CHAPTER - 2

REVIEW OF LITERATURE

2.1 Introduction

Oil Refineries extract and upgrade the valuable components of crude oil to produce a variety of marketable petroleum products that are vital to everyday life. In the next decade, the total worldwide demand for crude oil is expected to increase by 15 million barrels per day more than the current consumption. Much of the growth in oil consumption is projected for the emerging Asian Nations, where strong economic growth results in a robust increase in oil demand. Emerging Asia, including China and India, account for 45 percent of the total world increase in oil use over the forecast period.

Examples of valuable refinery products are Gasoline, Jet Fuel and Diesel [Figure 2.1 shows the overall refinery flow diagram]. The oil refining industry employs a wide variety of processes. It begins with the distillation, or fractionation of crude oils into separate hydrocarbon groups. The resultant products are directly related to the characteristics of the crude processed. Most distillation products are further converted into more usable products by changing the size and structure of the hydrocarbon molecules through cracking, reforming and other conversion processes. These converted products are then subjected to various treatments and separation processes such as hydrotreating and sweetening to remove undesirable constituents and improve product quality.
The objective of this Chapter is to give Literature study on the oil refinery processing and the latest concerns like, Supply Chain in refining industry. An overview of the Planning model in the oil refinery. Supply Chain models and Petroleum Supply Chain is given at the end.

2.2 Overview Oil Refinery Processes

Crude oil is a mixture of hundreds of Hydrocarbon compounds ranging in size from the smallest, Methane, to the large compounds containing 100 or more Carbon atoms. Crudes are characterized based on a number of qualities, including Sulfur content, density and distillation fraction (Gary, Handwerk and Kaiser et al. [41], Jones [64]).

Crude oil density is measured using a specific gravity scale developed by the American Petroleum Institute (API). Lighter crude oils high API has a greater value than heavier oils (lower API). Over the past two decades, the average API gravity of crude oil inputs has decreased from 32.5 to 30.2 degrees (Henderson, Rodwell and Harji [51]).
Refinery configurations are different from one refinery to another, which depends on the type of crude oil processed; the processing units operated complexity and the desired product state. Complex refineries have a variety of processing and treatment options, which can change in response to the availability of certain types of crude oil (Jones et al. [64]).

Refinery Operations essentially fall into four categories (Gary, Handwerk and Kaiser et al. [41]).

1) Fractionation:
Fraction involve in separating crude oil, in Atmospheric and Vacuum distillation, into different hydrocarbon groups or fractions.

2) Conversion Processes:
A) Cracking (Thermal and Catalytic); Involve in breaking large and heavy Hydrocarbon molecules into smaller ones. Cracking can be achieved either through the application of heat (Delayed Coking) or by Catalysts (FCC).
B) Rearrangement involve in restructuring the molecule and producing a new molecule with different characteristics, but the same number of carbon atoms (Catalytic Reforming and Isomerization),
C) Combination involve in linking molecules together to form a larger molecule (Alkylation and Polymerization).

3) Treating processes involve in preparing streams for additional processing and in removing impurities (Hydrotreating).

4) Blending is used to get the final product and it considers as the last phase of the refining process.
Different processes from each category are selected and included in this thesis. In the next section, each category and the selected processes will be explained in more details.

### 2.2.1 Distillation (Fractionation)

Crude Distillation Unit (CDU) is the first major processing unit in refinery. The basic function of the CDU is to separate the crude oil into fractions appropriate for further processing. According to the boiling points, ranging from $90^\circ F$ to over $800^\circ F$, crude oil is separated into many fractions, as the boiling points of different hydrocarbons. Lighter fractions are collected through atmospheric distillation; heavier fractions are collected in a vacuum tower at lower pressure due to their high boiling points.

Distilled crude oil separated into specific hydrocarbon groups with similar boiling points at the Atmospheric distillation column. Boiling range of fractions produced in atmospheric distillation go up to about $700^\circ F$. In this process, the crude is preheated with hot products. Finally it is heated to about $700^\circ F$ in a Tubular Furnace, (see figure 2.2). Many different configurations can be used for the furnace, but most use hot furnace flue gases to preheat pipes.

