COMPUTERIZED DAILY SIMULATION AND OPTIMIZATION IN A PETROLEUM REFINERY

by

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ABSTRACT

The essential purpose for the petroleum refineries is to produce more salable products depending on the crude oil characteristics, plant and product specifications and decisions on some variables. Therefore advanced computer-based control techniques and systems are finding increased use in refineries and petro-chemical plants to improve operating margins and product quality. Although computer-based controls have been used in process plants for many years, new techniques, utilizing advanced control strategies, allow further tightening of product specifications, reduction of energy usage, and improvement in the overall operation of a plant.

Implementation of these advanced concepts requires the use of advanced control concepts such as simulation and optimization techniques. These techniques allow control of process that historically have been difficult to control because of their interactive behavior.

In this study, it is intended to develop a program combining simulation and optimization models. For this purpose a simulation and an optimization models were constructed and realized as explained in chapter II and III. The aim is to show how an optimization and simulation models work together to determine the crude oil kinds and amounts to be used, production rates, and blending percentages in order to make profit maximum. Daily product

demands and prices,stock values and product specifications were used to construct these models. The linear optimizer package LINDO is also used to solve the optimiztion model created. The products of similar characteristics are combined, reducing the number to nine, for the simplicity. Results are shown at the end of chapter IV in the form of tables.

ÖZET

Petrol rafinerilerinin temel amacı, ham petrolün karakteristik özelliklerine, firma veya ürünlerin özelliklerine ve bazı değişkenler üzerine verilen kararlara bağlı olarak daha çok satan ürünleri üretmektir. Bu nedenle bilgisayar destekli ileri kontrol teknik ve sistemleri rafinerilerde ve petro-kimyasal firmalarda geniş kullanım alanı bulmaktadırlar. Eskiden beri bilgisayar destekli kontrol teknikleri firmalarda kullanılmasına rağmen, gelişmiş kontrol stratejilerini sağlayan yeni teknikler, ürünün spesifikasyonlarına daha çok uygun olmasına, enerji kullanımının azaltılmasına ve fabrikanın genel operasyonlarında gelişmeye yardım etmektedirler.

Simülasyon ve optimizasyon gibi gelişmiş kontrol tekniklerinin uygulanmasına dayanan bu yeni gelişmeler ile eskiden kontrol edilmesi zor olan prosesleri kontrol etmek mümkün olmaktadır.

Bu çalışmada, simülasyon ve optimizasyon modellerini birleştiren bir program geliştirilmeye çalışılmıştır. Bu amaçla II. ve III. bölümlerde açıklandığı gibi bir simülasyon ve bir optimizasyon modeli kurulmuştur. Amaç karı maximize edecek ham petrolün miktarını ve türünü, üretim hızlarını karışım yüzdelerini belirlemek için simülasyon ve optimizasyon

modellerinin birlikte nasıl çalıştığını göstermektir. Modellerin oluşturulması için ürünlerin günlük talep ve fiyatları, stok değerleri, ürün spesifikasyonları vs. kullanılmıştır. Optimizasyon modelinin çözümünde ise LINDO paket programı kullanılmıştır. Basitlik olması amacıyla aynı karakteristik özelliklere sahip ürünler birleştirilmiş ve sonuçlar IV. bölümün sonunda tablolar halinde gösterilmiştir.

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CHAPTER I

1. Introduction

The development of new processes in the chemical industry, especially in a petroleum refinery is becoming more complex and increasingly expensive. If the research and development of the process can be carried out with confidence the ultimate design will be more exact and the plant will operate more economically. Since petroleum processes and petroleum refineries are main inputs to the process industry, petro-chemical processes have a significant place in process production.

The production of gasoline, diesel oil, fueloil, naphtha and others depends on many factors, such as special characteristics of a crude oil, special conditions of a refinery, production decisions on some decision variables like blending amount etc. The relationship of all factors can be explained by constructing a model, a linear one, with easily and more confidence. As a result of increasing environmental influences on the industrial world, to make an adequate and confident model is also more important no matter what kind of model should be constructed, quantitative or unquantitative. Because most of the time it is impossible to see the environmental influences on the factors, variable influences of the model when they changed etc. in a quantitative model.

Considering variable demands, uncertain performance characteristics, poorly forecasting future and so forth, a simulation model can be more suitable than the others, because simulation in an oil industry involves the complex situation into a simpler and more convenient form which can be observed at leisure without some of the irrelevant and troublesome side effects which might accompany the original complex situation.

Many process optimization problems in current industrial interest have as their purpose the economic evaluation of proposed processing schemes. Such problems usally involve an objective function which represents some economic criterion and a set of constraints which represent overall engineering design relationships. This means of optimization in the chemical process industries infers selection of equipment and operation condition for the production of a given material (here crude oil) so that the profit will be a maximum. In other word, the problem of the optimal process design and plant operation involves both (i) determination of the optimal process configuration and (ii) determination of the optimal process parameters within a given configuration [1]. The first task requires the selection from a very large number of the classes of units, the best choice and sequence of the processing units.

The second task which is the determination of optimal process parameters within a given configuration is a more immediately tractable problem and has received a great deal of attention in the literature. Both Rudd and Watson, together, [2] have discussed possible means of incorporating optimization procedure into plant simulation packages so that this optimization can be done in a routine systematic way. This shows that the use of both quantitative and unquantitative models together will be more significant for more confidence. The important point is that the definition of the decision variables and the structure of the model used should be appropriate in terms of data available.

Because of the complexity of production processes and time limitation, solving every model manually is not economically feasible. Therefore, the computing power of computers are needed. Computers have been used as tools of computation since 1960. In the petroleum refinery to solve production and process problems to make more profits with a less cost and yield product with a quality, computers have been used for both optimization and simulation models. Powerful digital computers which provide alternative methods for solving more complicated problems, especially those in optimization study, are now available. So computing with computer continued its steady advance into the petroleum field during the past years. Earlier models, especially mathematical ones, could be constructed for only a small company with a small production rate. [3] Changes in inside and outside conditions could not be seen and followed easily. Even adding and evaluating new conditions and constraints were also difficult. By the time new techniques were carried out, those problems were eliminated. Recent advances in mathematical programming techniques and the ubiquity of digital computers have created great interest in the optimization of the complex chemical processes. In our study simulation and optimization models for TUPRAS Petroleum refinery were constructed and realized.

TUPRAS refinery located in Izmit is one of the largest industrial plants in Turkey with about 10 million tons of crude oil processing per year. It has the most complex processing structure of all refineries in Turkey. Yearly production rate of the refinery on some products are roughly given below. [4]

1.1 million ton gasoline per year

2.9 million ton diesel per year

3.8 million ton fueloil per year

In this plant dozens of different kinds of crude oil are processed,40 byproducts and 35 final products are produced by 3 crude oil processing units,2 FCC units, 3 Platformers and other necessary plants.

In a plant with this complexity conditions, a computer-aided quantitative model for production planning and chemical processing is needed. However, when a linear model constructed for TUPRAS run on a mini computer, it takes about half an hour to bring out solutions. Therefore both a simplified linear model and a simulation model were constructed and computerized to make daily decisions for producing nine important products namely light cracked gas, LPG, naphtha, gasoline, kerosene, diesel, coke, HVGO, fueloil. It should be noted that the product HVGO and coke normaly are not the final products. But they are store in the tanks to be used by the another refineries and petro-chemical industry. Therefore they are assumed to be the final products.(The product coke is also heated before the use). With these models it is possible to look after daily production and determine blending amounts and follow product demands, product and crude oil prices, export and import positions in the desired conditions. Making and constructing these models will be discussed further in detail.

