SUPPLY CHAIN MANAGEMENT IN INDIAN PETROLEUM REFINERIES

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CERTIFICATE

Certified that this thesis entitled **"SUPPLY CHAIN MANAGEMENT IN INDIAN PETROLEUM REFINERIES"**, submitted to the Cochin University of Science and Technology, Kochi for the award of Ph.D. Degree, is the record of bonafide research carried out by **Mr. Kemthose P. Paul** under my supervision and guidance at the School of Management Studies. This work did not form part of any dissertation submitted for the award of any degree, diploma, associate ship or other similar title or recognition from this or any other institution.

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Abstract

Petroleum oil is the lifeblood of a modern nation. The importance of its supply chain is therefore evident. Petroleum oil supply chains are large flow type supply chains. Sources of crude oil are fixed by natural availability to certain regions. Oil requirement is however more global with developed cold regions requiring more of it. Economics dictate that refining is to be done nearer to demand locations. The first problem that is tackled in this thesis is that of developing a model for refinery location selection. A multistage multi-factor model using weighted ranking has been developed for this.

Facility design and its creation lay the playground for operations. The importance of proper facilities planning is therefore worth noting. The importance of building flexibility of different types in to facility design is addressed in this thesis. The importance of flexibility is more because of uncertainty in terms of availability and price of crude oil on one side and products demand on the other side, over the long life time of a refinery.

Once facilities are ready, proper planning is necessary for their operations. For planning of refinery, supply chain hierarchical planning model to suit the post Administered Price Mechanism scenario in India is developed. The hierarchical planning models have annual planning, quarterly planning, monthly planning, and daily planning modules interconnected with appropriate data flows.

In order to implement supply chain planning and control models, an integrated information flow system is essential. A model for such a system is also presented in the thesis.

Lastly no study on operations is complete without looking at the current operations and problems involved therein. The inbound, internal, and outbound logistic system of a refinery (Kochi Refinery Limited) has been studied in detail. Bottlenecks, excess capacity, and other related problems are discussed in detail. Recommendations for solutions to some of the identified problems are also given in this thesis.

The attempt in this thesis is there fore to look at refinery supply chain problem in totality from locations planning to operations and to solve the relative problems.

Key words: Petroleum oil refinery, Supply chain management, Location, Planning, Information systems, Operations, and Models.

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Abbreviations used in this thesis

APM	-	Administered Price Mechanism
ATF	-	Aviation Turbine Fuel
BH	-	Bombay high
BPC	-	Bharat Petroleum Corporation Ltd.,
BRPL	-	Bongaigaon Refineries and Petrochemicals Ltd.,
CAGR	-	Compounded Average Growth Rate
COT	-	Cochin Oil Terminal
CPCL	-	Chennai Petroleum Corporation Limited
CRL	-	Cochin Refineries Ltd.,
DMT	-	Dimethyl Terephthalate
DRP	-	Distribution resource planning
DRP	-	Distribution Resources Planning
DSS	-	Decision Support System
EDI	-	Electronic data Interchange
EIA	-	Energy Information Administration
ERP	-	Enterprise Resource Planning
ETG	-	Expert Technical Group
GAIL	-	Gas Authority of India Ltd.,
GDP	-	Gross Domestic product
GIS	-	Geographical information Systems
GoI	-	Government of India
HPC	-	Hindustan Petroleum Corporation Ltd.,
IBP	-	Indo Burmah Petroleum Company
IOC	-	Indian Oil Corporation Ltd.,
IOC	-	Indian Oil Corporation Limited
JIT	-	Just - in - time
KRL	-	Kochi Refineries Limited
LNG	-	Liquefied Natural Gas
LPG	-	Liquefied Petroleum Gas

LS	-	Low sulfur
MIS	-	Management Information System
MMT	-	Million Metric Tons
MMTPA	-	Million tons per annum
MoP & NG	-	Ministry of Oil Petroleum and Natural Gas
MRL	-	Madras Refineries Ltd.,
MRP	-	Elaborate material requirement planning
MRP-II	-	Manufacturing resources planning
MRPL	-	Mangalore Refineries and Petrochemicals Ltd.
NRL	-	Numaligarh Refineries Limited
OCC	-	Oil Coordination Committee
OEB	-	Oil economic budget
OECD	-	Organization for Economic Cooperation and Development
OIL	-	Oil India Ltd.,
ONGC	-	Oil and Natural Gas Corporation Ltd.
OPA	-	Oil pool account
OPEC	-	Organization of Petroleum Exporting Countries
SPM	-	Single point mooring
TPS	-	Transaction Processing System
VLCC	-	Very Large Crude Carrier
WTO	-	World Trade Organization

CHAPTER I

Introduction to the Study

1.1 Introduction

This thesis deals with the study of the supply chain of petroleum refineries, more specifically, with the supply chain activities such as sourcing of crude oil, its shipping, storage, refining, product storage, blending, and finally dispatch of products from the refinery for distribution, and sale.

Petroleum refining is a material flow intensive industry where supply chain cost amounts to 40% of total refining and distribution cost. Uninterrupted flow of inputs and outputs including byproducts and wastes with minimum facilities are crucial to cost effective and efficient operation of capital intensive, process oriented, tightly coupled system such as a refinery. Mithcelson [1992] has discussed the importance of materials management in capital intensive industries. Raw materials and logistics are very important to refineries as the former constitutes a significant component of the total manufacturing cost and the later seriously affects the output, productivity and profitability of the plant. Supply chain management bottlenecks have long term as well as short term impacts on the economics of a refinery. In order to understand the implications of supply chain in materials and energy intensive refineries in the changing global scenario, it is essential to know the scope, coverage and importance of supply chain in general and supply chain management in particular. Supply chain management focuses on the technical organization of the flow of goods and services in the value chain, from the supplier to the customer. Shell global solution have claimed that supply chain management (SCM) has shown that changes in demand forecasting, feed stock selection and optimization of distribution, supply, and manufacturing have positively impacted their bottom line.

SCM involves in the decision-making activities of inbound logistics, internal logistics, outbound logistics, service logistics, and reverse logistics of any

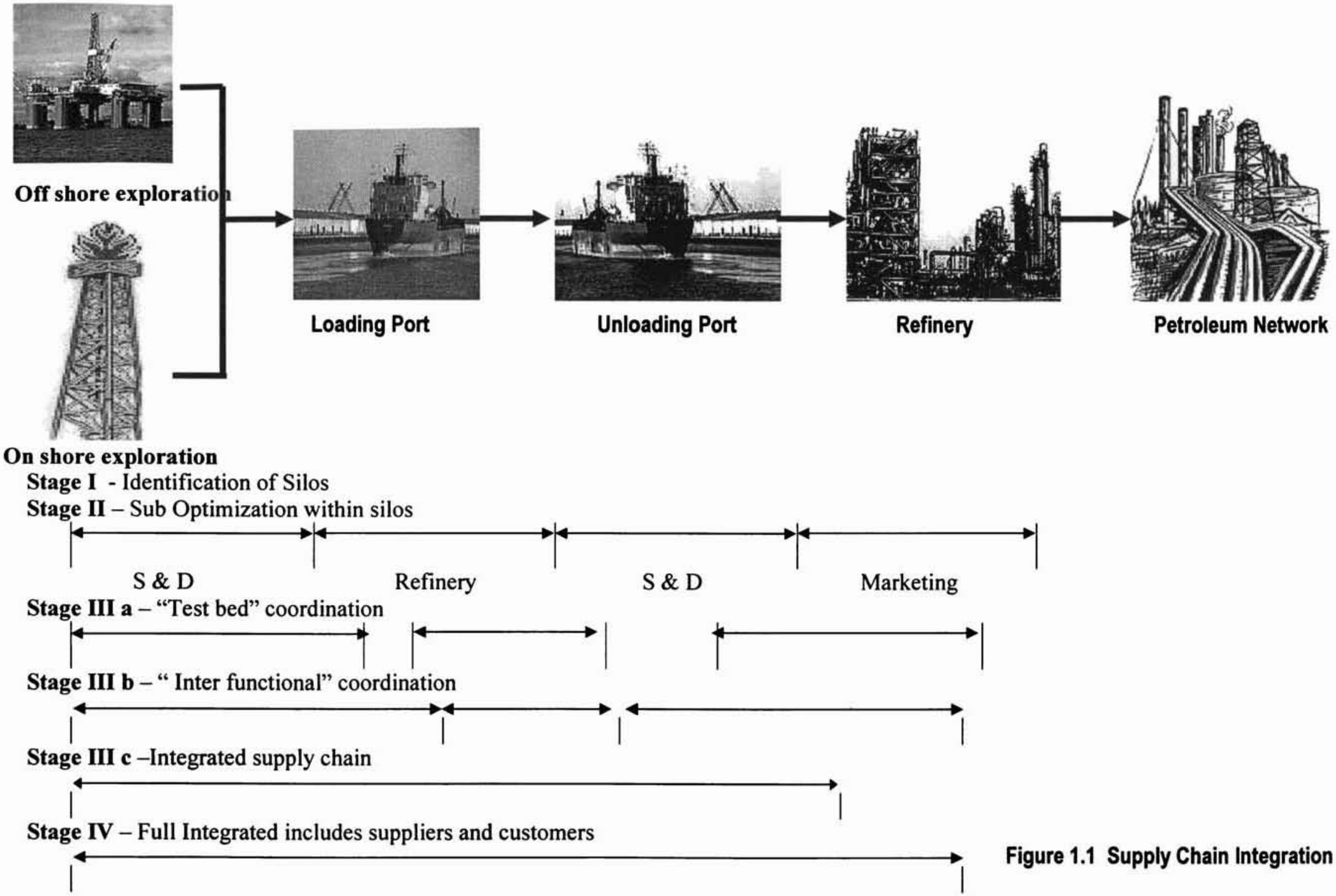


Figure 1.1 Supply Chain Integration

industry. In the case of petroleum industry, application of service and reverse logistics is very limited because these two activities are not that common. Inbound logistics deals with all the activities starting from selection of crude oil to receiving of crude oil in the tanks at refinery tank farm. Internal logistics deals with all the operations starting from crude oil tank to the pumping of refined products to the tanks for final products. Outbound logistics deals with the operations like selection of transport mode for distribution of products, making arrangements for delivery of products, and distribution of products through the selected mode of transport. Figure 1.1 shows stages of supply chain integration.