Atmospheric distillation products are often referred to as straight run product the major products of CDU are Gasoline, Naphtha, Kerosene, Gas oils and Heavy cured residue. The straight run liquids are further processed to make final products or blended with products from downstream processes.
Atmospheric columns also produce a light non-condensable fuel gas composed mostly of Methane and Ethane that is often referred to as refinery gas. Further heating of the atmospheric residue, greater than 750°F, might decompose the fractions in the residue. Also, excessive heat can lead to the formation of coke deposits, which must be removed. Vacuum distillation is effectively able to lower the boiling points of the fractions and permit separation at lower temperatures. Vacuum distillation column products are vacuum gas oil and heavy bottom residue. The vacuum gas oil can be used as feed to the catalytic cracker downstream vacuum bottoms can be used as fuel, or can be further processed in coking units where they can be converted to gasoline components (Gary, Handwerk and Kaiser et al. [41], Jones et al.[64], Maples [91] and Watkins [154]).

2.2.2 Fluidized Catalytic Cracking (FCC)

Fluidized Catalytic Cracking (FCC) is most widely used catalytic cracking process and many refineries consider FCC the primary conversion process, (see figure 2.3). FCC has been the workhorse of the oil refinery. It consists of a reactor regenerator section and a fraction section. Heavy gas oil flows from the atmospheric column and vacuum distillation unit to the FCC preheat furnace to the reactor riser, where it
is contacted with the catalyst returning from the regenerator. The resulting oil catalyst fluid mixture flows up the riser, in which the majority of the cracking reactions occur into the reactor vessel. Catalyst fines are separated from the hydrocarbon product through the use of cyclones within the reactor vessel. The product stream from the reactor flows to the fractionation section, from which three product streams leave. These are namely, Gasoline, Light Catalytic Gas Oil (LCGO) and Heavy Catalytic Gas Oil (HCGO).

On the other hand, FCC is the major source of the Olefin feed to the Alkylation’s process. (Gary, Handwerk and Kaiser et al. [41], Meyers [95], Sadeghbeigi [127] and Wilson [158]).

Figure 2.3 Fluids Catalytic Cracking Unit Flow Diagram

2.2.3 Hydrocracking Processes (HC)

The aim of Hydrocracking is the transformation of the heavy fractions of crude oil into light fractions. The use of this process is determined by the high quality of some of the products obtained, such as the Jet fuel, (see figure 2.4). Hydrocracking is the appropriate process for
all feedstocks that are difficult to process by either catalytic cracking or reforming. The process employs high pressure, high temperature, a catalyst and hydrogen. Therefore, the hydrocracking process is more expensive than catalytic cracking process.

In hydrocracking process heavy aromatic feedstock is converted into higher products under a wide range of high pressures (1,000-3,000 psi) and high temperatures (750°F-1, 500°F) and existence of hydrogen. Hydrogen has another important role in the hydrocracking process, which is reducing tar formation and preventing buildup of coke on the catalyst.

Hydrogenation also serves to convert Sulfur compounds and Nitrogen compounds present in the feedstock to Hydrogen Sulfide and Ammonia (Alenezi, Fawzi and Elkamel [2], Gary, Handwerk and Kaiser et al, [41], Maples et al.[91], Meyers et al.[95], Raseev [119]).

Figure 2.4 Hydrocracker Unit Flow Diagram
2.2.4 Catalytic Reforming (CR)

Catalytic Reforming is employed to increase the Octane rating of naphtha and heavy straight run gasoline produced by atmospheric cured oil distillation, (see figure 2.5). In addition to reformate, the process produces significant yields of aromatic hydrocarbons, used petrochemical feedstock and hydrogen gas, used in many other refinery processes. Catalytic reforming process restructures hydrocarbon molecules to the desired molecular configuration or structure without altering the number of carbon atoms in the molecule. There are four major reactions take place in during reforming, namely; dehydrogenation of naphthenic to form aromatic compounds, isomerization of paraffin’s and naphthenic, Dehydrocyclization of paraffin’s to aromatic compounds and hydro cracking.(Antons [6], Gary, Handwerk and Kaiser et al. [41], Little [81] and Meyers et al [95].

![Figure 2.5 Catalytic Reforming Unit Flow Diagram](image)

2.2.5 Hydrotreating Processes (Treatment)

Hydrotreating Processes are used to remove impurities such as sulfur, nitrogen, oxygen and metals from petroleum fractions, (see figure...
2.6). Usually hydrotreating units are placed ahead of processing units using catalyst so that the catalyst is not contaminated by untreated feedstock, such as FCC, HC and CR. The use of hydrotreating process is improving economics of conversion processes by lowering sulfur content. The main hydrotreating process variables affecting the treatment process are the reaction temperatures, hydrogen partial pressure and space velocity.

