CHAPTER - 1
INTRODUCTION

Crude Oil is the dominant fuel resource in the world today. Products from crude oil are extensively used in industry and normal life. The products directly coming from crude oil include Fuel gas, Liquified Petroleum Gas (LPG), Gasoline, Jet Fuel, Diesel, Heating oil, Lubricated oil, Fuel oils, Solvents, Asphalt, etc. Crude oil is also the raw material for the petrochemical and chemical industries.

To use crude oil efficiently and to make its usage environmental safe, it is necessary to refine crude oil into various products that have different specifications that satisfy the usage requirement and environmental regulations. The process of refining the crude oil into various products is normally carried out in refineries. Although, there is a long history of using crude oil as burning material, it is not until 1860’s that the first real petroleum refinery was built at Titusville, P.A, at a cost of about $15,000 (Nelson [103]).

Since then, petroleum refining has developed into a major industry in almost every country. In 1998’s, the total worldwide crude oil production was about 73 million barrels per day. Whereas, the worldwide refining capacity is about 67 million barrels per day only (Beck [11]). Population growth and continued world economic expansion produce an ever increasing demand for fuel. This indicates that worldwide refining capacity will keep increasing in the future.

Although conventional fuel from petroleum faces challenges from fuels obtained from renewable resources, it is expected to remain a dominant player at the beginning of the 21st century (Bensabat [13]).
The worldwide oil reserves in 1999’s are about 1 trillion barrels. If the oil production is maintained at the level of 1998’s, the current oil reserve can sustain about 39 years with technical advancement and further exploration, the oil reserve keeps increasing. The reasonable forecast is that crude oil will stay as the largest fuel resource in the first half of 21st century.

1.1 About Petroleum Refining Processes

Petroleum refining has developed from simple separation in the early stage to a very complex process today. The early development of petroleum refining technology includes applying continuous distillation, vacuum distillation and thermal cracking, etc.

The refining industry has undergone tremendous expansion and change since World War II. Many new processes with high efficiency have been invented; these new processes include Fluidized Catalytic Cracking (FCC), Catalytic Reforming (CR), Alkylation (ALK), Catalytic Desulfurization (CD), Delayed Coking (DC), etc. Enormous increases in the size of process units, new catalytic processes, shifting product demands and new sources of petroleum from Tar Sands and oil shale’s have made present-day technology and economics of petroleum refining a very complex and sophisticated science (Gary, Handwerk and Kaiser [40]).

For decades, the large and mature U.S. Transportation fuel market has been dominating the global petrol supply (Bensabat et al. [13]). Consequent transportation fuels including gasoline jet fuel and diesel, has the large quantity among all the products from crude oil. By far, passenger vehicles make up the largest sector with respect to number of vehicle and fuel consumption. Most of the passenger vehicles are fueled by gasoline in conventional combustion engines. They consume about
8.5 million barrel per day of gasoline or 12% of global petroleum damage (Bensabat et al. [13]). Most of transportation fuel consumed in U.S. is produced domestically. Due to such massive production, many refineries in U.S.A are fuel oriented refineries whose main function is to produce transportation fuel. There are other types of refineries, for examples, some refineries provide Aromatics and Olefin for petrochemical plan, some refineries also produce Lubricant and Asphalt while producing transportation fuel.

In the past thirty years, innovation in new products and new processing approaches has slowed down. The emphasis of the refining industry has shifted to improving economic performance of the existing plants. Increasing competition in the refining business, strict environmental and safety pressures have forced refiners to invest more money and time on process monitoring, process control and optimization. Recent crude oil price decrease resulted in the sharp decline in the refining margin and consequently, decline in revenues and profits for oil and gas companies (Beck [11]).

In order to survive in such changing market, companies needs to lower the operating cost and increase the revenue to remain competitive. Recent industrial practices showed that the Applications of Operations Research Technique in Oil refineries are the way to accomplish this.

The common goal of all refineries is to provide safe, profitable and quality product manufacturing (Beck et al. [11]). Operations Research Techniques like process control and optimization have become indispensable tools to realize this goal. Significant advancement in instrumentation and computers has made the implementations of (OR) tools like process control and optimization cheaper and more reliable.
Before we go into the discussion of Operations Research Techniques which is the main topic of this thesis we need to introduce some Operations Research tools like Process Control, first, since the benefits of optimization cannot be realized without implementation of process control. Chemical Process Control (CPC) is concerned with operating a plant such that the product quality and production rate specifications are met in a safe and reliable manner (Riggs [121]). Process control is also necessary to reach other operation objectives such as environmental protection, equipment protection, and profit return, etc. (Marlin [92]).

The controllers in a refinery 20 years ago were mostly Proportional Integral Derivative (PID) controllers. Two key technical developments occurred during the late 1970’s that led to dramatic acceptance and growth in the number of advanced control systems. The two key developments were the Distributed Control System (DCS) and Model Predictive Control (MPC) technology (Pelham [110]). The DCS combines the hardware and software needed for data acquisition and basic control functions. It is based on using a number of local control units which have their own microprocessors and are connected by shared communication lines as well as connected to operator/engineer consoles, a data acquisition system, and a general purpose computer (Riggs et al. [121]).