1.2 Supply Chain Management

According to Lambert and Stock [1993], logistics, a widely accepted term by today's professionals, had in the past a variety of names including physical distribution, supply chain management and business logistics. The Council of Logistics Management defines logistics as:

"The process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements"

According to the above definition logistics consists of the following four flows:

Material Flow: Flow of materials from their sources through necessary processes including their storage, retrieval and the delivery of finished products.

Merchandise Flow: Flow of finished goods from finished good's stores in the distribution channels to the customers.

Money Flow: Flow of money including advances from organizations to suppliers of raw materials, energy, services, etc. and into organizations from the wholesalers, distributors, customers, etc.

Information Flow: Flow of required information from and into the organization through various communication channels in the logistics system.

Table 1.1 A Classification of Logistics Related Managerial Decision Problems

	Infrastructure Management	Materials Management	Technology Management	People Management
Material Flow Raw Material, Work-in-process, Finished Goods	Facility Location Facility Design Improvement of Existing Facility	Procurement Transportation Inventory Control Storage WIP Finished Goods dispatch	Equipment Selection Systems and Procedures based on Technology	Organization Design Job Specifications Incentive Schemes
Merchandise Flow	Selection of supply / distribution channels Contract terms with members of supply / distribution channel	Inventory Control Distribution planning and scheduling	Mode of Transport and Handling Equipment Selection Systems and Procedures	Organization Design Job Specifications Incentive Schemes
Money Flow	Selection of Banks and credit/ payment arrangements modes	Budgeting Accounting and cash flow management	Equipment Selection Systems and Procedures based on Technology and regulations	Organization Design Job Specifications Incentive Schemes
Information Flow	Selection of modes of communication Design of logistic information system	How often who will communicate what information to whom for taking what decisions?	In this case it acts through infrastructure and systems	Organization Design Job Specifications Incentive Schemes

Since, interruptions in any of the above four flows affect an organization's raw materials supply (purchasing), manufacturing (operations) and marketing (distribution) functions. According to Fawcett and Fawcett [1995], there exists a need to integrate these flows through effective management of infrastructure, materials, technology and people. The typical managerial decision problem that one encounters in real life while dealing with the management of above four flows of the logistics system is summarized in Table 1.1. In this thesis, the concern is with the supply chain management of an oil refinery. More specifically, it is concerned with the decisions on infrastructure facilities and transportation of crude oil to the refinery, and the movement of finished products out of the Refinery.

1.3 Supply Chain Management Practices

In India approximately 13 percent of the GDP is spent on logistics (Planning Commission report-2002), whereas this Figure is only 10 percent for developed countries. Supply chain management and logistics are still in the embryonic stage in India. The current lull in the economy is forcing many industries to examine their costs, and cut it down in size. Today excellent logistics management has become essential for success of companies. Logistics function includes the total flow of material, from the acquisition of raw materials to delivery of finished products to the ultimate users. As such, it includes the activities of sourcing and purchasing, conversion including capacity planning, technology selection, operations management, production scheduling, materials planning, distribution planning and management of industry warehouse operations, inventory management, inbound, internal, and outbound transportation; linkage with customer service, sales, reverse logistics, promotion and marketing activities.

Successful supply chain management is extremely complex because of large number of players with varying interest or objectives are involved. Though the supply chain of each company has its own unique features, the following general principles help in management of supply chains.

- Begin with the customer
- Manage logistic assets
- Organize customer management
- Integrate sales and operations planning
- Leverage manufacturing and sourcing
- Focus on strategic alliances and relationship management
- Develop customer driven performance measures

A significant new trend has been evolving in logistics management in the last decade - one that involves the collaboration of all participants in the supply chain in order to reduce the cost of total logistics system. It has been referred to as “Supply Chain Management”, "Logistics Partnership" or "Inter-Corporate

Logistics Management". In traditional Logistics "total cost concepts" model, companies worked to manage logistics as an entity and to lower the total logistics costs to the organization. The model evolved balancing trade-off among production run lengths, inventory, transportation, and warehousing and customer service. Later an increasing number of companies realized that though the total cost concepts might be useful, it is tainted because it does not consider the efficiency of the entire supply chain. The supply chain management on the other hand involves the active collaboration of two or more participants in the supply channel (Supplier, manufacturer, distributor, and/or customer) to manage all the logistics resources in the most efficient manner possible.

The concept of "quick response" gained broad favour as companies in all parts of supply chain developed an appreciation of its potent benefits. Quick response involves the integration of the supply chain, effectively linking retailers, suppliers (manufacturers/ distributors) and carriers in close communication and integrated decision making. Key elements of quick response includes:

- Point-of-usage data capture
- Hem - level management
- Rapid Communication
- Partnerships
- Discipline and commitment

Effective quick - response systems' benefits include lowering inventories by as much as 40 percent, improving in-stock availability significantly, cutting transaction and administrative costs in to half, reducing replenishment lead to a third or less of their former levels, identifying slow-selling items sooner, and reducing operating costs for all players in the supply chain.

Supply chain management strategy involves determination of what performance criteria the logistics system must maintain - more specifically, the service levels and cost objectives the logistics system must meet. Because cost and service normally involve a trade-off, a company must consciously consider that trade-off and determine the desired supply chain performance. This process involves consideration of the company's strategic objectives, its specific marketing strategy and customer service requirements and its competitors' cost-service position.

Supply chain planning involves the development and management of all logistics resources in order to attain the desired cost-service performance consideration, it might include number and location of warehouses, type of warehouses, mode and carrier selection, inventory position, inventory levels, order entry technologies and information system, and so forth.

Opportunities for differentiation - based on operational, logistics, or customer services excellence - are more likely to be exploited. Supply chain management tends to have a more visible and more important role in the Company. Investments in the supply chain function or infrastructure are more likely to be approved.

Just - in - time (JIT) Logistics: It is useful to classify JIT programs into two categories, JIT production and JIT logistics. These programs typically focus on the reduction of set up funds for key operations, the reduction of lot size, and the enhancement of quality - all leading to lower work - in - progress inventories. JIT logistics programs, on the other hand, apply JIT principles to the management of raw materials, inventories and beyond supplies. For JIT logistics plans to work, four 'Pillars' must be in place. They are:

- STable production schedules
- Efficient Communication
- Co-ordinated transportation
- Quality control

These four principles are critical to the integrated management of suppliers.

The 1990s have been called the "decade of customer service". All industry sectors are placing a premium on quality, including quality customer service. Serving customers as they want to be served and "making company easy to do business with" is competitive objective for the next millennium. At the same time the meaning of effective customer service is changing, and companies must meet an increasingly higher standard. Customer Service Pyramid is an effective framework for formulating a customer service strategy in a fluid marketing environment.

1.3.1 Logistics as a Process

According to Prof. Bernard La Londe of Ohio State University[1998], logistics is not a focused functional activity but one that enables the integration of activities across functions. An effective way to promote this expanded role for logistics is to position logistics as a process, not as an activity or function. These are three important sub-processes as part of the logistic process. They are:

- Integrated Production and distribution strategy development
- The replenishment process
- The order management process

A well-designed forecasting system can contribute significantly to logistic performance. Many consumer products companies are trying to operate with a 25 to 60 per cent forecast error (on the stock-keeping unit level) in their one-month- out forecasts. This error range wreaks havoc with inventory levels and customer service performance. "Best Practice" companies, on the other hand, consistently are able to achieve 15 to 20 percent forecast error rates. Companies that perform poorly in their forecasting typically commit two or more of the "Six of forecasting" given below:

- Letting finances drive forecasts
- Having no forecast "owner"
- Having insufficient analytical support
- Using a single forecasting approach for every thing
- Having no sales and operations planning meeting
- Failing to track forecast error.

Many companies are discovering that distribution resource planning (DRP) systems can reduce costs, improve customer service, and better their inventory management. DRP systems provide a full view into the warehouse network by first examining demand at the end of the channel and accumulating requirements back through the warehouse network. This approach allows for full visibility of needs and better management of inventories. DRP involves both inventory management and distribution planning. A module of distribution requirement planning (DRP) extends the concepts of materials requirements planning in to a multi-echelon-warehouse inventory environment. The results are time-phased replenishment schedules for moving inventories across the warehousing network. DRP offers an accurate simulation of distribution operations with extended planning visibility, allowing logistics departments to manage all resources better.

1.4 Literature on Importance of Supply Chain

The last decade of this century has seen many significant changes. The important ones are: the end of cold war, breaking up of the former USSR, formation of trade blocks (EU, ASEAN, NAFTA, etc.), emergence of World Trade Organization, and globalization of World Economy. Feasibility of global sourcing and marketing of quality products and services at competitive prices in the world market have called for serious re-look into the logistics functions in such industries as steel, cement, fertilizer, chemicals, petroleum, etc., where logistics cost forms a significant component of the cost of goods sold. Gyula et. al.[1994] and Scully and Fawcett[1993] gives details on global manufacturing.