Hydrogen is added to the feed, to improve product yields and quality in conversion units. The amount of hydrogen required by the hydrotreating unit to reach the desired objective must be considered in early stage. It would be necessary to have a hydrogen balance for the refinery to know how much hydrogen may be available for addition. It might end with a need for extra source of hydrogen and this raise the need of appropriate hydrogen management (Gary, Handwerk and Kaiser et al [41], Maples et al, [91] and Meyer et al. [95]).

![Catalytic Hydrotreating Unit Flow Diagram](image)

Figure 2.6 Catalytic Hydrotreating Unit Flow Diagram
2.3 Planning Model in the Oil Refining Sector

Production Planning is the discipline related to the macro level problem of allocation of production capacity and production time (with less emphasis on the latter) like raw materials, intermediate products and final products inventories, as well as labor and energy resources. Its primary objective is to determine a feasible operating plan consisting of production goals that optimizes a suitable economic criterion, typically of maximizing total profit or equivalently, of minimizing total costs. This plan is over specific extended period of time into the future, typically in the order of few months to few years, given marketing forecasts for prices, market demands for products and considerations of equipment availability and inventories (Grossmann and Biegler [43]).

In essence, its fundamental function is to develop a good set of operating goals for the future period. In the present setting of the oil and gas industry, planning requirements have become increasingly difficult and demanding because of the need to produce more varied, higher quality products, while simultaneously meeting increasingly tighter environmental legislations and policies as reported by Bodington [15].

On the other hand, production scheduling, in the context of the chemical processing industry, deals with micro level problems embedded in the production planning problem that involves deciding on the methodology that, determines the feasible order or sequence and timing, in which various products are to be produced in each piece of equipment, so as to meet the production goals that are laid out by the planning model. Its major objective is to efficiently utilize the available equipment among the multiple types of products to be manufactured, to an extent necessary to satisfy the production goals by optimizing a suitable economic or systems performance criterion; typically, over a short term
time horizon ranging from several shifts to several weeks. Scheduling function specifies the tasks of each stage of production and this includes defining and projecting the inputs to and outputs from each production operation. It is particularly required whenever a processing system is used to produce multiple products by allocating the available production time between products (Bodington et al. [15], Grossmann and Biegler et al. [43] and Sahinidis, Fornari and Chthrathi [131]).

Hartmann [50], stresses the difference between a planning model and a scheduling model. In general, process manufacturing planning models consider economics of the operations by handling the issues of what to do and how to do it, whereas process manufacturing scheduling models consider feasibility of the operations by addressing the question of when to do it. In particular, planning models ignore changeovers and stress products grouped into aggregated families conversely; scheduling models explicitly consider changeovers and consider products in greater details, including the shipment of specific orders for specific products to specific customers.

Bodington et al. [15], emphasize that a planning model differs from a daily scheduling model or an operational process controller. For example, he pointed out that the product or process yields predicted or estimated in the planning model should not be expected to be used exactly in executing operating conditions. This is because planning models are almost always an average over time. As opposed to planning models, operations are not averaged over the scheduling period as time and operations move continuously from the beginning of the particular period to the end. The schedule is revised as needed so that it always starts from what is actually happening with revisions typically occur on each day or each shift.
As was mentioned in the previous section, oil refinery is one of the most complex chemical industries involving different processes with various possible connections. The aim in refinery operation is to generate as much profit as possible by converting crude oil into valuable products. Operations Research has become indispensable tools to realize this goal. Linear programming is the most widely used technique in refinery operation optimization, which is called Planning and Scheduling in industry. The goal in planning to determine high level decisions such as production levels and product inventories for given marketing demands.

Linear Programming (LP) is an approach to the solution of a particular class of Operations Research problems. It is concerned with finding values for a set of variables that maximize or minimize a linear objective function of the variables, subject to a set of linear equality or inequality constraints. LP problems exhibit the special characteristic that the optimal solution of the problem must lay on some constraints or at the intersection of several constraints, Dantzig first proposed the most popular algorithm in LP called the Simplex Algorithm.

Despite the many contributions that have been reported on planning models, very few can be found that specifically address the oil refining industry, Symonds [141], developed an LP model for solving a simplified gasoline refining and blending problem. The advantage of LP is its quick convergence and ease of implementation. Allen [1], presented in his paper an LP model for a simple refinery that consists mainly of three units; distillation, cracking and blending.

One of the first contributions to consider nonlinearity in production planning is that of Moro, Zanin and Pinto [101]. A nonlinear planning model for refinery production was developed; this model
represented a general refinery topology. Also, a real world application was developed for the planning of diesel production in one of the refineries in Brazil. The model was solved and the results were compared to the current situation where no computer algorithm was being used. The developed model gives a better result compared to the current situation.