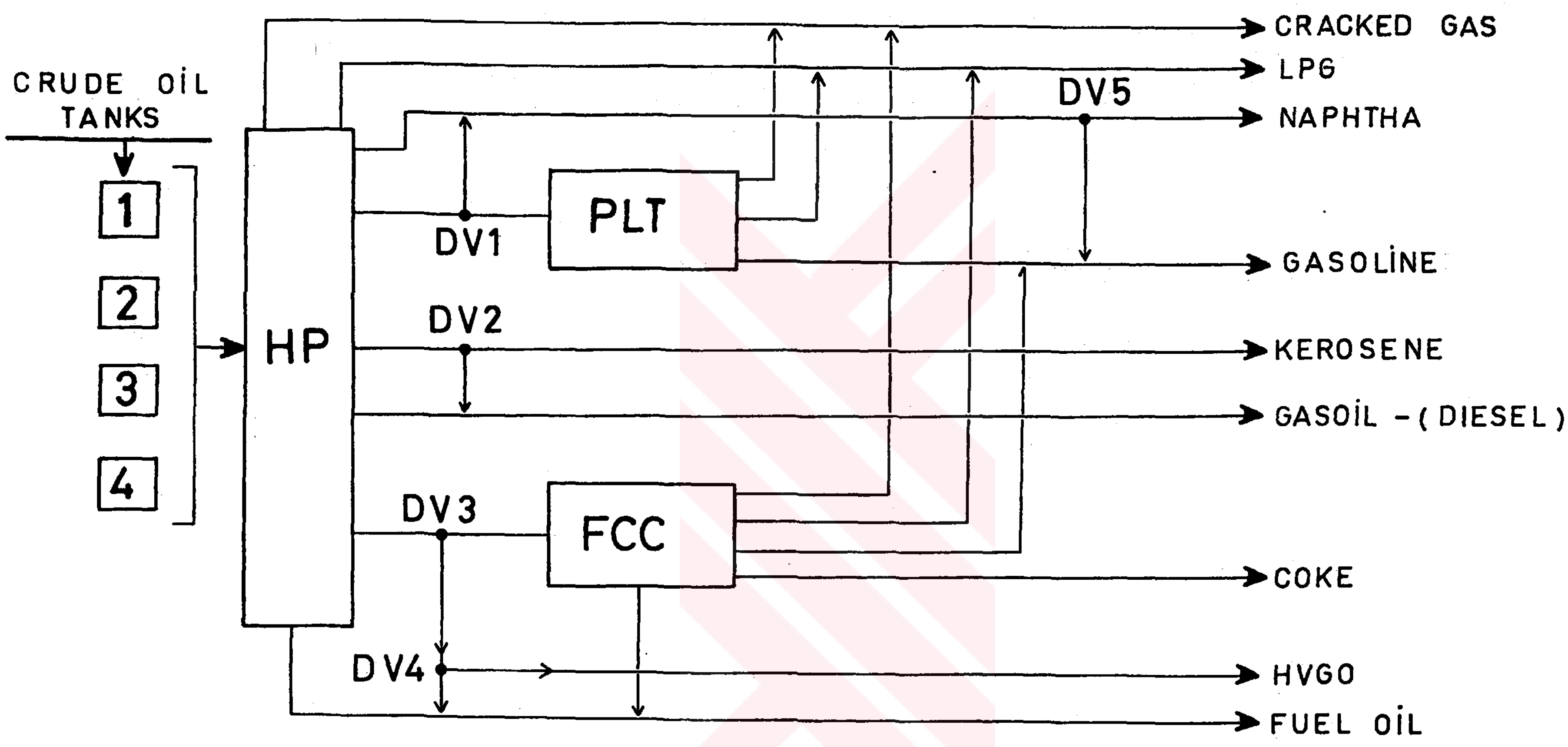


Figure 1- Simulation model for an HP, PLT, FCC combination.

CHAPTER II

SYSTEM AND SIMULATION MODEL

1. Analysis of the system

In our study there is no further research and investigation on the techno-chemical aspect of the petroleum processes. But just to give an idea, the process is reviewed here in a general form. More information can be found in the books and papers about the petro-chemical processes.

Because of wide differences in crude oil kinds, it is found that processing methods differ. It may be safely said that no two plants employ exactly the same processing scheme. What may be a perfect method of handling one type of crude oil may be inadequate for the others. The refining of oil is also an economic problem. The value and the accesibility of the raw stock, the products and the possiblity of marketing them, the yields of products to be expected, and the cost to process the stocks are the factors which promote the choice among the different processing plans. Generally there are three kinds of processing units in the plant, as mentioned above.

1) Crude oil processing units denoted as HP.

2) Platformers denoted as PLT.

3) Cracking units denoted as FCC.

1.1 General processing in crude oil processing units (HP)

In the crude oil processing units, different kinds of crude oil are separated into seven or eight different products. The most widely used method of separating petroleum products is distillation. Hence the products should be compared with one another in the order of their boiling ranges, the crude oil is heated for separating purpose [5]. Figure-1 indicates the relation among the raw materials, the intermediate refinery stocks, and finished market products of the specified company. The products obtained by distillation are called raw products and most of them can not be sold until they have been further refined.

Raw gasoline and naphtha are often treated with chemical agents such as caustic soda, copper chloride, or doctor solution. Naphtha can be catalytically reformed into high octane gasoline. Kerosene usually requires only a sweetening treatment, but for fine colors acid treatment or filtration is used. Diesel fuel, distillate fuels, gas oil and residual fueloil are usually sold without any treatment. Heavy naphtha and heavy vacuum gas oil are processed in platformers and cracking units respectively [5] . Transmission pumps, heat exchangers, furnaces , distillation coloumns are the main equipments for the crude oil processing units. All units are numbered. there are three crude oil processing units namely HP-2, HP-5, HP-25 in the plant studied here.

1.2. Platformers (PLT)

These units are the naphtha hydrotreating units. Heavy naphtha (called HSRN) is separated into LPG, gasoline, and natural gas. For this purpose, heavy naphtha is passed through hydrogen gas by some chemical reactions to remove hydrogen sulfide and other components [6]. Three platformers are also numbered as PLT-3, PLT-6, PLT-36

1.3. Cracking processes and cracking units (FCC)

Cracking means the decomposition of heavy or high-boiling oils into lighter products by exposure to a high temperature. At temperatures exceeding about 360 C materials such as gas oil, fueloil, and tars are decomposed into gas, gasoline, coke, and a residue of heavy material (cracked fueloil). Catalytic cracking, as well as thermal cracking, has been widely used since 1941. It differs from the thermal cracking mainly in the introduction of an observant type catalyst which holds the asphaltic or tarlike products of cracking on the surface of the catalyst in the form of coke. At the same time the octane number of catalytic gasoline is higher with the result that catalytic cracking is now absolutely necessary in meeting octane number requirements. the large volume of olefine gases produced in catalytic cracking requires extensive gas recovery and purification systems, and the conversion of these gases into salable products such as polymer gasoline, alkylate gasoline, synthetic rubber, LPG etc [5]. In the plant under study, two FCC cracking units namely FCC-4 and FCC-7 are in use.

1.4. Final products

Again referring to figure-1, after processing all petro-chemical reactions and blendings with certain values of decision variables, nine final products come out for industrial and civil consumption. In the reality number of final products exceeds 30. In this simplified approach, products of similar characteristics are combined, reducing this number to 9. These products are ;

Cracked gas - household and industrial fuel,
LPG - Liquified petroleum gas,
Naphtha - paint thinners stocks for the blending motor fuels, petrochemical feedstock,
Gasoline - fuel for internal combustion engines,
Kerosene - burning oil for household lamps, jet fuel or gas turbine engines and for rockets,
Diesel - fuels for industrial and household furnaces

and diesel engines,

Coke - solid industrial fuels, (see page 5)

HVGO - heavy vacuum gas oil, (see page 5)

Fueloil - industrial fuel.