Based on a survey of 1000 major European companies, Kearney[1995] observes that logistics function is becoming more demanding and complex as the business environment itself is becoming complex and demanding. The critical factors responsible for demanding logistics management are: (1) Escalating customer expectations and demand, (2) Cycle time compression, (3) Global sourcing, (4) Global market, (5) Corporate restructuring, (6) Supply chain partnership, (7) Productivity pressures and (8) Environment awareness. In-spite of the above challenges, revolutions in communication and information

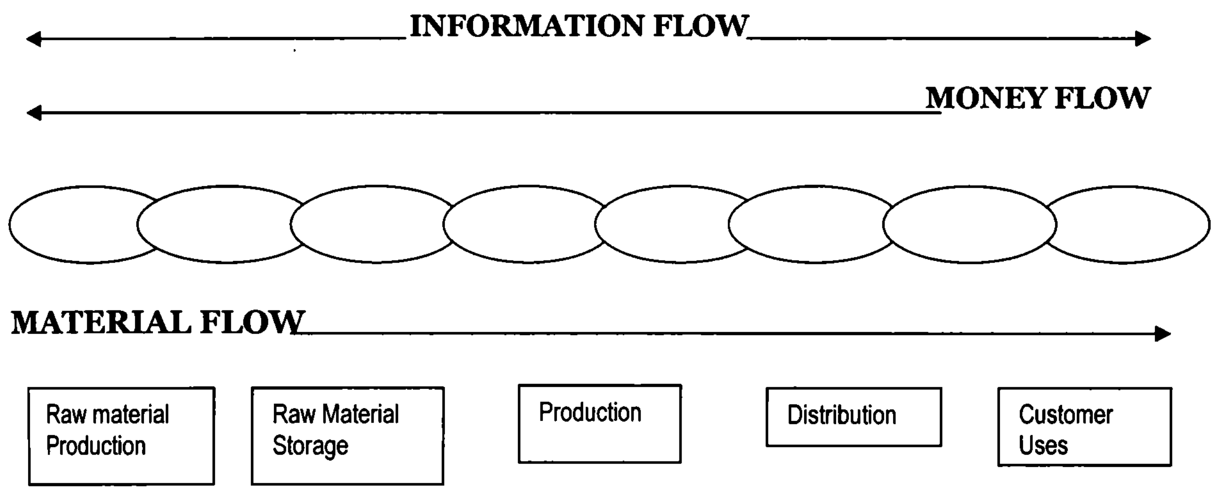


Figure 1.2 Three important flows in a supply chain

Though supply chains have existence since the beginning of civilization, this name and associated approach to looking at the issue is new. The focus so far in the area has been to look at different aspects of the supply chain such as procurement, storage, production, distribution etc, separately and there are different specialists for each. An integrated view of the links as parts of a supply chain is of quite recent origin. Therefore, when one changes the focus from different functional areas to the supply chain concept, some fundamental issues arise that need to be addressed.

The entities of the chain or the departments of the supply chain become dominant and try to form sub-goals and achieve them at the expense of the total supply chain goal. Different entities in the supply chain have different strength. This leads to a condition that the chain is only as strong as the weakest link. The extra money spent in making some areas of the supply chain very strong is wasted because this extra strength does not in practice contribute to the operation of the total supply chain significantly. In a chain if two adjacent rings are not connected the chain is not one but two. The same is the case with the case of a supply chain where strong connections between adjacent links are vital for its existence and functioning. These are called supply chain disconnects. The presence of a loop or a cross-link in the supply chain creates multiple paths to choose from one end of the chain to another. At each such loop or cross-link the conditions under which each path should be taken should be spelt out clearly.

Looping and cross linking of supply chains create many information flow problems, information about the same thing coming from different links might not be at agreement. It has been found that in most supply chains there are people to study and look at the individual departments, because of the organizational structure followed, but almost no one looks at the supply chain as such in total. It is the performance of this complete chain that ultimately matters.

1.6 This study and its objectives

This study was started in September 1998, at the time of dismantling of Administered Price Mechanism (APM) in India. The objectives of this study are:

1. Model development for selection of location for refinery in India and identification of characteristics to be looked in to when configuring it.
2. To develop models for integrated supply chain planning for a refinery.
3. Overall design of a logistic information system for a refinery.
4. To make a detailed study of the supply chain management in an Indian refinery and make suggestions for improvement.

1.7 Scheme of the Study

This thesis is organized under seven chapters. In the second chapter presents a survey of literature relevant to the study. The third Chapter discusses world petroleum industry and Indian petroleum industry along with the model to find out the location for a refinery and the importance of maintaining flexibility in refinery. The fourth chapter deals with models for supply chain planning for a refinery. The fifth chapter is dedicated to the information flow in inbound logistics, internal logistics, and external logistics. Kochi Refineries Ltd. and strategies for its long-term supply chain improvement form the ground of the sixth chapter. The findings from the data collected and recommendations related to this area are presented in this chapter. In the last chapter presents the summary of findings and recommendations, and discuss scope for further related work.

CHAPTER II

Review of Literature

2.1 Introduction

In this chapter, a review of literature is carried out. Theoretical concepts in the area of SCM are reviewed. SCM being a practice-dominated area, SCM practices in industry, reported in the literature is reviewed. Since this work focuses on petroleum oil refinery, logistics literature in this area is also presented. Since supply chain management is broad area, for clarity of presentation, we have divided the literature in to nine section covering areas such as location, flexibility, planning, etc. Application of Information Technology and its advantages are investigated.

Theoretical literature is reviewed first to get a strong foundation on concepts. Application of those theories in industrial environment is analyzed next. Industrial applications are divided in to service and manufacturing sector. Literature on manufacturing is again sub-divided in to discrete and continuous. Refining of petroleum products literature is reviewed towards the end in all the sections discussed in this chapter.

2.2 Concept of Supply Chain Management

Supply chain management literature offers many variations on the same theme when defining a supply chain. The most common definitions [See for example, Jones and Riley [1984], Houlihan [1985], Stevens [1989], Scott and Westbook [1991], Lee and Billington [1993], and Lamming [1996]] are a system of suppliers, manufacturers, distributors, retailers and customers where materials flow down stream from suppliers to customers and information flows to in both directions. Main definition of a supply chain is from Stevens [1989] who defines it as:

"A connected series of activities which is concerned with planning, co-coordinating, and controlling material, parts, and finished goods from supplier to customer. It is concerned with two distinct flows (material and information through the organization)"

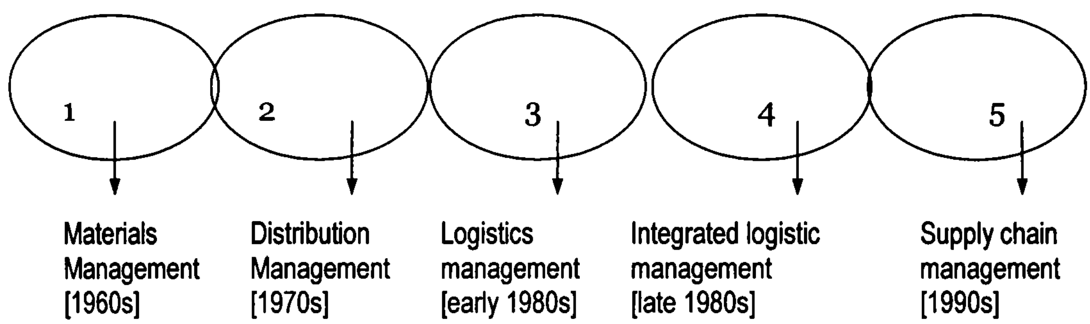
Oliver and Webber [1192] state that the supply chain should be viewed as a single entity that is "guided by strategic decision making". Gentry [1996] included the carriers in supply chain. O'Brien and Head [1995] included governments as part of the chain. Managing the supply chain would include all the issues associated with the government regulations and customs. Towill [1997] argues that the definition needs to be flexible. Houlihan[1985] is credited with coining of the term supply chain. Cooper, Ellram, Gardner, and Hanks [1997] suggest that the span of management control should be determined by the added value of any relationship to the firm. Houlihan [1985] makes it clear that the differentiating factor between the integrated logistics and supply chain management is the strategic decision making as part of supply chain management.

2.3 Evolution of Supply Chain Management

The literature suggests that SCM has its roots in the evolutionary path followed through materials management and physical distribution after the Second World War, functional logistics (different managers for each functions) and integrated logistics (one manager for all functions). Forrester [1958] justifies the first step beyond functional logistics by using a systems analysis approach. Bowersox [1969] discussed the evolution of integrated logistics. Theoretically development of SCM has different stages. Langley [1992] suggests four stages of development. (1) Cost control, (2) profit centers orientation recognizing the positive impact on sales, (3) view of supply chain as key to product differentiation, and (4) as a principal strategic advantage. Masters and Pohlen [1994] describe the evolution of supply chain in to three phases. (1) Functional Management [1960-1970]-functions such as purchasing, shipping, and distribution, each managed separately. (2) Internal integration [1980s]- the management of such supply chain functions of a single facility is identified and becomes the responsibility of a single individual, and (3) external integration [1990s]-the management of supply chain functions throughout the chain. La

Londe [1994] describes the evolution of integrated supply chain in three phases. (1) Physical distribution – distribution of goods is all that needs to be managed by a logistics manager. (2) Internal linkages-it is important for the logistics manager to control both internal supply functions and physical distribution. (3) External linkages- logistics management requires co-operation in the management with upstream and down stream entitles in order to maximize the benefits of the total logistic system.