Pinto and Moro [115], also developed a nonlinear planning model for refinery production, the model described represents a general petroleum refinery and its framework allows for the implementation of nonlinear process models for few units 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 products. Two real world applications are developed and in both cases, different market scenarios were analyses using the planning model and the result were compared with the current situation, however, the model was based on the assumption that many of the refinery processes are linear which affect the overall predictability of the model. Pinto, Joly and Moro [117], discussed planning and scheduling applications for oil refinery operations. They presented a nonlinear planning model in the first part similar to the one developed earlier by Moro, Zanin and Pinto et al. [101]. In the second part, they addressed scheduling problems in oil refineries that were formulated as mixed integer optimization models and relied on both continuous and discrete time representations. The paper considered the development and solution of optimization models for short term.

Scheduling of set of operations including products received from processing units, storage and inventory management in intermediate tanks, blending in order to attend oil specifications and demands and
transport sequencing in oil pipelines. Important real world examples on refinery production and distribution were reported. The diesel distribution problem at one refinery in Brazil and the production problems related to fuel oil, asphalt and LPG were considered.

Zhang and Zhu [164], showed in their paper a novel modeling and decomposition strategy for overall refinery optimization to tackle large scale optimization problems. The approach was derived from an analysis of the mathematical structure of a general overall plant model. This understanding forms the basis for decomposing the model into two levels. These levels were a sit level (Master model) and a process model (Sub model). The master model determined common issues among the processes. Then, sub model optimized the individual processes. The results from these sub model were fed back to the master model for further optimization. This procedure terminates when convergence criteria are met. Linear yield correlations were used in their study.

Zhang, Zhu and Towler [163], studied a simultaneous optimization strategy for overall integration in refinery planning. They presented a method for overall refinery optimization through integration of the hydrogen network and the utility system with the material processing system. To make the problem of overall optimization solvable, they adopted a decomposition approach, in which material processing was first optimized using linear programming technique to maximize the overall profit. Then, the supporting systems, including the hydrogen network and the utility system were optimized to reduce operating costs for the fixed recess conditions determined from the LP optimization.

Recently, Li, Hui and Li [79], presented a refinery planning model that utilized simplified empirical nonlinear process models with
considerations for crude characteristics, products, yields and qualities. The study integrated crude distillation, FCC and product blending models into refinery planning models.

Neiro and Pinto [105], studied multi period optimization for production planning of petroleum refineries. The developed model was based on a nonlinear programming formulation that was developed to plan production over a single period of time. First, the model in corporate multiple planning periods and the selection of different crude oil types. Uncertainties related to petroleum and product prices as well as demand were them included as a set of discrete probabilities. The model was successfully applied to real world case study.

From the previous discussion, the need is clear to have an efficient refinery planning model with more accurate outcome for the petroleum refinery decision maker. The model should be capable to deal with different types of crudes without major changes in the model. Also, the model should represent refinery operation planning in order to optimize the operating variable in individual processing units.

The most important operating variable will be the CDU cut points which will affect the products flow rates and properties for all the streams in the refinery, as well as the conversion in the processing units. The model should also meet market demand with quality constraints for each final blended product. A general model will embed the different rigorous refinery process models and the blending model. Products properties as well as market demand will be taken into account.

2.4 Supply Chain Model

Companies have been forced to over step their physical frontiers and to visualize the surrounding business environmental before planning their activities. Range vision should cover all members that participate
direct or indirectly in the work to satisfy a customer’s necessity. Coordination of this virtual corporation may result in benefits for all members of the chain individually.

Beamon [10], defines such virtual corporation as an integrated process wherein a number of business entities suppliers, manufacturers, distributors and retailers, work together in an effort to acquire raw materials, convert them into specified final products and deliver these final products to retailers. Under another point of view, Tan [144], gives definition of Supply Chain Management (SCM), which emerges from transportation and logistics literature. The whole selling and retailing industry that emphasizes the importance of physical distribution and integrated logistics according to Lamming [74], this is probably where the term supply chain management was originally used.

According to Thomas and Griffin [146], current research in the area of SCM can be classified in three categories; buyer - vendor, production - distribution and inventory - distribution coordination. The authors present an extensive literature review for each category. Vidal and Goetschalcks [152], present a review of Mixed Integer Problems (MIP) that focuses on the identification of the relevant factors included in formulations of the chain or its subsystems and also highlights solution methodologies.