2. Simulation model

2.1 Introduction to simulation

Process engineering problems can be extremely complex because they can involve the need for simultaneously accounting, uncertain data component failure, and more importantly external and internal variability such as cost and demand positions. Methods of simulation have been refined to the point where they are useful in interpreting these situations.

Although the concept of simulation is not new for many engineering fields, its importance has increased with the improvement of the digital computers and their ability of handling large quantities of information rapidly. The capability of the digital computers to solve large sets of equations rapidly can be used effectively in the design of simulation of the petroleum processes. That is why simulation is an attractive tool for oil industry. In the table below, the simulation of a petroleum process is to compared to the design of the process in terms of their inputs and outputs.

	Design	Simulation
Input variables....>	known	known
Decision variables.>	to be determined	known
Output variables...>	known	to be determined

Simulation of a petroleum process is to determine the output of a process for a given set of inputs and decision variables. A simulation model can be executed over and over again by varying the values of the decision variables until the desired outputs are reached. This means that a simulation model could be used as a design program if necessary.

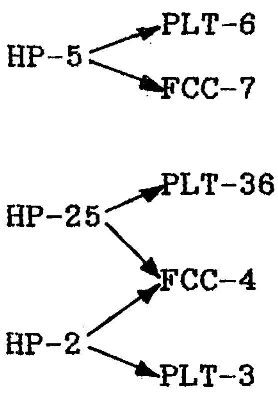
The aim of this thesis is to prepare programs which call proper computation subroutines for a given process flow sheet as in figure-1

Figure-1 is the simplest model of an oil refinery. Executive simulation model provides daily decision on producing more valuable and important yields to give an idea of the simulation of an oil industry.

2.2. Definition of the Model

As seen in figure-1, simulation model of a certain company involves HP-PLT-FCC plant combinations to produce certain products.

In the plant mentioned in chapter I, three plant combinations exist as follow;



where HP represents a crude oil processing unit, PLT represents a platformer unit and FCC represents a cracking unit with their corresponding plant numbers, as explained earlier.

2.3. Decision variables (DV)

Decision variables for the simulation of this model are the blending amounts. There are five decision variables, denoted as DV, for one plant combination. These decision variables are explained below. (See figure-1)

DV1 : Percentage of the blending amount of oil from the product HSRN (Heavy naphtha) obtained from the crude oil processing units, to the product napthta obtained from the crude oil processing units in the same way.

DV2 : Percentage of the blending amount of oil from the processing units, to the product diesel, obtained from the crude oil processing units.

DV3 : Percentage of separeted amount of oil from crude oil processing unit to the products HVGO and fueloil, obtained from the same oil processing unit.

DV4 : Percentage of separeted amount of oil from HVGO (final product) to the final product fueloil.

DV5 : Percentage of the blending amount of naphtha from the HP units to product gasoline obtained from FCC and platformers. (see figure-1)

3. Inputs and Outputs of the Plants

3.1 Inputs to the Crude Oil processing Units

There are four crude oil tanks numbered 1-4 in this study. Each tank may contain any kind of crude oil. Certain amounts of these crude oils are the main inputs to the crude oil processing units. Now the plant mentioned earlier has twelve kinds of crude oil. See appendix C for more detail information about those.

3.2. Outputs From The Crude Oil Processing Units

Referring to figure-1, any kind of crude oil taken to the crude oil processing units will contribute to produce eigth kinds of products, according to the certain percentages given in appendix A. Products are cracked gas, LPG, naphtha, HSRN, kerosene, diesel, HVGO, fueloil. Some of these products is going to the tanks of final products while some of them are processed again . As explained before some amount of HSRN goes to the platformers and some amount of HVGO is taken to the FCC cracking units for processing. These amounts are decision variables and defined by the operator during the simulation .

3.3. Outputs From The Other Plants;

The amount coming from the crude oil processing units to the platformers is processed and three products come out namely, cracked light gas, LPG, gasoline. Meanwhile, the certain amount in FCC cracking units contributes to produce five different products namely, cracked gas, LPG, gasoline, coke, fueloil. These processes depend on some percentages given in Appendix B. Data structure of the simulation model will be discussed later in detail.

CHAPTER III

OPTIMIZATION MODEL

1. Introduction

Many process optimization problems of current industrial interest have as their purpose the economic evaluation of proposed processing schemes like figure-1. Such problems involve an objective function which represent some economic criterion and a set of constraints which represent over-all engineering design relationships.

Detailed descriptions of the physical and chemical phenomena which occur within the individual plant components usually is not included in such models. Typically problems of this type are described by continues linear and nonlinear mathematical models of moderate dimensionality containing both equality and inequality constraints.

Because of the capability of the digital computers to hand large amounts of information, it is possible to solve large problems by optimization techniques. Some problems with larger number of constraints and variables can be simplified by decomposition techniques [7]. Because of the time limitation and economic conditions, the realities of process industry are such that answers to the questions must be reached quickly and easily. Thus a need exists for one or more mathematical techniques which will allow process optimization problems to be solved with minumum effort as well as computational efficiency.

One of the classes of which frequently satisfies these requirements is linear programming techniques. This will be discussed later in detail.

Benefits from the optimization must come from improved plant and business performance. The specific sources can vary widely for a variety of reasons. In general terms the revenue come from improved yields of valuable products, reduced energy consumption and higher processing rates etc. Optimization may also influence reduction in a number of other operating costs including maintenance equipment wear and staff utilization. The engineering benefits come from improved process trouble shooting and assistance in making quicker and more accurate decisions.

In our study, under these objective of benefits, a linear model was constructed and solved to show how an optimization technique works in the petroleum refinery. Constructing the model, solving it by LINDO (Linear programming model solver), reading solutions and creating solution tables are all performed by the computer programs.

2. Types of Optimization

Jenson and Jeffrays clasified optimization as follow;

" Optimization in the petro-chemical field can be divided into two categories as Himsworth have defined in 1962

Static optimization

Dynamic optimization. " [8]

2.1. Static Optimization:

Static optimization is the establishment of the most suitable steady-state operation conditions of the process. In other words static optimization is the optimization of the process paremeters such as production amounts, selection of the crude oil to be processed, the blending percentages, temperature, pressure, flow rates etc. They would be established by setting up the best possible mathematical model of the process which is maximized by some suitable techniques to give most favourable operating conditions. We ignore some special specifications of the products for the simplicity.

2.2. Dynamic Optimization:

Dynamic optimization is the establishment of the best procedure to determine the optimum process structure. It requires a knowledge of the dynamic characteristics of the equipment and also necessitates predicting the best way in which a change in the process conditions can be corrected. In reality it is an extension of the automatic control analysis of the process.

In addition to above type of optimizations there are the operational research aspects which have been applied extensively in the process industry in recent years.

3. Constructing and Solving the Model

The model to be introduced has the following basis

i. Production demand pattern ,

ii. Crude oil amounts ,

iii. Product specifications ,

iv. Cost of crude oil kinds ,

v. Price of the products ,

vi. Yield data on crudes , blending indices ,

vii. Existing plant and tank capacities .

Three crude oil processing units, three platformers and two FCC cracking units described in previous chapters are incorporated to construct the model. This model shows how an integrated oil company can be represented in linear programming form which will be solved for maximum profit. The model constructed here has 57 variables and 51 constraints. This model will be solved by LINDO which is a linear programming package with the capability of solving

4500 variables with about 800 rows. No political and social criterion are implemented in the model. Special specifications of the products are also omitted for the simplicity. For the kinds of crude oil, HI, SR, ES, the model created is introduced in appendix D.