Industrial application of supply chain pioneered the concept of (1)-integrated logistics that eventually came to be called SCM (Bowersox [1969], Slater [1976]), and (2) partnership lending and management [Slater [1976], Gentry [1996], and Walton [1996]]. Forrester [1958] predicated that the introduction of computer and the adoption of many mathematical models and other optimization tools had a great impact upon the development on supply chain. In 1960's, Bowersox [1969] notes that computers emerged from their infancy and formed application in physical distribution. Slater [1976] argues that a total systems approach to the logistics channel will reduce total cost and considerably improve the overall quality of the operations. Fuller [1993] states "logistics has the potential to become the next governing element of strategy as an inventive way of creating value for customers, an immediate source of savings, a discipline on marketing, and a critical extension of production flexibility".



In the last two decades, logistics slowly evolved in to SCM. Houlihan [1988], Copanino and Rosefield [1992], Lee and Billington [1993], Fuller [1993], Thomas and Griffin [1996], Gattorna [1998] and Mitra and chatterjee [2001] have tried to account for the increasing awareness and implementation of SCM. To have maximum benefit, the supply chain must be managed as a single entity.

Firms must avoid sub-optimization through self-interest at any link in the chain by managing the entire chain as a single entity while simultaneously dealing with the power relationship that are inherent in the chains. Baganha and Cohen [1998] point out that application of the variability of demand in the supply chain has been recognized and described. Bhaskaran [1996] notes that manufactures have recognized the need to optimize the performance of the supply chain connecting raw material to the finished product. Gavirneni, Kapuscinski, and Tayur [1998] note that the focus of managing the supply chain has led to radical changes in thinking about supplier/customer relations.

Stevens [1998] suggested that integrating the chain elements has to be done for the improvement in SCM performance. Stock and Lambert [1992] observed that to become a world-class company, a company must focus on logistic integration. Bowersox and Daugherty [1995] identified that logistic integration will be possible by the development in information technology Cooper, et al. [1997] made it clear that SCM is not the integration of logistics alone, it is the total integration from vendor to customer. Kopicki [1999] identified that developing countries are investing in supply chain to compete in the world-class marketing. Sahay [2001] suggests that managing supply chain is the only way to meet the global challenges. Paul, et al. [1998] identify the changes in definition, growth and approaches. It is noted that integration using information technology and strategic planning are areas of focus now. Gilmour [1999] made some efforts to benchmark supply chain operations. Bench marking SC operations is useful in performance improvement.

From the above literature review it is clear that SCM focus in refinery is a pertinent research problem. It is also clear that an integrated supply chain approach and use of information technology should be taken in SCM studies.

2.4 Location for a New Refinery

Planning the size and location of facilities are traditional problems. It has been established theoretically the importance of location for industry in the SCM context. Weber [1922], Beckman [1968], and Drezner [1995] have addressed the problem by applying the methods of operations research. Hall [1987], and

Daganzo [1996] have tried to solve the location of transportation terminals as an optimization problem. Compbell [1990] developed a continuous approximation model for relocating terminals to serve expanding demand. Noritake and Kimura [1990] developed models to be identified with the optimal size and location of a seaport using separable programming technique. Eichi Taniguehi et al. [1999] suggests a mathematical model for determining the optimal size and location of a logistics terminal. Ganeshan and Terry [2001] suggest that there are four decision areas in SCM (1) Location (2) Production (3) Inventory (4) Transportation. Ioannis et al. [2000] make an analysis on supporting decision makers in land use planning around chemical sites. Min and Melachrinoudis [1999] analyze the relocation problems of a distribution facility and Papazolon et al. [1999] discuss the risk involved in decision making in land use planning. Kuehn, et al. [1963] have used a heuristic programme for locating a warehouse. Geoffroin & Arthur [1976] predict the scope of computer application in selection of location. Hamel, et al. [1985] point out the importance of location when a company is planning for global marketing. Khumawala, et al. [1971] made a comparison of some warehouse location techniques. Klassen, et al. [1994] have identified the barriers in international operations. They have identified location of the plant as one of the major bottlenecks in global marketing. Fordows & Kasra [1997] suggest to find the location correctly for foreign companies. Agostino Villa [2001] introduces some SCM problems. Importance of location is stressed in this article. Mac Cormek, et al. [1994] note the new dynamics of Global manufacturing site location. Porter [1990] suggests the competitive advantage of nations in the location selection especially for continuos manufacturing. Nation must be selected on the basis of target market. Lee & Larry [2002] note that the term globalization describes business deployment of facilities and operations around the world. Globalization results in more exports and imports. East Asia has become the fastest growing and foremost trading regions in the world. They have identified six groups of factors, which dominate location decision for a new plant. Location selection is a very vital decision, which has long-term implication. This strategic decision is not easy to solve because (1) uncertainty of future (2) complexity and conflicting factors associated with the site selection problem, and (3) constraints and limitation of resources to produce site. Pair wise compassion of factors gives fairly good results for site selection.

Literature shows that the location for refinery must be first selected on a global basis due to the global competition. When looking on the global basis, it will come to a country to setup a refinery. The selection of country can be solved as a non numeric problem. Selection of the country can be followed by state selection and location selection. This can be solved with composite method. Final site selection can be made with the help of numerical solution. So the selection of locations for a new refinery is possible with the integration of both quantitative and qualitative techniques. Selection of site for production setup is complex when compared to the selection of location for a warehouse. Warehouse problems can be solved with operations research or techniques. But manufacturing location selection can not be solved with the help of techniques alone. Composite techniques are ideal for finding out suitable location for a process industry like refinery.

2.5 Flexibility of Resources

Theoretically flexibility is more important for industry with continuous production. Lee and Larry [2002] say that manufacturing process that can be changed easily to handle various products is flexibility. The ability to reprogramme process is useful for high customization. Nemetz and Fry [1998] describe the characteristics of a flexible manufacturing organization. Eric and Amitabh [2002] discuss the sources of volume flexibility and their impact on performance. The inventory will be minimum if the organization can control the volume at sources itself. Cox Jt. [1989] suggests methods for measuring flexibility in manufacturing. This method will give an idea how flexible is the organization. George [1994] and De Toni and Tonchia [1998] discuss the advantages of flexibility in production process and the organizations with flexibility in the competitive market environment. Fiegenbaum & Karnani [1991] studied the competitive advantage for an organization with flexibility in output. Product range can be maximum so it will satisfy more customers. Savoie [1998] describes flexibility as the last word on supply chain improvement. He suggests that only flexibility can improve a well performing organization. Huchzermeier and Cohen [1998] prove that exchange rate value change risk can be minimized by operational flexibility. This is more useful for organizations, which are operating in the export marketing. Eric and Amitabh [2002] establish the drivers and sources of volume flexibility. They argue that short and long-term sources of volume flexibility have a positive, albeit differential impact on a firm's performance. A refinery has less resources flexibility because it is a process industry. Identifying flexibility resources will give performance gain for a refinery also.

Flexibility is needed for projects with long life. Short life projects need not have flexibility because the project will be completed before any significant change in technology occurs in market or resources. Projects with longer life are prone to undergo changes in all areas, so there must be provision for adoption of changes. Flexibility must be incorporated at the time of design and implementation itself. A process industry like refinery exists for quite a long period and a lot of changes will take place in the field of refining. So a refinery must identify the areas where they have to be flexible to remain competitive in the market.

2.6 Supply Chain Planning

Planning for all organizations includes both long term and short term to have better performance. Planning can be divided into strategic and short term. Literature on both the types is sufficient to have good idea on planning. Kogut [1985] gives an idea how to design a global strategy to have a comparative and competitive value added chains. Tyndall [2000] discusses the global challenges in supply chain. Lambert, et al. [1998] have discussed on the issues on implementation of SCM. Bnges [1998] & Evans, et al. [1995] suggest steps to avoid failures in SCM. Ganeshan & Terry [2001] and Beth [2000] suggest the importance of strategic planning. They also observed that if the margins are going down, look at the performance of supply chain. Bridleman, et al. [1997] note that the situation in process industry and make-to order industry are different. Scope for SCM is more in process industry such as petroleum refinery.

Eliram, et al. [1990] noticed that the relationship with shipper is important in process industry. Partnership is the most efficient method in the third party logistics. Johnson, et al. [1995] observed that SCM is the best method to gain an edge over the competitors. Inventory reduction and flexibility are the main reasons. Lee, et al. [1992] discuss the problems and opportunities associated with supply chain inventory. He has developed a mathematical model for the reduction in inventory. Production, planning and control using fitter theory is done by Towill and Del Vecchio [1994] for supply chain dynamics. The performance measurement procedure is developed by Beaman [1999]. As per Jones and Riley [1985] inventory must be used for the competitive advantage through SCM. Lee and Billington [1993] suggest that material management will be complex in decentralized supply chain. Mathematical model is also developed for the decentralized supply chain. Lee and Billington [1995] high lights the evolution of supply chain management models and practices in the industry. Bowersox [1997] observed that world class leaders in industry have better control over their supply chain. Cavinato [1999] developed a cost/value model for supply chain competitiveness. Cooper and Eliram [1993], and La Londe [1997] identified characteristics of SCM and its implications on purchasing and supply chain strategy.