Bok, Grossmann and Park [16], present an application to the optimization of continuous flexible process networks. Modeling considers intermittent deliveries, production short falls, delivery delays, inventory profiles and job changeovers. A bi level solution methodology is proposed to reduce computational expense. Zhuo, Cheng and Hua [166], introduce as supply chain model that involves conflicting decisions in the objective function. Goal programming is used to solve
the multi objective optimization problem by Perea, Grossmann, Ydstie, and Tahmassebi [112]. Perea Lopez, Grossman and Ydstie [113], present an approach that is capable of capturing the dynamic behavior of the supply chain by modeling flow of materials and information within the supply chain. Information is considered as perturbation of a system control whereas material flows are considered to be control variables.

Therefore, this approach is able to react on time and to coordinate the whole supply chain for changing demand conditions. Similarly, Ydstie, Coffey, and Read [161], apply concept from dynamics and control in the management of highly distributed supply chains. Important aspects of the supply chain problem are captured in a graph representation, such as topology, transportation, shipping, receiving, market conditions, assembly and disassembly, storage of assets, forecasting and performance evaluation. Song, Bok, Park and Park [136], present a design problem of multiproduct, multi echelon supply chain. Transportation cost is treated as a continuous piece wise linear function of the distance and a discontinuous piece wise linear function of the transportation volume, whereas installation costs are expressed as a function of the capacity. Feord, Jakeman, and Shah [37], propose a network model whose main objective is to decide which orders should be met, delayed or not to be delivered.

The petroleum industry can be characterized as a typical supply chain. All levels of decisions arise in such a supply chain, namely, strategic, tactical and operational. In spite of the complexity involved in the decision making process at each level, much of their management is still based on heuristics or on simple linear models. According to Forrest and Oetti [38], most of the oil industry still operates its planning, central engineering, upstream operations and refining, supply and transportation
groups as complete separate entities. Therefore, systematic methods for efficiently managing the petroleum supply chain must be exploited. In the next section, the petroleum supply chain will be explained in more detail.

2.5 Petroleum Supply Chain (PSC)

Petroleum Exploration is at the highest level of the Petroleum Supply Chain (PSC). Decisions regarding petroleum exploration include design and planning of oil field infrastructure. Petroleum may be also supplied from international sources. Oil tankers, transport petroleum to oil terminals, which are connected to refineries through a pipeline network. Decisions at this level incorporate transportation modes, supply, planning and scheduling. Crude oil is converted to various products at refineries, which can be connected to each other in order to take advantage of each refinery design within the complex. Products generated at the refineries are then sent to distribution centers (see figure 2.7).

Figure 2.7 General Petroleum Supply chain (PSC)
Crude oil and products up to this level are often transported through pipelines. From this level, products can be transported either through pipelines or trucks, depending on consumer demands. In some cases, products are also transported through vessels or by train.

In general, production planning includes decisions such as individual production levels for each product as well as operation conditions for each refinery in the network, whereas product transportation focuses on scheduling and inventory management of the distribution network.

Products at the last level presented in (figure 2.7) are actually raw materials for a variety of processes. This fact indicates that the petroleum supply chain could be further extended.

Sear [132], was probably the first to address the supply chain management in the context of an oil company. The author developed a linear programming network model for planning the logistics of a downstream oil company. The model involves crude oil purchase and transportation, processing of products and transportation and depot operation. Escudero, Quintana, and Salmeron [33], proposed an LP model that handles the supply, transformation and distribution of an oil company that accounts for uncertainties in supply costs, demands and product prices. Dempster, Pedron, Mdedova, Scott and Sembos. [27], applied a stochastic programming approach to planning problems for a consortium of oil companies. First, a deterministic multi period linear programming model is developed for supply, production and distribution. The deterministic model is then used as a basis for implementing a stochastic programming formulation with uncertainty in product demands and spot supply costs.
More recently, Lasschuit and Thijssen [75], pointed out how the petrochemical supply chain is organized and stress important issues that must be taken into account when formulating a model for the oil and chemical industry.