The industrial standard for MPC is Dynamic Matrix Control (DMC) technology, which was implemented in late 1960’s. Since then, model based process control has become a common industrial practice in refining industry. It has been estimated about 3% incremental profit can be realized through implementing model based process control. (Ellis [31]).
The basic task for a controller is to maintain a process variable at a given Set Point. Since every refining company needs to make profit, these set points must be as economically favorable as possible. This economic target can be expressed in different form largest production, the greatest profit, the minimum cost and the least energy usage (Edgar [30]).

Now the question is raised how to choose those set point which make the process most profitable while observing process constraints and meeting all product specifications, this is an Operations Research Problem (ORP). In some refineries, the values of those set points are set by operators and process engineers based on their experience and intuition. Such decision making approach cannot be consistent due to different backgrounds of people making the decisions.

In a modern refinery, a more systematic approach is followed, usually, there is one experienced individual known as a planner - scheduler. The responsibility of this individual is to develop an operating plan for the next several days, given current levels of crude stocks, operating capacities, off takes and inventory constraints (Pelham and Pharris [111]), he may use Linear Programming (LP) as a pragmatic guideline. Today, large scale linear programming technology is well established with respect to planning and scheduling no major change in that status is anticipated (Pelham [110]). After the solution is found using an LP, the planning engineer sends the values of the solution as set points to engineers in unit operation. Usually, the planer - scheduler give a range for the set points to a process variable instead of a single value in order to enable some flexibility. In plant operation, the engineers in a specificity unit then use the information to choose the set points for each
respective control loop. They also need to decide the set points that are not provided by the LP.

1.2 **Issues of this study**

To find the best combination of those decisions to maximize the overall profit for overall plant. Oil refinery production planning presently continues relying on Linear Programming (LP), while process optimization mainly has used Mixed Integer Linear Programming (MILP), Nonlinear Programming (NLP), or Mixed Integer Nonlinear Programming (MINLP).

There is still no overall plant linear programming optimization and different process optimization in mixed integer linear programming, nonlinear programming or mixed integer nonlinear programming.

However, for process operations which have highly Nonlinear Formulation, with respect to kinetics, thermodynamics, hydromechanics, etc. Since overall refinery optimization almost covers all the aspects relating to the profit making refinery operations, this is still considered as one of the most difficult and challenging optimization task. Therefore, the competence has become hard and many oil refineries and petrochemical industries are being restructured for competing successfully in this scenario with requirement of low profit margin, tighter environmental regulations and more efficient plant operation.

1.3 **Objectives of this study**

- To use linear programming model for optimizing the overall plant, oil refinery production planning. At the same time mixed integer linear programming model will be used for refinery supply chain and optimizing the total operational cost for all the operations that includes the scheduling of crude oil unloading, inventories, blending
and feed to oil refineries that usually unloads several kinds of crude oils with different compositions.

- To find the maximum profit production of petroleum products by using the objective function for overall plant and oil refinery production, while at the same time the objective function for process optimization will consists of minimizing the operational cost generated during the mentioned operation.

- To obtain the optimal solution for overall plant, oil refinery production and for optimal operation of crude oil unloading, optimal transfer rates among equipment’s in accordance with the pumping capacities and tank volume limitations, optimal oscillation of crude oil blended composition is fulfillment of the oil charging demand per process unit.

- To develop different models for oil well and rate allocation by using different methods including, linear programming and mixed integer liner programming.

- To give some numerical examples and comparisons to explain the benefits of the model.

- To present a case study of Aden Refinery Company and illustrating the capabilities of the model to solve operation problem in this area and to support future expansion projects for the systems as they happen in real situations.

### 1.4 Hypothesis of this study

- Operations Research techniques are suitable and applicable in solving oil refinery problems related to production of petroleum products.
- Linear programming model is useful for optimizing the overall plant and oil refinery production planning.
• Mixed integer linear programming model is suitable for optimizing production scheduling related to crude oil unloading, inventories, blending and feed to oil refineries. Also, in refinery supply chain.

• The objective function for the overall plant and oil refinery products consists of maximizing profit production of petroleum products, while at the same time the objective function for process optimization will consists of minimizing the operational cost generated during the mentionable operation.

• Both linear programming model and mixed integer linear programming model are applicable for optimizing oil well model and rate allocation.

1.5 Research methodology

This study combines the use of theoretical and field work for its research process. An extensive literature search using library based resources and media research (primary data) was conducted to understand the past and current level of thinking by experts in Operations Research techniques and oil refinery. Recent reports were also investigated to identify key trends and decision criteria that lead to implemented strategies. The assembly and study of the secondary data improved the understanding of the various lines of inquiry that could be followed, as well as the alternative courses of action which might be pursued. Information from the media and published articles were scrutinized for optimistic and pessimistic results from the publishers’ perspective. Statistics and their reliability also change over time, consequently, for the purpose of this study. The publication year of all cited sources will be disclosed.
Building on the secondary research, primary data were collected from two sources because it was vital to get varying organizational perspectives for better understanding. The first was from oil industry experts, which include software providers, consultants and major players in the oil industry. The second was with managers at the case study company, where information was collected through unstructured and open ended interviews with the managers of a case study company. An open ended interview allowed the respondent to talk expansively on the related subjects which provided more information useful for this study.