2.6.1 Strategic Planning

The importance of long term purchasing planning is emphasized by Carter [1996]. Chan & Huff [1997] suggest that the strategy for purchasing must be focused on customer requirement. Zahra and Covin [1993] have suggested that purchase strategy must be in tune with the policy and performance of the organization. The importance of knowledge management for developing strategy for an organization is discussed by Morten [1999]. Procedure for checking the performance of strategy is developed by Robert, et al. [2000]. Literature shows the development and importance of strategic planning in process industries. Peter and Richard [1976] give guidelines for designing strategic planning. The importance of control of production on the basis of strategic planning is discussed by Burbidge [1984]. Jones and Riley [1985] suggest the use of raw material inventory for the competitive advantage through SCM. They suggest that the long term planning will have a better control on the raw material inventory and they add procedures for systematic planning. Ballint Jin [1993] recommends method for optimizing the level of inventory in a refinery. A mathematical model was developed for finding the solution. Mac Berth and Ferguson [1991] have identified the strategic aspects of SCM. They have suggested that having a strategy for the purchase as well production and marketing will improve competitiveness. Porter [1996] clearly defines strategy as the long term planning for an organization. The length of plan period must be divided depending on the nature of business. Andrew & Alexander [1997] suggest the precautions to be taken in strategy. If proper planning is not there for short period, then the strategy will fail. Hierarchical planning is important for the best performance of the organization, Pagh and Cooper [1998] discuss the supply chain postponement and speculation management. They are suggesting that the final decision on the product must be delayed as much as possible to have better customer satisfaction. Tyndall, et al. [1998] suggest methods for increasing the value through global operation. Miller [1998] suggested methods for making strategy and structure. Fredric [1986] suggests methods for strategic decision for developing organization structure. He suggests the need for a designed infrastructure for the development of an organization with strategic planning. Morash, et al. [1996] suggest that long term planning in logistics capabilities is essential for competitive advantage and success of the organization. Sahay, et al. [2001] also suggests that to meet global challenges long term planning is essential through out the chain. Harwick and Tom [1997] thought on optimum decision making for the supply chain. Optimum decision in logistics planning is essential for the global competition. Porter [1980] developed a competitive strategy for analyzing the performance of an industry. Oral and Dominique [1989] make an analytical approach to competitive strategy formulation for an industry. Young [1991] suggested that manufacturing must be given more importance in developing strategy.

Miller [1992] warned about the strategy trap. Keeping the planning in the top management is taken as the trap. Pelham& Plarris [1996] see the future for refineries lie in the strategic planning for operation and control. Chow, et al.

[1995] developed a framework for logistics frame work. Integration of logistics with strategic planning is the objective. Theodure, et al. [1998] suggest that logistic strategy is at a cross road now. Integration must be considered for strategic planning. La Londe and Masters [1994] suggest that strategic planning for logistics is the blue print for success in the next century. Process industries like refinery need long-term planning for the existence in the competitive global market. Strategic planning is essential to maintain the correct sequence of information flow for decision taking in a refinery.

2.6.2 Hierarchical Planning

Theoretically hierarchical planning is required for a process industry. Some of the decisions must be strategic where as some other decisions must be daily. The planning procedure also must be different. Hans and Wolfgang [1992] suggest the importance of strategic planning. They are claiming that to have competitive advantage an organization must plan for developing edge over others. Managers do short term planning. Importance of supply chain planning model development is discussed by Fisher [1997]. He suggests that each industry must have its own unique model. Raghuram [1999] suggests that there must be specially designed long term planning procedure for each organization. Focus required in purchase is discussed by Murray [1998]. Miller [2001] stresses the importance of hierarchical planning in supply chain management. Hartveld [1996] discusses the hierarchical planning importance for a chemical industry. Haulilan [1985] also suggests the importance of hierarchical planning importance for international marketing. Bechtel [1993] gives the use process industry modeling system for the efficiency improvement of planning department. Pinto, et al. [2000] have developed a planning and scheduling model for a refinery.

Firstly, the development of a non-linear planning model for refinery production is presented. The model is able to represent a general refinery topology and allows the implementation of non-linear process models as well as blending relations. Considering the market limitations for each oil derivative usually supplied by the refinery, the optimization model is able to define new operating points, thus increasing the production of more valuable products while satisfying all specification constraints. Real-world applications are developed for the planning of diesel production in refinery in Brazil. The second part of the work addresses scheduling problem in oil refineries with mixed integer optimization models and rely both continuous and discrete events representations. The paper also discusses the development and selection of optimization models for short-term scheduling of a set of operations that includes, product receiving from process units, storage and inventory management in intermediate tanks, blending in order to attain oil specifications and demands, and transport sequencing in oil pipelines.

2.7 Integration of Operations

Optimization at different levels is common in all industries. In production a lot of researches have been taking place. Some literature is available on inbound logistics and more work has been carried out in outbound logistics. Stevens [1986] presents the importance of integrating supply chain. He suggests that total integration alone will improve the performance. Lambert, et al. [1979] notes the appraisal of the integrated physical distribution. Total integration is not covered in this paper but importance of physical distribution is discussed. Towill [1991] discusses the dynamics of supply chain. In his paper the importance of inbound logistics is discussed. Stevens [1989] and Stevens, et al. [1989] suggest integrating from supplier to the end customer. Use of decision models are also discussed in this paper. Dieasli [1984] discusses the importance and application of functional integration. Back, et al. [1996] compared the performance and procedure of reengineering with SCM. Bell & Stukhast [1986] studied and identified the attributes of material management.

Ross and David [1996] identify the main challenge of SCM for integration. Wu, et al. [1999] suggests the special issue of supply chain management in the integration of operations. Gattorana [1998] suggests that alignment of operations is the key activity for the success of SCM. Gattora, et al. [1991] observed that reducing complexity in the logistics operation is important for the effective implementation of SCM. Bodington [1995] suggested the integration procedure for planning, scheduling, and control. Barney [1991] identified the importance of resource identification to have competitive advantage in the market. Bowersox [1997] states the importance of integrating the operations of an organization. Integration, to the customer side and supplier side is discussed. Amundson [1998] suggests the importance of theory driven researches in the field of SCM. In his paper it is noted that the application of research can be made only by integrating the results. Patterson [1999] discusses decision integration between manufacturing and marketing/sales and Scott, et al. [2002] compare that with original performance to establish the benefits of decision integration. Lenz [1981] identified integration as one of the determinants of organizational performance for a refinery. Stevens [1989] also suggested that integration is the only way for improvement of supply chain. Narasimhan and Carter [1998] stress the importance of linking business organization within material sourcing strategies. Wisner and Stanley [1999] developed an integration model for internal relationships and activities associated with high level of purchasing service quality. Narasimhan & Kim [2002] studied the effect of supply chain integration on the relationship between diversification and performance. Diversification is easy in an integrated organization. The performance will be improved by integration Mohan, et al. [2000] suggest that E-commerce can be used for integrating the customer and organization. Sahay, et al. [2001] suggest a framework for developing customer relationship. Eliram and Cooper [1990] make the point that developing partnership with shipper will make the scheduling and movement of materials more efficient. Lewis and Talalayevsky [1997] add the application of integration of logistics operations using information technology. Lewis, et al. [1997] suggested an integrated approach to reengineer material and supply chain control in a process industry.

2.8 Information Technology

Operations of SCM are widespread. Supplier may be at one place, operations in another place, and market can be in the third place. For a company which is doing international marketing, the market will be at different continents. So the integration of operation is really complex. Blois [1980] identified the need of information for orientation of manufacturing. The focus is on information from market. Balcer and Lipman [1984] suggest the need for technology adoption in information gathering. Broinarezyk & Alba [1994] notice the role of collection of information from consumers for process planning. Deveport and Short [1990] identify the need for redesigning the business process to make use of the development in information technology. Jones and Clarke [1990] made the point that effectiveness of SCM can be made only through integration of information.

Bowersox and Daugherty [1995] suggest the importance of information technology in logistics. Stress of the paper is inbound and outbound logistic operations. Petri [1996] suggests a life-cycle approach to automation and information management in a process industry. Importance of total integration using information systems is established in the paper. Elizondo [1996] emphasizes on the importance of networking firm's knowledge. He suggests that, the decision must be network based rather than individual based. Zipkin [1999] suggests to have a co-operative inventory policy through the supply chain. Feitzinger & Leed [1997] report that investment in IT has resulted in the availability of more information on channel activities to decision makers. Stalk, et al. [1992] discusses how the distribution centers obtain information in making replacement/delivery decisions. In article Forbes [1997] there are reports that the distributors can re-route shipments using IT. Fisher [1997] has identified a method to check the rightness of a company's supply chain. Moinzadeb & Aggarwal [1997] have developed an information based multi echelon inventory system with emergency orders. It also emphasizes the need for networking with suppliers and customers. Whang [1998] shares his experience of information sharing in supply chain. The main advantage is fast movement of material. Bour Land, et al. [1996] suggest that timely information reduces inventories. Chen [1998] says that the reorder point can be lowered by sharing information. Lee & Whang [2002] notice the importance of information sharing among partners. Aviv and Federgruen [1998] recommend the operational benefits of information sharing and vendor managed inventory programmes. Evans, et al. [1993] assessed the impact of information system on the dynamics of supply chain performance and predicted that it will reduce the inventory. Lin & Shaw [1998] suggest methods for re-engineering the order fulfillment process in supply chain network. Srinivasan, et al. [1995] identify that the increased speed of data flow can be achieved using information technology. Gustin, et al. [1995] suggested that the integration of logistic is achievable with the development in information flow. Mason Joues and Towill [1998] note that time compression in the supply chain information management is the vital action required for benefiting SCM performance.

Many organizations have recently recognized that sharing of information with other members in their supply chain can lead to significant reduction in the total cost. Gairneni [2002] suggets that information flow can be used for reducing fixed ordering cost. Cochan & Fisher [2002] note that inventory management will be efficient by information sharing. Many recent papers study the direct effect of supply chain information sharing. This line of research includes Cachon & Fisher [2000], Xiande, et al. [2002], Mehmet. et al. [2002]. Decter [1997] identified the importance of data acquisition and team building. In that paper the importance of team is discussed for the development of information sharing. Thouemann [2002] identifies the improvement in supply chain performance by sharing demand information from the market. Kefeng, et al. [2001] suggest that information technology can better co-ordinate the supply chain activities. Lode-Li [2002] writes on the importance of information sharing in a supply chain with horizontal competition.