Important developments of subsystems of the petroleum supply chain can be found in literature. Iyer, Grossmann, Vasantharajan, and Cullick [60] and Wang, Litvak and Aziz [153], developed a multi period MILP for planning and schedule offshore oil filed infrastructure investments and operations. The nonlinear reservoir behavior is handled with piecewise linear approximation functions. A sequential decomposition technique is applied. Van den Heever and Grossmann [150], presented a nonlinear model for oilfield infrastructure that involves design and planning decisions. The authors consider nonlinear reservoir behavior. A logic based model is proposed that is solved with a bi-level decomposition technique. This technique aggregates time periods for the design problem and subsequently disaggregates then for the planning sub problem. Van den Heever, Grossmann, Vasantharajan and Edwards [151], addressed the design and planning of offshore oilfield in restructure focusing on business rules. A disjunctive model capable to deal with the increased order of magnitude due to the business rules is proposed. Ierapetritou, Floudis, Vasantharajan and Cullick [58], studied the optimal location of vertical wells for a given reservoir property map. The problem is formulated as a large scale MILP and solved by decomposition technique that relies on quality cut constraints. Kosmidis, Perkins, and Pistikopoulos [71], described an MILP formulation for the well allocation and operation of integrated gas oil system whereas Barnes, Linke and Kokossis [9], focused on the production design of offshore platforms.
Cheng and Duran [24], focused on the crude oil worldwide transportation basic on the statement that this element of the petroleum supply chain is the central logistics that links the upstream and downstream functions, playing a crucial role in the global supply chain management in the oil industry. Another level of the supply chain, Lee, Pinto, Grossmann, and Park [77], concentrated on the short term scheduling of crude oil supply for single refinery. Mass and Pinto [93] and Magalhaes and Shah [88], focus on the crude oil supply scheduling. The former developed a detailed MILP formulation comprised of tankers, piers, storage tanks, substations and refineries, whereas the latter addresses a scheduling problem composed of a terminal pipeline, a refinery crude storage area and its crude units. Pinto, Joly, and Moro [116] and Pinto and Moro [115], focused on the refinery operations. The former work focuses on production scheduling for several specific areas in a refinery such as crude oil, fuel oil, asphalt and LPG, whereas the latter addresses a nonlinear production planning. Jia and Ierapetritou [61], concentrate on the short term scheduling of refinery operations. Crude oil unloading and blending, production unit operations and product blending and delivery are first solved as independent problems. Each sub system is modeled based on a continuous time formulation; integration of the three subsystems is then accomplished by applying heuristic based lagrangean decomposition.

Wenkai and Hui [155], studied similar problem to that addressed by Jia and Ierapetritou [61] and propose a new modeling technique and solution strategy to schedule crude oil unloading and storage. At the refinery level, units such as crude distillation unit and fluidized bed catalytic cracking were modeled and a new analytical method was proposed to provide additional information for intermediate streams inside the refinery.
Pannambalam, Vannelli and Woo [118], developed an approach that combines the simplex method for linear programming with an interior point method for solving a multi period planning model in the oil refinery industry. Still at the production planning level, Liu and Sahinidis [83], presented a fuzzy programming approach for solving a petrochemical complex problem involving uncertainty in model parameters. Bok, Lee, and Park [17], addressed the problem of long range capacity expansion planning for a petrochemical industry. Ross [126], formulated a planning supplier network model on the petroleum distribution downstream segment. Resource allocation such as distribution centers new and existing and vehicles is managed in order to maximizing profit. Delivery cost is determined depending on the geographic zone, trip cost, order frequency and travel distance for each customer. Iakovou [55], proposed a model that focuses on the maritime transportation of petroleum products considering a set of transport modalities. One of the main objectives of this work was to take into account the risks of oil spill incidents. Magatao, Arruda, and Neves [90], propose an MILP approach to aid the decision making process for schedule commodities on pipeline systems. On the product storage level, Steble, Arruda, Fabro, and Rodrigues [140], present a model involving the decision making process on storage operations of Liquified Petroleum Gas (LPG).
2.6 Conclusions

This Chapter provides a background of the petroleum refining industry and describes the major processing units in the refinery (i.e.) Crude Distillation Unit (CDU) which consist of Atmospheric Distillation Unit (ADU) and Vacuum Distillation Unit (VDU), Fluidized Catalytic Cracking Unit (FCC), Hydrocracker Unit (HC), Catalytic Reforming Unit (CR) and Catalytic Hydrotreating Unit (HT). These are the major parts of the oil refinery which will be used in this study.

The second part of the Chapter gives a review of many previous studies related to topic of the thesis i.e. planning model in the oil refinery and briefly reviews all the developments made for planning model in oil refinery, pointing out their main particularities. Also, this Chapter included wide details on the topic of supply chain model and the development made in this topic. In addition, there is a huge amount of literature used for covering the main topic of this study in depth which is the petroleum supply chain and the important developments of the subsystems of petroleum supply chain which can be found in literature.