octane rating, sulfur content, viscosity are changed. That can be done by modifying coefficients and R.H.S. values of the model. This model facilitates in decision making process by keeping the focus on profit under any situation. Bottlenecks in processing more crude and benchmark for operations can be identified using this model and it helps to do future action plans in this sector.

5.2 Operational Difficulties and Assumptions

This model has been applied only for Iranian Light crude oil which can be used to get maximum yields from the refinery. It has been assumed that, this refinery use only Iranian Light crude oil. But it is difficult to import Iranian Light crude oils, when there are sanctions against Iran. Refinery yields of the process units may vary from type of the crude oil. In this research work it has been assumed that 350 as the refinery working days for a year. All the calculations were done by assuming that.

It has been assumed that there is no payment delay to settle the bills for imported crude oil. If there is a delay then exchange variation should be paid. If the bill payment day has been extended and CEYPETCO is failure to settle it on the extended date then the bank interest Rs.4.20 per litter should be paid.

There are two types of dealers named codo and dodo who sells petroleum products Gasoline (petrol), Diesel and Kerosene through petroleum sheds. In this research work the average value has been considered even if they have been given separate dealer discounts. If there is possibility to check all the sales details of aforesaid dealers, then the accurate average dealer discount value for each product can be calculated.

Petroleum products should be assessed by considering its density and temperature. It’s better to sell or buy petroleum products by considering weight rather than volume because there may be expansions in high temperatures and compression in law temperature. From the customer’s view it is better to buy petroleum in the morning. It is negatively affected to the petroleum industry. It has been assumed that all the transactions were done in the relevant temperature atmosphere. .

5.3 Computational Difficulties

This LPP problem was solved by using TORA software. The problem was solved in TORA. In Big M - method it is important to assign the sufficient large value for M. Therefore it was solved using M = 4 000 000. Otherwise the solution will not be the optimum.

CHAPTER 6

CONCLUSION AND FUTURE RECOMMENDATION

6.1 Conclusion

The crude oil refinery station has no still a profit maximization plan. In this research work the necessary data was obtained using the collected data. The optimum result was obtained using the TORA software. Profit maximization for the daily scheduling strategy was successfully carried out. From the optimum tableau, Rs.65 358 650.61 can be considered as the maximum daily profit. Therefore the maximum daily profit based on this research work was greater than the present situation of the station. Importation process has not been considered. Necessary stream values in MT per day also were obtained. It has been summarized for finished products below. All the values are given in MT per day.

Crude Oil = 5886.87, Avtur = 559.16, Kerosene = 265, Fuel Oil 1500 sec. = 1293.93, Blown Asphalt (Bitumen) = 50, LPG = 33.28, High Sulfur Diesel = 114.94, Auto Diesel = 1465.48, Fuel Oil 800 sec. = 250, SBP = 101.21, Chemical Naphtha = 58.43, Gasoline = 647.40 and Heavy Fuel Oil = 750. All the production amounts have been increased except LPG, Auto Diesel and Chemical Naphtha. Model is significant since there are higher productions for the most profitable products such as Gasoline (petrol) and SBP. This Refinery station currently refines about 5536.3 MT Crude Oils per day. But from this research work this value can be increased to 5886.87 MT per day. It is affected to the daily profit positively, since the production capacity has been increased.

The analysis was done using the Big M and Two Phase methods. Using the TORA software the drawback of the Big M method is the possible computational error that may result from assigning a very large value to the constant M. The two phase method was designed to assuage this difficulty. The use of the constant M is eliminated by solving the LP problem in **Two Phase method.** The formulated objective function was a linear. All the constraints used linear relationships.

The Model was checked for feasibility. The results were shared with the crude oil refinery station. There is a long term economical effect for the Oil Refinery Station in Sapugaskanda, from this project since they have no still a profit maximization LP plan.

6.2 Future Recommendation

This research work has been done only by considering Iranian Crude Oil. Some of the primary data such as output mass yields for process units were collected for Iranian type crude oil which is commonly used. But the Arab Light, Arab Heavy, Oman Type, Murbun, Miri Light crude oils can also be refined. I hereby recommend considering the above type of crude oils for future research works. Some of the process units produce for Fuel Gas and it has not been considered in this research work. Fuel Gas can be re- used in other refinery operations.

In this refinery station the main disadvantage is absence of cost reflective domestic retail selling prices in line with international oil price movements. In addition supply of furnace oil to CEB at subsidized rates, is a disadvantage. But in this research work, it has been assumed that all the products can be solved in specific prices. I hereby recommend considering the above situation.