Literature shows that increasing use of Information Technology is the main reason for the success of SCM. Application of information technology is ineviTable for any industry to implement SCM. Information sharing is the essence of speed of material flow. Literature shows that the sharing of information must go up to the supplier. So that they can also plan their production and delivery of goods. A model for information flow is essential to have efficient functioning. Efficiency of the information flow depends on the selection of technology and the appropriateness of information flow model used.

2.9 Tools Used in Supply Chain Management

SCM integration has to take place after optimizing all the elements of SCM operations. Optimization can be achieved only by the use of tools. Many tools are available in literature and a series of studies are taking place for developing new tools. Mohauty & Desutch [2001] emphasize the application of Decision Support Systems (DSS), and Linear Programming for the successful implementation of supply chain management.

2.9.1 Decision Support Systems (DSS)

Cox and Adam [1980] developed a DSS for manufacturing resource planning. Important information required for the top management for planning is discussed. Vanttee & Wilbrands [1988] developed a DSS for container terminal planning. Suggestions are given for the utilization of terminals. Karacapilids and Pappis [1997] developed a framework for group DSS by combining artificial intelligence and operations research techniques. A general algorithm for scheduling batch operations was developed by Koudili, et al. [1993]. Pasqale Leguto and Rina [2001] developed a DSS for berth planning in a port for container terminal. They have used discrete event simulation for developing the DSS. Yuss and Choi [1999] developed a simulation model for container terminal operations. This model optimizes the waiting time of containers. A discrete event simulation is used for the development of DSS. Bhasi and Acharya [1997] developed a DSS for ship lightering operations. A discrete event simulation method is used in it. Ronex [1986] developed a ship scheduling for short period. Ronex [1993] analyzed the ship operation in the decade.

Simulation in earlier stages were done using programme written using Fortran or other general-purpose computer languages. Developing logic and coding was very complex and time consuming and naturally the quality was also not very good. Expertise was essential for doing simulation. Packages like GPSS, SIMAN, SIMFACTORY, EXTEND, etc. came to help in the next stage. Developing simulation with package was much faster and simple. Still it could not be used as a general-purpose tool. The development of Object Oriented Languages made the use of simulation more popular. Speed of developing simulation programme reduced drastically because of splitting of operations to objects. Finally the development of Agent Based Simulation made the use of simulation simpler. Agents are developed for doing the simulation.

2.9.2 Optimization Tools.

Linear programming problems (LPP) are formulated and solved extensively for process industry operation. Garrod & Mikkirs [1985] developed an LPP for finding out the optimal ship size for transportation of bulk materials. Ship size problem was attacked by many people. Some of them are by Janson and Shmerson [1982], Pope and Talley [1988] and Ronen [1983] who developed a ship-scheduling model using LPP. Rubin & Wagner [1990] used LPP for fixing the shadow prices as tool for managers. Bodington [1992] used non-linear optimization for gasoline blending operation. Bodington & Shobrys [1996] suggest the application of optimization in supply chain. Lee, et al. [1996] used mixed integer programming model for refinery short term scheduling of crude oil unloading. Mansfield, et al. [1993] used integer programming for gasoline blending optimization. Mora, et al. [1998] developed an optimization model for production of diesel using LP. Moro and Pinto [1998] used mixed integer model for short-term crude scheduling. Pinto and Grossmann [1994] used LP for scheduling production for multi product plants. Pinto and Grossmann [1998] used assignment and sequencing models for the scheduling of chemical process industry. Salinidis and Grossman [1991] used MINLP model for multi product scheduling. Rigby, et al. [1995] used LP for blending refinery products. Slah [1996] developed LPP for crude oil scheduling. He has listed the assumptions made for developing the LP. Symonds [1995] has suggested that LP has the maximum applications for solving the refinery problems. Xueya & Sargent [1996] developed LPP for optimal operation of mixed production facilities. Gurmani & Tang [199] developed an LPP for finding out optimal ordering decisions with uncertain cost and demand forecast updating. Ravi & Raddy [1998] developed an operation planning model for a refinery using fuzzy linear fractional goal programming. Mand Gothe, et al. [2002] developed production scheduling model using fuzzy linear fractional goal programming. Importance of security analysis is discussed by ward & Wendell [1990] and Jansen, et al. [1997].

Jansen warns about the usage of changes. If not carefully done, the variations in results will not have any use. Variable selection must be in line with actual variation in the organization. Vehicle scheduling problem was formulated and solved by Foster and Ryan [1976]. They have used integer-programming approach. Li-Hsing Shih [1997] used mixed integer programming method for planning coal imports. Efficiency of supply chain vehicle scheduling problem was formulated and solved by Foster & Ryan [1976]. They have used integer-programming approach.

2.9.3 Demand Forecasting Methods

Demand forecasting has history of long standing. All types of industry needs demand forecasting for the material flow as well cash flow control. Forecasting demand for the products of a refinery is a similar problem when compared with other industries. Li-Hsing Slil [1997] used mixed integer programming method for planning coal imports that has a bearing on the correctness of demand forecasting. Battachargee [1998] noticed the importance of demand forecasting and claims that it is the major bottleneck in world class marketing. Laugly & Halcomb [1992] suggest that the customer value of the product decides the demand. Mass customization is discussed in the paper. Mentzer [1993] identified the importance of outbound channel management for better demand forecasting. Min & Mentzer [2000] emphasis the role of marketing in supply chain performance. Marien [2000] identifies demand forecasting as one of the major supply chain enablers. Muller [1991] discusses on competitive advantage through customer satisfaction for SCM. Lee, et al. [1997] suggests that the distortion in information as it passes up the supply chain is the reason for bullwhip effect in the demand forecasting. Melters [1997] has quantified the bullwhip effect in supply chain. It is also mentioned that it can be reduced by proper data collection. Federgruen and Zipkin [1989] introduced an inventory model, with limited production capacity. Lee, et al. [1997] studied the bullwhip effect in supply chain and found that bullwhip effect is the most important limiting factor in the performance of supply chain. Clen, et al. [2000] have quantified the bullwhip effect in a supply chain. The impact on forecasting, lead-time, and information are discussed in the paper.

Models are established with the help of case studies. Case studies provide data for checking the models developed. Eisenhurt [1989] did in the other way also. He was establishing that theories could be build from case studies. Stuart, et al. [1998] make point that case studies leverage the understanding. Meredith [1998] also suggested that theory with case study makes better understanding of the theory. Thomas & Yunsook [2002] developed the structure of supply network. It was established with the case of Honda. They compared these cases to establish the importance of supply network [outbound logistics]. Lamming, et al. [2002] did an initial classification of supply chain in to, inbound, internal, and outbound logistics. It was established in a case study.

Forecasting is the first major activity in the planning. It involves careful study of past data and present scenario. The main purpose of forecasting is to estimate the occurrence, timing or magnitude of future event. If the required level of accuracy for the forecast is less, then prediction is on the basis of past data and experience. It is not based on any analysis. To know the future demand on the basis of the demand in the past, extrapolation method can be used. The demand is forecast on the basis of data collected in the past. Volume of data is depended on the policy of forecasting. Morphological analysis can be done for finding out the consumption of petrol or diesel per head in a state or district. Literature shows that forecasting methods must be used for demand forecasting. Trend analysis is one of the commonly used methods for demand forecasting in a process industry.

2.10 Conclusion

Some of the major contributions to the existing vast literature in SCM are briefly reviewed. The literature survey was started with review of literature on concepts, definition and evolution of SCM. From the above literature survey it was seen that as time passed, researches have been widening the scope of SCM to the present status where it covers planning, coordination, controlling, materials, parts, and finished goods from original supplier to final customer focussing on material and information flows, guided by strategic decision making. The literature review brought out the importance of study of integrated SCM using IT.

The literature review on sub problem related to supply chain such as location selection, operational flexibility, strategic planning, hierarchical planning has established their importance in the case of petroleum refinery SCM. The importance of integration of operations and use of information technology to do the same was also seen in literature. SCM integration has to take place by integrating the optimum performing sub elements. Optimization and decision support systems tools used were reviewed. It was seen that mathematical programming tools are more popular in structured small size problems. Fussy logic methods are also popular; simulation models are increasingly being used in supply chain systems. Demand forecasting methods were reviewed and the problem caused by bullwhip effect in supply chains was found to be an important limiting factor for forecasting systems. Morphological analysis was seen to be another approach that could be used for product demand forecasting for a refinery for long term.

It was seen that different aspects of SCM in general and certain SCM functions of petroleum refinery in particular have been studied by researchers. A vide verity of tools have been used to solve the problems. The studies focussed on optimizing sub processes of the supply chain. Integration of the complete supply chain was not to be found. This presents opportunity for work on developing integrated supply chain for refinery.