4. Variables

To make the model linear the amount passing through each pipe is taken as decision variables in addition to the export and import amounts and final stock amounts. In other word, the model will determine the optimum production amount, final stocks, export and import amounts and the amount blended. If the final stock of any product exceeds the stock capacity of that product, the excess amount will be exported by the model whilst necessary will be imported in the same way when the inital stock and production amount do not satisfy the demand of that product. Otherwise export amount or import amount of that product will be zero. Export variables reprepesent the amount to the out of the company not out of the country. And import variables represent the amount from the out of the company not out of the country.

5. Mathematical Statement of the Problem

In our study an example of linear model was constructed. The apparatus shown diagramatically in figure-1 and some other data given in appendixes are to be used for the information required. Full form of the model is in appendix D. General linear model form is as follow ;

MAX Z=P*X

$G1_z*X = B_z$ {z=1.......m1}

$G2_i*X = 0$ {i=1.......m2}

$G3_t*X <= C_t$ {t=1.......m3}

$G4_k$*(some xk's)<= or >= max(min) CAP_k

X_j>= 0 {j=1......n}

where

P: price vector including sales prices, export and import prices and the price of three crude oil kinds.

X: variable vector such that X=(x1,.............,xn)

n: number of variables in the objective function;

m1,m2,m3 : number of the first, second and third types of constraints; respectively

k: number of plants ;

B_z: (demand-initial stock) of the z th product ;

C_t: tank capacity of the t th product;

CAP_k : maximum or minimum capacity of the k th plant ;

Z is an objective function such that

Z={- crude oil cost + final stock values + Export values - import values }

will be maximized. Here final stock values represent the values of the final stocks in terms of sales prices, export and import values also represent the values of export and import amounts with their related prices.

G1 , G2 , G3 , G4 are different types of constraints ;

$G1_z$ type of constraints are demand and production constraints such that ;

$$\text{total production of the z th product} - \text{Export amount} - \text{Final stock} = \text{demand of z th product} - \text{initial stock of z th product}$$

in the case of import ,import amount is added to the left hand side of the equation instead of the export amount. The total production of the z th product is sum of the production amount of the z th product from the three plants (HP-PLT-FCC). These constraints will contribute to determine the final stock, export or import amounts.

$G2_i$ type of constraints are balance and equality constraints such that;

$$\text{Produc. of i th item from a plant} - \text{Blending amount from product i to another} - \text{final product} = 0$$

These type of constraints involve one plant combination not all the plants and blending amounts related to that combination of the plants.

e.i.(HSRN from HP-5)-(HSRN to PLT36)-(HSRN to NAPHTHA) = 0

$G3_t$ type of constraints are also capacity constraints Such that ;

$$\text{final stock of t th product} \le \text{capacity of t th product}$$

Capacity of t th product is the stock capacity of the t th product. These constraints will allow to export the amount of exceeding stocks.

e.i. (final stock of Naphtha)<=(stock capacity of Naphtha)

$G4_k$ type of constraints are plant capacity constraints .

Such that ;

crude oil amount will be used in k th plant $\leq$ Max. capacity of plant k

Maximum or minumum Capacity of any plant is the maximum or minumum crude oil processing amount of that plant. So these type of constraints will control the processing amounts so as not to exceed the maximum processing amounts or be less then the minumum processing amounts of the plants.

e.i.(the amount to be processed in HP-5)<=(max. processing capacity of HP-5)

CHAPTER IV

DATA STRUCTURE

In order to make a simulation or optimization in a petroleum refinery, some computer programs have been created. These programs call some subroutines which are able to read the data files and create the results so as to contribute to decision making.

1 . Types of Files

There are two types of files included in this study.

i. Program files ,

ii. Data files ,

1.1. Program files

Six program files have been created during the study. They are able to read the data files, and make some calculations to create solutions which are saved in the other data files. These program files are explained below;

1.1.1. PROGX .

This file is used if only simulation will be made. User determines the blending percentages and the amounts to be taken from the desired crude oil tanks to the specified crude oil processing units. Program provides the kind and the amount of the crude oil in every tank to make a decision. Program also gives defalut blending percentages used before. Program, after using these data and reading the kind of crude oil percentages from the data file called HP.DAT, makes simulation to determine the final products, the products from the plants, the final stocks, the export and import amounts and the crude oil amounts remaining in the crude oil tanks with their kind names. Results are saved in the specified data files that will be explained later.

1.1.2. PROGY .

This program file is executed after either simulation or optimization. It reads the solutions created by another programs and creates tables which represent all of the solutions to the user. These tables are representing;

i. Products from the crude oil processing units with their volume percentages .

ii. General products from the plant combinations with the their total production amounts .

iii. Blending positions with the default values and the amounts of the final products

iv. The final stocks, demands, the export and import amounts and the plant charges.

v. The crude oil kinds available and their amounts in the tanks.

1.1.3. DEMPRICE .

This program file is applicable if there are some changes on the daily demands and/or the prices of the products, the crude oil kinds, the export or import prices of the product. It is always possible to have these changes. This file can update new values by executing it in both cases, optimization or simulation.

1.1.4. TANK .

This program file is executed if there is any shipment to the company. It shows the amount and the kind of crude oil in every tank and ask whether there is any unloading of oil to the plant or not.

1.1.5. LP

This file is executed in the case of optimization only. It creates the linear optimization model by reading the initial stocks, daily demands, current prices, and crude oil specifications. It also asks the number of the tank in which the crude oil is planned to be taken for each crude oil processing unit. (See chapter V).

1.1.6. SOLUTION .

This program file is also executed in the case of optimization only. It reads the solutions of the model created by LP and solved by LINDO. It also reads the crude kinds used and makes some calculations (simulation) to determine the products from the plants and the crude oil amounts remaining in the tanks according to the solution by LINDO. The final stocks and another solutions computed are saved in the data file called PROD.DAT.

1.2. Data Files

There are three kinds of data files used by the programs. Some files are not changed by the user, some files are updated after every simulation, and others are updated by the user if necessary.

These data files are explained below.

1.2.1. HP.

This data file includes the crude oil kind percentages from the crude oil processing units to the other plants and to the stocks of the final product. If there are no technical and chemical changes, data included in this file may not be changed (See appendix A).

1.2.2 . PERCENT.

This data file contains the percentages of the final products from the Platformers or FCC cracking units. Changing these data are also depend on some technical changes (See appendix B).

1.2.3 . CAPACITY .

This data file contains the stock capacity of the final products. Data in this file can also be changed under the technological changes (See appendix E).

1.2.4. PLANTCAP.

Data for maximum and minumum processing capacity of any crude oil processing unit, platformer or FCC cracking unit are contained in this file. If there is any change according to the plant conditions and the company policies, these data can be changed by entering to this file (See appendix E).

1.2.5. PROD .

This data file contains the amount of the general products from the plants, the plant charges, total production amount of any plant combination, the export and import amounts and the final production amount of every product. These data are updated after every simulation or optimization by subroutines. Users do not make any change on these data.

1.2.6. STOCK .

This file contains the amount of the initial stocks of the products at the begining of the simulation or optimization. After the simulation or optimization the final stocks are saved in this file. Because these final stocks will be the initial stocks of the next experiments. These data are also updated by the programs after every simulation or optimization.

1.2.7. MODELX . and SOLUX .

Data file MODELX includes the model constructed by the program LP. It is solved by LINDO and solutions are saved in the data file named SOLUX . The program files read these solutions and makes those available for the another program files (See appendix D).

1.2.8. EIPRICE . , PRICE . , KPRICE.

The data file EIPRICE contains export and import prices of the products. The data file called PRICE also contains the sales prices of these products. The price of the crude oil kinds are included in the data file KPRICE in the same way. The data in these files can be changed and updated by executing program file called DEMPRICE if necessary.