Petroleum importation process has not been applied for this research work since it was difficult to collect some data under company regulations. Importing Prices, taxes, loading costs, custom duty, and other relevant costs should be considered for this. I hereby recommend considering the importation process.

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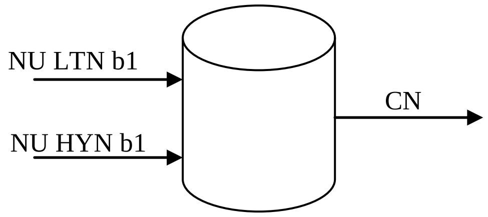
APPENDICES

APPENDIX A

<table>
<tr><th>Blender</th><th>Figure</th></tr>
<tr><td>Blending 1</td><td>
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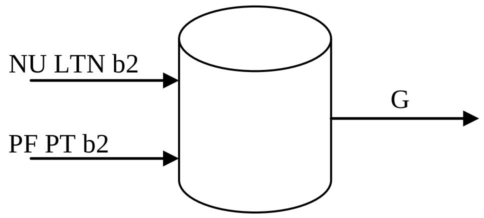
<tr><td>Blending 2</td><td>
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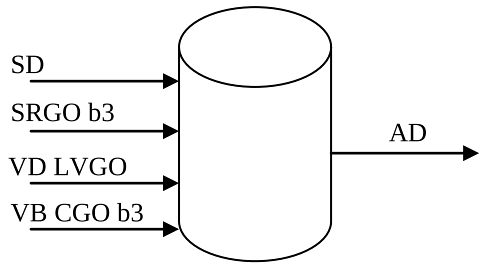
<tr><td>Blending 3</td><td>
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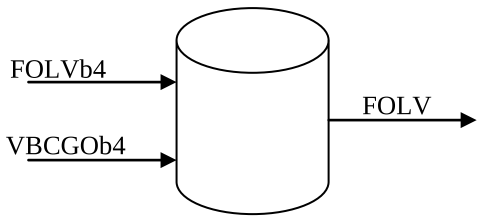
<tr><td>Blending 4</td><td>
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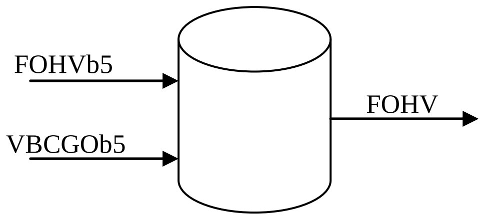
<tr><td>Blending 5</td><td>
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Figure 4.1: Blending numbers and associated figures

APPENDIX B

Table 4.17: TORA out put

LINEAR PROGRAMMING OUTPUT SUMMARY

Title: max
Final Iteration No.: 48
Objective Value = 65358650.61

Variable	Value	Obj Coeff	Obj Val Contrib
x1:	5886.87	-104390.18	-614530971.55
x2:	941.90	0.00	0.00
x3:	1878.18	-8.64	-16227.48
x4:	587.04	0.00	0.00
x5:	125.00	-16.32	-2040.00
x6:	13.45	-10.78	-144.99
x7:	947.23	-9.56	-9055.53
x8:	559.16	127973.00	71557536.25
x9:	265.00	124603.00	33019795.00
x10:	1249.50	-21.41	-26751.80
x11:	1224.51	0.00	0.00
x12:	222.22	0.00	0.00
x13:	18.78	0.00	0.00
x14:	1596.45	0.00	0.00
x15:	18.75	0.00	0.00
x16:	1293.93	93012.00	120351211.35
x17:	50.00	104937.00	5246850.00
x18:	33.28	126062.00	4195958.92
x19:	0.00	0.00	0.00
x20:	114.94	142688.00	16401047.64
x21:	1465.48	131313.00	192436106.27
x22:	250.00	95978.00	23994500.00
x23:	101.21	240055.00	24295966.55
x24:	58.43	0.00	0.00
x25:	181.36	0.00	0.00
x26:	0.00	0.00	0.00
x27:	58.43	134533.00	7861396.31
x28:	568.34	-16.97	-9644.70
x29:	466.04	0.00	0.00
x30:	647.40	167301.00	108309985.98
x31:	34.10	-10.78	-367.60
x32:	214.47	0.00	0.00
x33:	1219.02	0.00	0.00
x34:	750.00	96378.00	72283500.00
x35:	35.53	0.00	0.00
x36:	74.91	0.00	0.00