CHAPTER III

Model for Selection of New Refinery Location

3.1 Introduction

Crude oil, available in a few parts of the world, is being used all over the world. Production of crude oil depends on demand. Availability of crude is not unlimited; so many countries are tapping it carefully. This chapter discusses factors relating to availability of crude oil through out the world, its production, and consumption. Global petroleum logistics analysis is done using secondary data. Indian petroleum scenario is also analyzed using secondary data. India is still importing refined petroleum products. Hence setting up refineries may be an option in the near future to reduce or even to eliminate import of refined petroleum products and improve the potential for export of the same to neighboring countries (IOC corporate presentation 2003). A model is developed for finding out location for a refinery anywhere in the world. This model is adopted to locate a refinery in India. Like location, flexibility is also important in refinery logistics. Need for flexibility and areas of flexibility are also discussed in detail here but no attempt is made to quantify the flexibility. Refinery configuration in the Indian context is also discussed in this chapter. Similar analysis is done in the United States. So the developments in the US are taken as benchmark in this section. Initial portion is presented with basic activities in oil industries. This will help in getting a basic idea on the formation of crude oil, availability of crude oil, collection of crude oil, storage, trade practices, transportation through land and sea, and procedure of refining. The refined product related activities are also discussed in this section. Reports from Energy Information Administration (EIA) are taken as the basic material for the oil market basic description presented in this section. This information is not used in any of the model developed. Data presented is not taken for any calculations in the models developed in the research, but is used to set understanding of the background in which our models can be appreciated better.

3.2 Global Petroleum Supply Chain

Location of a refinery is strongly dependent on the place of drilling of crude oil, purchase procedure, mode of transport, and place of consumption. So this section also analyzes in detail, these aspects with respect to the world crude oil industry.

3.2.1 Demand for Crude Oil

This section reviews the uses of petroleum and the data sources connected to that. The energy produced by burning petroleum products may be used to propel a vehicle as gasoline, jet fuel, or diesel fuel. The energy produced is also used to heat a building as heating oil or residual fuel oil. Electric energy can produced by spinning a turbine directly or by creating steam to spin a turbine with help of heat produced from petroleum products. Crude oil products are used as raw material (feedstock) to produce petrochemicals or products such as plastics, polyurethane, solvents, and many other intermediate and end-user goods. These products play vital role in the present day to day life. So the dependence on crude oil for energy is steadily increasing.

3.2.2 Global Oil Consumption

Largest consumers of crude oil are the industrialized countries. Until 1998 these were not the most important growth markets for some years. The countries of the Organization for Economic Cooperation and Development (OECD) account for almost 2/3 of worldwide daily oil consumption. Oil demand in the OECD grew by around 11 percentages over the 1991-97 periods, while demand outside the OECD (excluding the Former Soviet Union) grew by 35 percent. The collapse of the Russian economy led to a decline in oil consumption of more than 50 percent over the 1991-98 periods. This consumption has regained almost to the same level in the next five year period.

Economic condition of a country has direct bearing on the consumption of crude oil. Developed economies use oil much more intensively than the developing economies. Canada and the United States stand almost alone with their high per capita consumption of oil. Oil consumption in the United States and Canada equals almost 3 gallons per day per capita. The difference in these countries is largely due to their transportation system. People in developed countries mainly depend on private vehicles to travel relatively long distances. Oil consumption in the rest of the OECD equals 1.4 gallons per day per capita. Outside the OECD, oil consumption is only 0.2 gallons per day per capita. Dependence of public transport is the main reason for lesser consumption of crude oil in the under developed countries.

In petroleum consumption North America is the first. In North America, it is dominated by the United States. It is followed by Asia (with Japan the largest consumer). Europe is holding the third position (consumption is more evenly spread among the nations). The other regions follow almost the same pattern.

3.2.3 Measuring Oil Consumption

Crude oil consumption can be measured to know the growth of each nation, region, and continent. Measuring oil consumption presents a dilemma for public and private analysts. The size and complexity of the market and the number of consumers and suppliers make data collection a daunting task. The EIA, like other governmental agencies and analysts, uses a variety of approaches to measure oil consumption.

Consumer surveys can provide a good deal of insight into how people use oil, the characteristics of the fuel-burning equipment they use, and other factors that affect consumption. EIA has undertaken a variety of complex surveys to examine oil consumption, such as the Residential Energy Consumption Survey and the Manufacturing Energy Consumption Survey. These surveys are costly, time-consuming, and have a long lag before publication. They are not practical alternatives for short-term data collection.

Collecting data from suppliers is a better option for estimating consumption on a routine basis. Here the depth of required information is critically affected by the frequency with which it must be reported. On an annual basis, for instance, EIA collects and publishes detailed sales data such as its Sales of Fuel oil and Kerosene. It also reports the source for sector-by-sector information on consumption of these fuels. Available on a State-by-State basis, the report's data also feed EIA's multifuel State Energy Data System (SEDS). On a monthly basis, EIA collects sales data for major products from refiners and from prime suppliers. Such data is published in the Petroleum Marketing Monthly (PMM). The prime supplier data, reflecting first sales into a State for local consumption, are published in the PMM on a State-by-State basis.

As for other goods, EIA also routinely monitors the sources of supply of petroleum in order to estimate the amount of product delivered to the market. To make data collection manageable, it focuses on the 'primary supply' system. The primary system involves refiners, importers, pipelines, and marine transporters of petroleum, large storage facilities, and storage facilities with access to waterborne deliveries or pipelines. For most refined petroleum products, the balance is:

- Refinery production (output)
- plus imports of the product
- plus or minus the change in inventory
- plus or minus shipments from other domestic regions
- minus exports
- equals Product Supplied

Petroleum analysts equate 'Product Supplied' with consumption; there is a lag between petroleum delivered into the market and petroleum actually consumed. The product may be stored in a tank belonging to a wholesaler, a retailer, or a consumer before it is used. It is not possible to capture these and therefore can be surprised by short-term volume fluctuations as these tanks are unexpectedly filled or emptied. The methodology overstates demand when the product moves into wholesaler or retailer storage and understates it during the period when it is actually consumed. So the actual data may not be available for computation.

3.2.4 Supply of Crude Oil

Knowledge on the formation of crude oil, types of crude oil, drilling procedures, place of availability, present practices in the industry, etc will be added advantage in making the decision on purchase of crude oil. So this section provides a detailed discussion on those details relating to crude oil.

3.2.4.1 What is Oil and Where It Comes From?

Formation of oil is a natural time consuming process. According to the most widely accepted theory, oil is composed of compressed hydrocarbons, and was formed millions of years ago in a process that began when aquatic plant and animal remains were covered by layers of sediment, particles of rock and mineral. Over millions of years of extreme pressure and high temperatures, these particles became the mix of liquid hydrocarbons that we now know as oil. Different mixes of plant and animal remains, as well as pressure, heat, and time, have caused hydrocarbons to appear today in a variety of forms: crude oil(liquid), natural gas (gas), and coal (solid). Even diamonds are a form of hydrocarbons.

The word 'petroleum' comes from the Latin words *petra*, or rock, and *oleum*, oil. Oil is found in reservoirs in sedimentary rock. Tiny pores in the rock allowed the petroleum to seep in. These 'reservoir rocks' hold the oil like a sponge. It is confined by other non-porous layers that form a 'trap'. The world consists of many regions with different geological features formed as the earth's crust shifted. Some of these regions have more and larger petroleum traps. In some reservoir rocks, the oil is more concentrated in pools, making it easier to extract, while in other reservoirs it is diffused throughout the rock.

Both favorable characteristics are visible in the regions of Middle East, the petroleum traps are large and numerous, and the reservoir rock holds the oil in substantial pools. This region's dominance in world oil supply is the clear result. Other regions also have large oil deposits, even if the oil is more difficult to be identified and more expensive to produce. Geologists generally agree that crude oil was formed over millions of years from the remains of tiny aquatic plants and animals that lived in ancient seas. Petroleum owes its existence largely to one-celled marine organisms. As these organisms died, they sank to the sea bed and buried with sand and mud. They formed an organic-rich layer that eventually turned to sedimentary rock. The process repeated itself, one layer covering another.

There are three essentials in the creation of a crude oil field:

First, a 'source rock' whose geologic history allowed the formation of crude oil. This usually is fine-grained, rich in organic matter.

Second, migration of the oil from the source rocks to a 'reservoir rock', usually a sandstone or limestone that is thick and porous enough to hold a sizable accumulation of oil. A reservoir rock that is only a few feet thick may be commercially producible if it's at a relatively shallow depth and near other fields. To warrant the cost of producing in more challenging regions (the Arctic North Slope) the reservoir may have to be several hundred feet thick.

Third, entrapment of these material in a region. The earth is constantly creating irregular geologic structures through both sudden and gradual movements - earthquakes, volcanic eruptions and erosion caused by wind and water. Uplifted rock can result in domelike structures or arched folds called anticlines. These often serve as receptacles for hydrocarbons. The probability of discovering oil is the greatest when such structures are formed near a source rock. In addition, an overlying, impermeable rock must be present to seal the migrating oil in the structure. The oldest oil-bearing rocks date back to more than 600 million years and the youngest is about 1 million. Most oil fields have been found in rocks between 10 million and 270 million years old.

Critical factor in the creation of oil is subsurface temperature, which increases with depth. Petroleum hydrocarbons are rarely formed at temperatures less than 150 degree Fahrenheit and generally are carbonized and destroyed at temperatures higher than 500 degrees. Most hydrocarbons are found at temperatures ranging from 225 to 350 degrees. It is the particular crude oil's geologic history that is most important in determining its characteristics. Some crude oils from Louisiana and Nigeria are similar because both were formed in similar marine deposits. In parts of the Far East, crude oil generally is waxy, black or brown, and low in sulfur. It is similar to crude oils found in central Africa because both were formed from non-marine sources. In the Middle East, crude oil is black but less waxy and higher in sulfur. Crude oil from Western Australia can be a light, honey-colored liquid, while that from the North Sea typically is a waxy, greenish-black liquid. Many kinds of crude oils are found in the United States because there is great variety in the geologic history of its different regions.