1.2.9. KIND2 . , VALVE . , TANK .

The amounts of the crude oil and their kinds available in the company's tanks are contained in the data file called TANK. On the other hand, default blending percentages and selected ones are stored in the files VALVE and KIND2 respectively.

1.2.10. DEMAND .

This data file contains the current daily demand of all the products. If there is any change on the demand of any product , program file DEMPRICE can be executed to update the data (See appendix E).

1.2.11. NAME .

This data file involves the names of the products which are currently produced in the plant under study.

2. Batch File Processing (SIMMOD.BAT)

Batch file used in this study has two options. One of them is about choosing whether there is any shipment to the company or not. The other is about making simulation or optimization. Batch file firstly executes the program file named TANK to control unloaded and shifted amounts. And then executes the program file called DEMPRICE for controling any price and demand change. After that the program asking if optimization will be made is executed. then in the case of optimization, program files namely LP, SOLUTION, and PROGY are executed consecutively (see figure-2). Otherwise program files PROGX and PROGY (see figure-3) are executed to create results and tables.

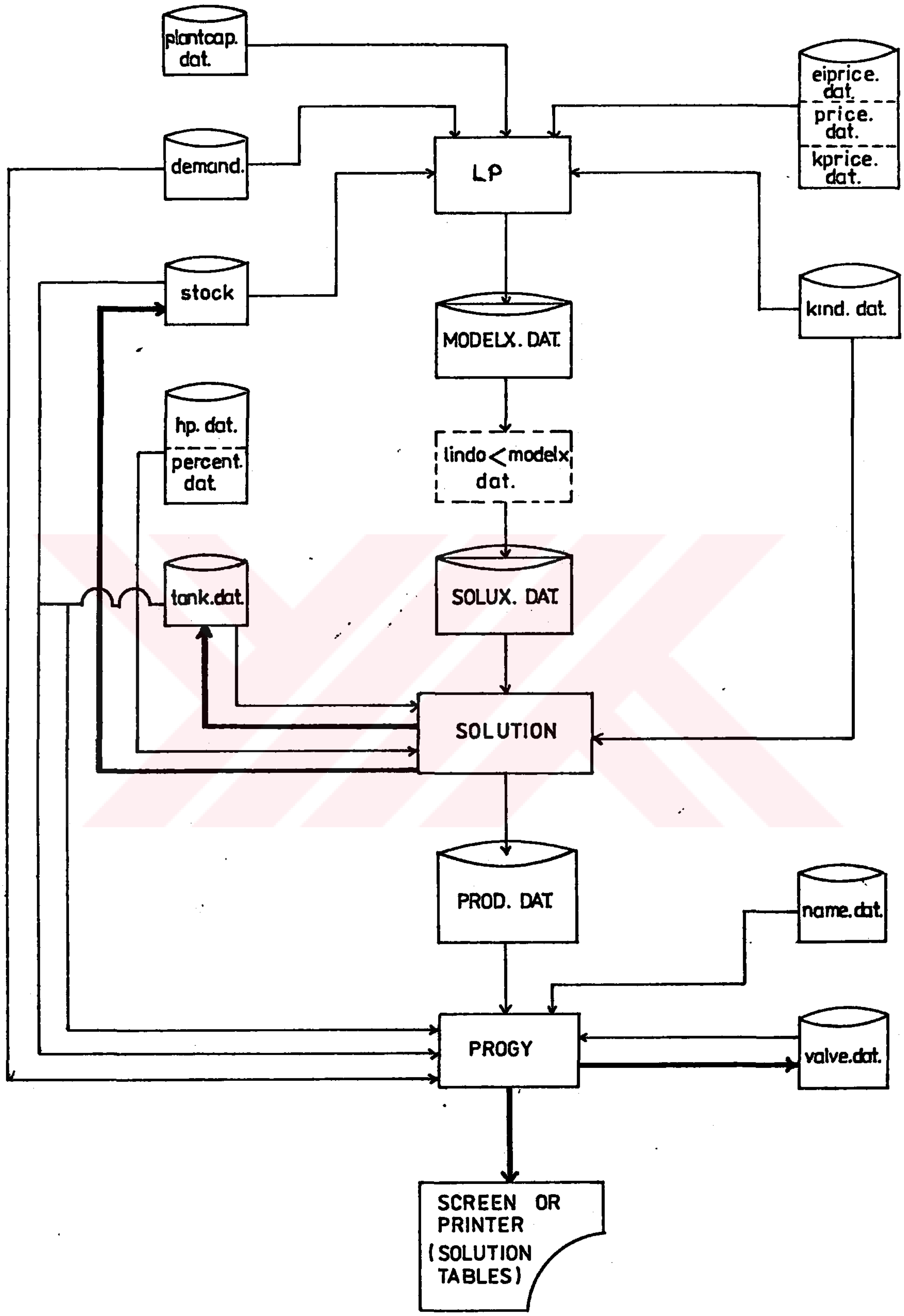


Figure 2 _ The configuration of the data structure of optimization model.

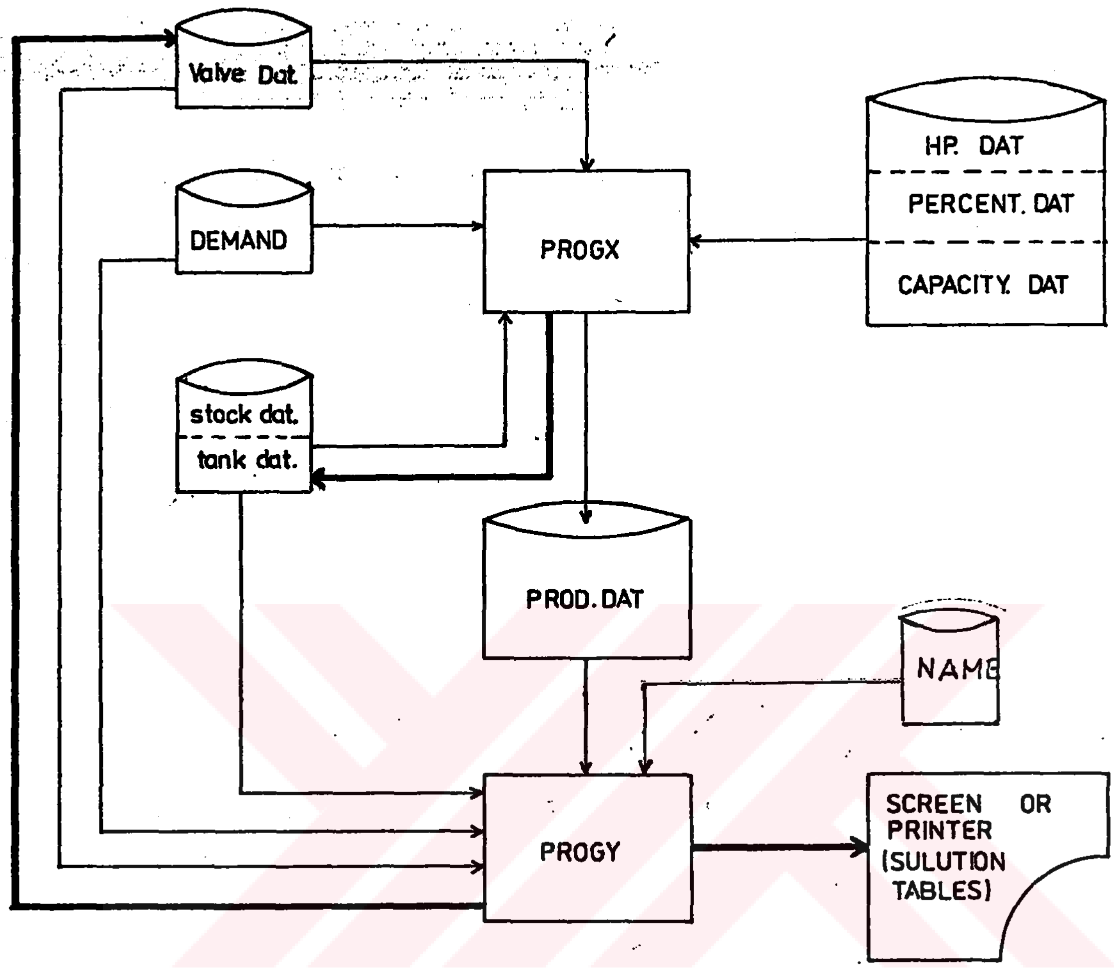


Figure 3 _ The configuration of the data structure of the simulation model.