The case study required a site visit to the office location of the Aden Refinery Company where heads of relevant business units were individually interviewed.

1.6 Organization of the thesis

In this proposed study, some models of Oil Refinery Problems (ORP) are formulated and solved using Operations Research techniques. This thesis consists of Seven Chapters.

Chapter 1 - Introduction

This Chapter gives an introduction of the oil refinery problems, basic definitions terminology of ORP. Brief history of oil refinery development is discussed. Introduction to O.R. techniques in oil refinery. Basic history, tools and goals of O.R. techniques in oil refinery are also discussed. The application of O.R. techniques in oil refinery is presented. At the end an overview of this thesis work is also presented.

Chapter 2 - Review of Literature

In this Chapter, we present a brief literature review of previous research efforts in oil refinery, starting from the extract and upgrade the valuable components of crude oil to produce a variety of marketable
petroleum products that are vital to everyday life. The structure of the oil refinery and the refinery processes which fall into four categories, distillation processes, conversion processes, treating processes and blending processes are discussed. Literature review of planning model in oil refinery, supply chain model and petroleum supply chain are also discussed. Finally, at the end an overview of this Chapter is also presented.

Chapter 3 - Aden Refinery Company (A Case Study)

In this Chapter, we give a brief history of Aden Refinery Company (ARC) with its office located in Little Aden at Al Burgh district, Aden governorate, Republic of Yemen. Geographically, (ARC) is divided to four locations that consist of refinery area, coast area, Aden administration for ship chandelling and the general services for (ARC). The laboratory and safety department of (ARC) and its sections, mission and modern devices are presented. A short historical resume about development and modernization in (ARC) are also discussed. At the end, an overview of this Chapter is also given.

Chapter 4 - Oil Well Model and Rate Allocation

In this Chapter, we present oil well model and rate allocation problem which refers to allocating production rates and gas lift rate of single well to achieve certain operational goals. These goals vary with the field and time. Such field rate allocation can be an effective way to increase the oil rate or reduce the production cost. The objective of this chapter is to maximize the total production of oil, so that by using some properties of rate allocation problem, we reformulate the problem in the form of Linear Programming (LP) model and Mixed Integer Liner Programming (MILP) model. We solved this problem by using branch
and bound method. Finally, proposed method is illustrated by a numerical example.

Chapter 5 - Optimization Production Scheduling Model for Oil Refinery

This Chapter described the problem definition and the mathematical formulation in an algebraic form of the optimization production scheduling model, for managing and optimizing the operational cost in an oil refinery, regarding the scheduling functions of unloading, storage, blending and feeding of crude distillation units. The main objective of this Chapter is to minimize the total operational cost of the system including among other, the changeover cost, unloading cost and inventory cost. The model is formulated using a general MILP formulation, showing the possibility of using the model for general problem of this matter.

Moreover all equations, constraints and variables required for the MILP model were well described, explaining in some cases their particularities. The different directions for solving scheduling problems, we are pointing out the complementary, constraints that must be used in model to solve each one of the different options. Finally, proposed method is illustrated by a numerical example.

Chapter 6 - Planning Model for Oil Refinery

In this Chapter, we deeply describe the Linear Programming Problem (LPP) which is very useful for solving blending problem. Similar programming models can be applied in maximizing the profit of the overall refinery, with different other objectives, like selecting the most suitable crude oil types for processing for different period of the year and different market demands, minimizing the product stocks etc.
The main objective of this Chapter is to develop a linear planning model for refinery production. The model described here represents a general oil refinery and its framework allows the implementation of linear process model as well as blending relations. This model assumes the existence of several processing units, producing a variety of intermediate streams, with different properties that can be blended to constitute the desired kinds of products.

In this Chapter, Linear Programming Problem (LPP) is solved by using simplex method and getting optimal solution for this problem. Finally, a numerical example is illustrated for proposed method.

**Chapter 7 - The Oil Refinery Supply Chain Model**

This Chapter concentrates on supply chain problem in oil refinery. A mathematical model for the oil refinery supply chain characterized by complete horizontal integration of systems from crude oil purchase through to product distribution. We assume that the configuration of the integrated refinery network already exist, therefore, the decision variables that are discrete or binary in nature are avoided by establishing them prior and making them parameters in the LP model. The oil refinery supply chain problem was developed in A Mathematical Programming Language (AMPL) as a LPP and some test cases are solved.

Finally the scope of the further study is discussed. At the end of the thesis, comprehensive Bibliography on applications of Operations Research techniques in oil refinery problem is listed.