CHAPTER V

PROGRAMMERS GUIDE AND SOLUTIONS

This chapter explains the use of the computer programs to make both optimization and simulation which are the cases in our study. In other word, this chapter provides the detailed information about entering the data and creating the solutions.

First of all, batch file called SIMMOD should be run for both cases. This file executes directly the program file called TANK. This program file asks whether there is any shipment to the plant or not.

IS THERE ANY SHIPMENT TO THE COMPANY (Y/N) ?

The answer to this question is 'Y' or 'N'. If 'Y' is entered from the keyboard this means there is some unloading to the plant. Then the program asks about the shipment amount and the tank number to which the shipment will be made. If the tank which is specified is empty then the program asks the kind of crude oil shifted. In the case of 'N', the batch file asks another question

DO YOU WANT TO MAKE AN OPTIMIZATION (Y/N) ?

No matter which case the user selects, the batch file executes the program file which is called DEMPRICE. This program file is used to control any change on the products and the crude oil prices and demands. The screen will be as below;

```
Do you want to make any change  on.....

        1- The product demands
        2- The product prices
        3- The crude oil prices
        4- The Export/Import prices
        5- No changes


        Your choice < >
```

Now it is easy to make any change just by pressing the related number. If there is no change the choice 5 should be entered.

In the case of 'Y', after DEMPRICE is executed, the batch file executes the program files which are called LP, LINDO, SOLUTION, and PROGY consecutively. The program file LP asks the user to determine the tank number from which crude oil will be taken for the specified crude oil processing units. The program also shows the amount of the crude oil in every tank with its kind. User should pay attention that the amount of crude oil in the specified tank should be more than the maximum processing capacity of the related crude oil processing unit. As mentioned earlier this program file creates the linear model for optimization. Then LINDO solves this model, creates solutions and writes them into the data file called SOLUX. The program file SOLUTION is used to read the solution of the linear model. And it makes simulation to determine the values of the decision variables. Next, the program file PROGY is executed for creating the solution tables for both cases, optimization and simulation.

In the case of 'N' the batch file executes the program files namely DEMPRICE, PROGX, PROGY in order. After making necessary changes (if any), the program file PROGX is executed to determine the blending amounts. The program also provides default values of the blending percentages. User can determine the default values for the new simulation just by pressing the RETURN key. Otherwise new values should be determined from the keyboard. After that, the program asks the taking amount of crude oil to the processing units with their related tank numbers and kinds. In other words user can determine the amount to be processed and the tank number from which crude oil will be taken for every processing unit. The program makes a simulation and creates solutions. The Program file called PROGY then read these solutions and creates tables. The screen will be the following;

```
1- Outputs from the crude oil processing units.
2- Genaral products from the plants
3- The blending amounts and final products
4- Available crude oil kinds and their amounts
5- The final stocks/demands/exp./imp. positions
6- Print solutions
7- Quit

Your choice < >
```

Any table can be seen on the screen just by pressing the corresponding number. The contents of these tables are explained in the previous chapters. If a hardcopy of these tables is desired then the choice 6 should be entered. In this choise the program asks if user wants to change paper between tables or not.

DO YOU WANT TO CHANGE PAPER AFTER EVERY TABLE (Y/N) ?

Answer is 'Y' or 'N'. In the case of 'N' program provides a hardcopy of all the tables consecutively. Otherwise it waits for changing paper after creating a hardcopy of every table. The structure of the tables are given below.

Table 1. Outputs from the crude oil processing units

Products	HP-5		HP-25		HP-2	
	amount (m3)	volume (%)	amount (m3)	volume (%)	amount (m3)	volume (%)
Cracked Gas	8426.00	----	3300.00	----	0.00	----
LPG	269.00	3.80	237.00	4.09	158.00	2.60
Naphtha	1027.00	14.30	800.25	13.80	873.00	14.39
Kerose	1120.00	15.81	1027.50	17.72	567.00	9.35
Diesel	1330.00	18.77	1125.00	19.40	1580.00	26.04
HVGO	1440.00	20.32	960.00	16.55	2275.00	37.50
Fueloil	900.00	12.70	862.50	14.87	154.00	2.54
HSRN	1000.00	14.11	787.50	13.58	460.00	7.58
TOTAL	7086.00	100.00	5799.75	100.00	6067.00	100.00

Table 2. General products from the plants

plants -->	HP-5	PLT-6	FCC-7	TOPLAM
CHARGE (m3)	10000.00	900.00	1267.00	
Cracked Gas	8426.00	16200.00	69696.00	94332.00
LPG	269.00	62.00	430.00	761.00
Naphtha	1027.00	0.00	0.00	1027.00
Gasoline	0.00	738.00	608.26	1347.16
Kerosene	1120.00	0.00	0.00	1120.00
Diesel	1330.00	0.00	0.00	1330.00
Fueloil	900.00	0.00	172.97	1072.97
Coke	0.00	0.00	152.06	152.06
HSRN	1000.00	0.00	0.00	1000.00
HVGO	1440.00	0.00	0.00	1440.00

	HP-25	PLT-36	FCC-4	TOPLAM
CHARGE (m3)	7500.00	708.75	864.00	
Cracked Gas	3300.00	3189.00	12960.00	19449.00
LPG	237.00	34.39	80.44	352.38
Naphtha	800.25	0.00	0.00	800.25
Gasoline	0.00	576.71	282.10	858.81
Kerosene	1027.50	0.00	0.00	1027.50
Diesel	1125.00	0.00	0.00	1125.00
Fueloil	862.50	0.00	342.58	1205.08
Coke	0.00	0.00	69.12	69.12
HSRN	787.50	0.00	0.00	787.50
HVGO	960.00	0.00	0.00	960.00

	HP-2	PLT-3	FCC-4	TOPLAM
CHARGE (m3)	10000.00	404.80	1956.50	
Cracked Gas	0.00	9180.00	29347.50	38455.00
LPG	158.00	24.13	182.15	364.28
Naphtha	873.00	0.00	0.00	873.00
Gasoline	0.00	336.79	638.80	975.59
Kerosene	567.00	0.00	0.00	567.00
Diesel	1580.00	0.00	0.00	1580.00
Fueloil	154.00	0.00	775.75	929.75
Coke	0.00	0.00	156.52	156.52
HSRN	460.00	0.00	0.00	460.00
HVGO	2275.00	0.00	0.00	2275.00

Table 3. The blending percentages and final products

	% Blending for HP-5	% Blending for Default	% Blending for HP-25	% Blending for default	% Blending for HP-2	% Blending for Default
Hsrn :	0.10	0.12	0.10	0.10	0.12	0.10
Kero :	0.10	0.10	0.10	0.06	0.13	0.30
Hvgo :	0.12	0.20	0.10	0.25	0.14	0.22
F.oil:	0.13	0.17	0.12	0.12	0.15	0.35
Lsrn :	0.14	0.18	0.15	0.15	0.10	0.18

Final Yields

Products	Amount	Products	Amount
Cracked Gas	152226.87	Diesel	4323.46
LPG	1478.61	Coke	377.70
Naphtha	2551.75	HVGO	505.54
Gasoline	3564.01	Fueloil	3207.80
Kerosene	2426.04		

Table 4. Available crude oil kinds and their amounts

Tank	kind	amount
1	LI	96666.67
2	HI	91544.00
3	IR	77676.67
4	ES	140768.00

Table 5. Summary table

Plants		Products	Stock	Demand	(+)/(-) Exp/Imp
HP-5	:10000.00	Cracked Gas	1000000.00	11500.00	1812.37(+)
PLT-6	: 900.00	LPG	0.00	3090.00	1611.40(-)
FCC-7	: 1267.00	Naphtha	20506.38	2400.00	0.00
-------		Gasoline	55604.00	4590.00	0.00
HP-25	: 7500.00	Kerosene	44902.84	2000.00	0.00
PLT-36	: 708.75	Diesel	0.00	8660.00	4336.54(-)
FCC-4	: 864.00	Coke	4799.78	1000.00	0.00
-------		HVGO	8751.39	400.00	0.00
HP-2	:10000.00	Fueloil	0.00	10909.00	7701.20(-)
PLT-3	: 404.80				
FCC-4	: 1956.50				

CHAPTER VI

CONCLUSION

To make a correct decision is very important in every industry. Therefore a lot of computer programs which provide the use of advanced techniques in every cases have been using for decision making. Under the importance of the decision making, a simulation and an optimization model for the petroleum industry were created by the computer programs in this study. They provide to make decisions on the daily production of the petroleum products. To follow the characteristics of these models, system was simplified as much as possible. Products which had similar characteristics were combined and the number of products were reduced to nine. The demand of any product was calculated by summing the demand of the products which had the same characteristics. In the same way, the sales price of any product was calculated by taking the average of the prices of the similar products.

It was observed that the system was very complex and to create the linear optimization model which represents over-all characteristics of the system and products was very difficult. This is true. Because most of the relations between the products are nonlinear. And some parameters like prices, demands and arriving of crude oils etc. are random. Even to run such models will take at least half an hour to create solutions. The number of the constraints and variables are much more to process these models in the personel computers. In order to solve these complex models the decomposition techniques may be adequate. In that approach, model may be solved for the similar type of constraints. Then results are combined according to the specified decomposition algorithm.

But the simplified linear model and the simulation model, together, for some valuable and important products were executed in a short time -three or four minutes- to help daily decision making about the determination of the blending amount of the products. Some special specifications of the products were omitted for the simplicity. Every day these two models can be run together to determine the values of decision variables such as export and import amounts of the products, final stocks and, production amounts etc. Results were illustrated in the form of tables.

APPENDIX A

CRUDE OIL PERCENTAGES IN THE OIL PROCESSING UNITS

(Note) First line of every kind represents crude oil percentages for HP-5 whilst second and third lines are for HP-25, HP-2 respectively.

LI

*	GAS	LPG	LSRN	HSRN	KERO	GAS OIL	HVGO	FUELOIL
*								
	0.14750	0.02230	0.10700	0.10000	0.14000	0.12400	0.16500	0.11200
	0.14750	0.02230	0.10700	0.10000	0.14000	0.12400	0.13510	0.12100
	0.14750	0.02230	0.10200	0.04300	0.05500	0.28500	0.01300	0.01700

HI

*	GAS	LPG	LSRN	HSRN	KERO	GAS OIL	HVGO	FUELOIL
*								
	0.84260	0.02690	0.10270	0.10000	0.11200	0.13300	0.14400	0.09000
	0.84260	0.02690	0.10270	0.10000	0.11200	0.13300	0.11700	0.11000
	0.84260	0.02690	0.10170	0.04600	0.05000	0.26000	0.20100	0.00122

SR

*	GAS	LPG	LSRN	HSRN	KERO	GAS OIL	HVGO	FUELOIL
*								
	0.00000	0.02200	0.10100	0.08700	0.11000	0.13800	0.15700	0.09800
	0.00000	0.02200	0.10000	0.08700	0.11200	0.13800	0.13500	0.11700
	0.00000	0.02200	0.09800	0.04000	0.05300	0.27400	0.23500	0.01100

LA

*	GAS	LPG	LSRN	HSRN	KERO	GAS OIL	HVGO	FUELOIL
*								
	0.00000	0.01900	0.11600	0.09500	0.13000	0.14700	0.14500	0.09800
	0.00000	0.01900	0.11600	0.09500	0.13000	0.14700	0.12000	0.11700
	0.00000	0.01900	0.11200	0.04900	0.06000	0.28500	0.21400	0.01400

MA

*	GAS	LPG	LSRN	HSRN	KERO	GAS OIL	HVGO	FUELOIL
*								
	0.00000	0.01200	0.09800	0.08700	0.11500	0.12900	0.15000	0.09500
	0.00000	0.01200	0.09800	0.08700	0.11500	0.13800	0.12900	0.11000
	0.00000	0.01200	0.09500	0.04200	0.05300	0.26900	0.22400	0.01200

```
HA
*    GAS      LPG      LSRN     HSRN     KERO     GAS OIL    HVGO    FUELOIL
*
   0.00630 0.02700 0.09300 0.07600 0.09700 0.11800 0.13500 0.07600
   0.63000 0.02700 0.09300 0.07600 0.09700 0.11800 0.11400 0.09200
   0.63000 0.02700 0.09000 0.03500 0.04500 0.22800 0.20000 0.01200

KR
*    GAS      LPG      LSRN     HSRN     KERO     GAS OIL    HVGO    FUELOIL
*
   0.84000 0.02080 0.13010 0.11380 0.13450 0.15010 0.12500 0.09500
   0.84000 0.02080 0.13010 0.11380 0.13450 0.15010 0.10600 0.11100
   0.84000 0.02080 0.12720 0.05530 0.06060 0.28190 0.17900 0.01100

IR
*    GAS      LPG      LSRN     HSRN     KERO     GAS OIL    HVGO    FUELOIL
*
   0.00000 0.00000 0.07200 0.08800 0.10500 0.32000 0.15500 0.02000
   0.00000 0.01580 0.09230 0.09550 0.12230 0.11900 0.11880 0.09710
   0.00000 0.01580 0.08730 0.04600 0.05670 0.15800 0.22750 0.01540

SB
*    GAS      LPG      LSRN     HSRN     KERO     GAS OIL    HVGO    FUELOIL
*
   0.42000 0.03900 0.15400 0.12500 0.15800 0.18500 0.14100 0.09400
   0.42000 0.03900 0.15400 0.12500 0.15800 0.18500 0.11000 0.11200
   0.42000 0.03900 0.14800 0.05800 0.08200 0.31700 0.16200 0.01500

ZR
*    GAS      LPG      LSRN     HSRN     KERO     GAS OIL    HVGO    FUELOIL
*
   0.21000 0.02900 0.14000 0.11700 0.13900 0.15900 0.13300 0.10200
   0.21000 0.02900 0.14000 0.11700 0.13900 0.15900 0.11500 0.11500
   0.21000 0.02900 0.13500 0.04600 0.07100 0.29800 0.18700 0.01300

YR
*    GAS      LPG      LSRN     HSRN     KERO     GAS OIL    HVGO    FUELOIL
*
   0.00000 0.02200 0.10000 0.07600 0.10200 0.12100 0.12400 0.10100
   0.00000 0.02200 0.10000 0.07600 0.10200 0.12100 0.12400 0.10100
   0.00000 0.02200 0.09700 0.03700 0.04600 0.23900 0.22000 0.01300

ES
*    GAS      LPG      LSRN     HSRN     KERO      LTDZ      SOIL     HVGO
*
   0.44000 0.03160 0.10670 0.10500 0.13700 0.15000 0.09800 0.15000
   0.44000 0.03160 0.10670 0.10500 0.13700 0.15000 0.11500 0.12800
   0.40000 0.03160 0.10730 0.03500 0.05900 0.28800 0.01800 0.22000
*
```

APPENDIX B

PROCESSING PERCENTAGES IN THE PLATFORMER AND FCC UNITS

	PLT-6			FCC-7				
	GAS	LPG	GASOL.	GAS	LPG	GASOL.	KOK	FUELOIL
H-5>	18	0.069	0.8210	55	0.34	0.48	0.12	0.1365

	PLT-36			FCC-4				
	GAS	LPG	GASOL.	GAS	LPG	GASOL.	KOK	FUELOIL
HP-25>	4.5	0.0493	0.8137	15	0.0931	0.3265	0.08	0.3965

	PLT-3			FCC-4				
	GAS	LPG	GASOL.	GAS	LPG	GASOL.	KOK	FUELOIL
HP-2 >	22.5	0.0596	0.8320	15	0.0931	0.3265	0.08	0.3965

APPENDIX C

CRUDE OIL KINDS

KINDS	DENSITY
LI : Light Iran	0.855
HI : Heavy Iran	0.870
SR : Sarrir	0.838
LA : Light Arab	0.852
MA : Medium Arab	0.871
HA : Heavy Arab	0.886
KR : Kerkuk	0.844
IR : Iraq (special)	0.878
SB : Saharan Blend	0.845
ZR : Zarzantine	0.817
YR : National	0.905
ES : Essider	0.835

APPENDIX D

LINEAR MODEL FOR TUPRAS REFINERY

MAX -185.79 hp5 - 196.51 hp25 - 164.24 hp2 + 0.50 fsga +
218.90 fslp + 194.10 fsls + 283.10 fsbe + 224.40 fske +
216.80 fsmo + 280.00 fsko + 200.00 fshv + 142.20 fsfo +
0.46 exga + 180.00 exls + 258.77 exbe + 200.00 exke -
240.00 imlp - 250.98 immo - 290.00 imko - 220.00 imhv -
160.90 imfo

ST

0.8426 hp5 + 0.4400 hp25 + 0.0000 hp2 + 18.0000 h5pt6 +
4.5000 h25pt36 + 22.5000 h2pt3 + 55.0000 h5fc7 + 15.0000 h25fc4
+ 15.0000 h2fc4 - exga - fsga = - 988500.00

0.0269 hp5 + 0.0316 hp25 + 0.0158 hp2 + 0.0690 h5pt6 +
0.0493h25pt36 + 0.0596 h2pt3 + 0.3400 h5fc7 + 0.0931 h25fc4 +
0.0931 h2fc4 + imlp - fslp = 3090.00

0.1027 hp5 + 0.1067 hp25 + 0.0873 hp2 + hs5ls + hs25ls + hs2ls -
ls5be - ls25be - ls2be - exls - fsls =-4561.75

0.8210 h5pt6 + 0.8137 h25pt36 + 0.8320 h2pt3 + 0.4800 h5fc7 +
0.3265 h25fc4 + 0.3265h2fc4 + ls5be + ls25be + ls2be -
exbe - fsbe =-33801.88

0.1120 hp5 +0.1370 hp25 +0.0567 hp2 - ke5mn - ke25mn - ke2mn -
exke - fske = -499.87

0.1330 hp5 +0.1500 hp25 +0.1580 hp2 + ke5mn + ke25mn + ke2mn +
immo - fsmo = 8660.00

0.1200 h5fc7 + 0.0800h25fc4 + 0.0800 h2fc4 + imko -
fsko = 1000.00

0.1440 hp5 + 0.1280 hp25 + 0.1280 hp2 - h5fc7 - h25fc4 -
h2fc4 - hv5fo - hv25fo - hv2fo + imhv - fshv =-8986.82

0.0900 hp5 + 0.1150 hp25 + 0.0154 hp2 + 0.1365 h5fc7 +
0.3965 h25fc4 + 0.3965 h2fc4 + hv5fo +hv25fo + hv2fo +
imfo - fsfo = 10909.00

0.1000 hp5 - h5pt6 - hs5ls = 0.00

0.1050 hp25 - h25pt36 - hs25ls = 0.00

0.0460 hp2 - h2pt3 - hs2ls = 0.00

0.1027 hp5 + hs5ls - ls5be - flsr1 =0.00

0.1067 hp25 + hs25ls - ls25be - flsr2 =0.00

0.0873 hp2 + hs2ls - ls2be - flsr3 =0.00

0.1120 hp5 - ke5mn - fker1 = 00.00

0.1370 hp25 - ke25mn - fker2 = 00.00

0.0567 hp2 - ke2mn - fker3 = 00.00

0.1330 hp5 + ke5mn - fmot1=0.00

0.1500 hp25 + ke25mn - fmot2=0.00

0.1580 hp2 + ke2mn - fmot3=0.00

0.8210 h5pt6 + 0.4800 h5fc7 + ls5be - fben1=0.00

0.8137 h25pt36 + 0.3265 h25fc4 + ls25be - fben2=0.00

0.8320 h2pt3 + 0.3265 h2fc4 + ls2be - fben3=0.00

0.1440 hp5 - h5fc7 - ara1 = 0.00

0.1280 hp25 - h25fc4- ara2 = 0.00

0.2275 hp2 - h2fc4 - ara3 = 0.00

hv5fo + fhvg1 - ara1 =0.00

hv25fo + fhvg2 -ara2 =0.00

hv2fo + fhvg3 - ara3 = 0.00

fsga <= 1000000.00

fslp <= 17800.00

```
fsls <= 97180.00

fsbe <= 98477.00

fske <= 60540.00

fsmo <= 86710.00

fsko <= 30000.00

fshv <= 23900.00

fsfo <= 204160.00

hp5 <= 15000

hp25 <= 20000

hp2 <= 12000

hp5 >= 4000

hp25 >= 4000

hp2 >= 3500

h5pt6 <= 800

h25pt36 <= 1000

h2pt3 <= 750

h5fc7 <= 2200

h25fc4 <= 2500

h2fc4 <= 2000

END.
```

APPENDIX E

DAILY DEMAND, PRICE, STOCK CAPACITIES OF THE YIELDS
AND
PROCESSING CAPACITIES OF THE PLANTS

Product		Demand	price($/M3)	stock capacities(m3)
Natural Gas	:	11500.00	0.50	1000000.00
Lpg	:	3090.00	218.90	17800.00
Naphtha	:	2400.00	194.10	97180.00
Gasoline	:	4590.00	283.10	98477.00
Kerosene	:	2678.78	224.40	60540.00
Diesel	:	8660.00	216.80	86710.00
Coke	:	1000.00	280.00	30000.00
Hvgo	:	400.00	200.00	23900.00
Fueloil	:	10909.00	142.20	204160.00

******** PLANT CAPACITIES (m3/day) ************************

Maximum capacity of			Minumum capacity of		
HP-2	:	12000.00	HP-2	:	3500.00
HP-5	:	15000.00	HP-5	:	4000.00
HP-25	:	20000.00	HP-25	:	4000.00
PLT-3	:	750.00	PLT-3	:	0.00
PLT-6	:	800.00	PLT-6	:	0.00
PLT-36	:	1000.00	PLT-36	:	0.00
FCC-4	:	2500.00	FCC-4	:	0.00
FCC-7	:	2000.00	FCC-7	:	0.00

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