3.2.4.2 Drilling for Oil

Prospective site identification for crude oil production is a difficult task. Companies use a variety of techniques, including core sampling and Seismic testing . Core sampling is physically removing and testing a cross section of the rock. Seismic testing is the return vibrations from a man-made shockwave are measured and calibrated. Advances in technology have made considerable improvements in seismic testing. After these exploratory tests, companies must then drill to confirm the presence of oil or gas. A 'dry hole' is an unsuccessful well, one where the drilling did not find oil or gas, or not enough to be economically worth producing. A successful well may contain either oil or gas, and often both, because the gas is dissolved in the oil. When gas is present in oil, it is extracted from the liquid at the surface in a process. Oil production and this process is not the same.

Searching for oil in a field where it had not yet been discovered is called wild cat well. It has a low chance of success. Only one out of five wildcat wells found oil or gas. The rest were dry holes. Better information, especially from seismic technology, has improved the success rate to one out of three and, according to latest information, one in two. Reducing the money wasted on dry holes is one of the aspects of upstream activity that has allowed the industry to find and produce oil at the prices prevailing over much of the 1990's. After a successful well that identifies the presence of oil and gas, additional wells are drilled to test the production conditions and determine the boundaries of the reservoir. Finally, production wells, or development wells are put in place, along with tanks, pipelines and gas processing plants. So the oil can be produced, moved to markets and sold. Once extracted, the crude oil must be refined into usable products for marketing.

3.2.4.3 How Oil is Produced

The most important determinant of whether the reservoir is economically viable or not is the naturally occurring pressure in the underground reservoir. The pressure varies with the characteristics of the trap, the reservoir rock and the production history. Most oil is produced by 'natural lift' production methods. The pressure in the underground is high enough to force the oil to the surface. Reservoirs in the Middle East tend to be long-lived on 'natural lift' that is the reservoir pressure continues to be great enough to force the oil out. Underground pressure in older reservoirs eventually dissipates, and oil no longer flows to the surface naturally. It must be pumped out by means of an 'artificial lift'. A pump powered by gas or electricity is used to lift crude oil. Majority of the oil from the reservoirs in the United States are produced using some kind of artificial lift using pumps. It gives better output also.

Primary production methods become ineffective over a period of time and continued production requires the use of additional secondary production methods. One common method uses water to displace oil, using a method called waterflood, which forces the oil to the drilled shaft or wellbore. Producers may need to for tertiary or enhanced oil recovery methods. These techniques are often focussed on increasing the flow characteristics of oil through the use of steam, carbon dioxide and other gases or chemicals. In the United States, primary production methods account for less than 40 percent of the oil produced on a daily basis, secondary methods account for about half, and tertiary recovery the remaining 10 percent. Both the varying reservoir characteristics and the physical characteristics of the crude oil are important components of the cost of producing oil. The costs can range from $2 per barrel in the Middle East to more than $15 per barrel in some fields in the United States. This cost includes capital recovery also.

3.2.4.4 The Impact of Upstream Technology

Revolutionizing the information available about the features of a geologic structure has enhanced the finding of crude oil. A primary benefit is the ability to eliminate poor prospects. This is considerably reducing wasted expenditures on dry holes. Drilling and production technologies have made it possible to exploit reservoirs that would formerly have been too costly to put into production and to increase the recovery from existing reservoirs. Technology also has contributed to making oil exploration and production safer for the industry and for the environment. Offshore production can be operated from onshore. The automatic shutoff systems is used to minimize the pollution risk. The proven crude oil reserves have increased from about 650 billion barrels in 1977 to about 900 billion barrels in 1987 and further to about 1074 billion barrels as at the end of 2001. This has been possible due to the sustained efforts in Oil exploration. The Organization of Petroleum Exporting Countries, popularly called the OPEC continues to dominate the share of world oil reserves. Its share in world oil reserves has increased from 67 % in 1977 (436.2 billion barrels) to 77% in 2001 (845 billion barrels). As a country, Saudi Arabia has the highest oil reserves in the world with a share of 25 %, followed by Iraq, UAE, and Iran, each with 10 -11 % of world oil reserves. The proven crude oil reserves as at end of 2001 are given in Table 3.1

Table 3.1 World proven crude oil reserves by region, 1996-2001 (m. b.)

Region	1996	1997	1998	1999	2000	2001
North America	30722	30652	31272	30147	33066	33346
Latin America	138762	140342	141909	123104	123780	123896
Eastern Europe	67366	67374	67281	67260	67160	66790
Western Europe	18540	18751	18348	18843	18033	18128
Middle East	675996	676755	677806	678737	694754	696261
Africa	74776	75195	76980	83504	90004	92797
Asia and Pacific	43428	43438	44255	44387	44391	44980
Total World	1049590	1052508	1057853	1045381	1070686	1074850
OPEC	802819	806080	810144	818247	840538	845412
OPEC Percentage	76.5	76.6	76.6	78.2	78.5	78.7

Source: OPEC Annual report 2001

Crude oil available at all places does not have the same quality. Specific Gravity and sulfur content of crude oil mainly decide quality. Production of crude oil is gradually increasing because the demand is increasing. Table 3.1 shows that availability of crude is increasing, rather it is not decreasing when compared to production. Phenomenon of increasing production is continuing in all other countries.

Figure 3.1 (on world crude oil supply) shows that crude oil supply by NON-OPEC countries is declining while that from OPEC countries is increasing. It means that, out of the total demand, nearly 50% is supplied by OPEC countries. World is mainly depending on OPEC countries for the crude oil supply.

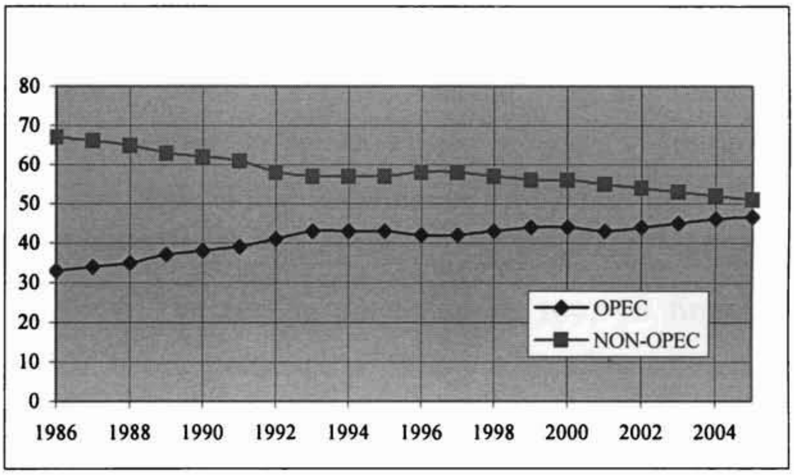


Figure 3.1. World Crude oil Supply

Table 3.2 World output of refined products by region, 1996-2001(1000b/d)

Region	1996	1997	1988	1999	2000	2001
North America	18355.2	18675.2	18918.4	18934.9	19305.1	19200.2
Latin America	6469.6	6554.7	6750.3	6592.6	6653.1	6801.6
Eastern Europe	5814.7	5839.8	5768.0	5697.9	5828.0	6165.4
Western Europe	14590.2	14885.9	15262.7	14572.8	14833.1	14774.8
Middle East	5060.4	5190.6	5534.4	5554.4	5534.2	5521.1
Africa	2360.1	2365.1	2298.6	2376.3	2404.8	2584.4
Asia and Pacific	15540.9	16351.5	16306.8	1256.7	17843.9	17941.8
Total World	68191.0	69862.9	70839.1	70985.5	72402.2	72989.1
OPEC	7275.0	7386.7	7657.5	7622.2	7638.7	9840.7
OPEC %	10.7	10.6	10.8	10.7	10.6	10.7

Source: OPEC Annual report,2001

3.2.5 International Petroleum Trade

This section looks at petroleum trade and transportation. The main oil producing areas are not the main consuming areas. Hence, oil must be moved from regions where supply is greater than demand (exporting regions) to regions where demand is greater than supply (importing regions). The demand and supply balance results in oil flows from one international region to another, from one country to another, and from one region within a country to another. These flows, dictated by economics, logistics, and temporary imbalances in supply and demand, are vital to the efficient operation of the oil market.

3.2.6 Regional Importers and Exporters

North America, Europe, and Asia-Pacific are the world's three largest consuming regions. They are all importers. All the other regions are exporters. The Middle East still exports more oil than any other region. Despite the strong growth in production in other areas in recent years they continue to be the largest exporters. This global dependence on Middle East oil makes the geo-political importance of the Middle East. There is less variation among the importing regions. In the decade preceding its 1997-98 financial crisis, Asia-Pacific's economic boom propelled it into the number one spot, with import growth more than double that of any other region's. The United States is the largest individual importer, both net and gross put together. North America as a region ranks third because Canada and Mexico are two of the United States' three top oil suppliers. Their exports to the United States offset U.S. imports from these neighbors in the regional calculation. Net imports are gross imports minus gross exports. This has kept North America's import dependency down to around 30 percent, half that of the Asia-Pacific region at its 1997 peak. Asia-Pacific region's import dependency and even its import volume make it as the world's top importing region. This is mainly due to the lesser domestic production.

3.2.7 Global Patterns of Oil Trade

Purchasing is an important activity in the petroleum supply chain. To make the purchasing effective, one must be aware of the trade practices prevailing in the industry. This section deals with the crude oil trade patterns and practices prevailing in the industry.

3.2.7.1 Oil Trade: Highest Volume, Highest Value

International trade of oil is more than anything else. This is true whether one measures trade by volume or by its value, or by the carrying capacity needed to move it. All measures are important for different reasons. Volume provides insights about whether markets are over supplied or under-supplied and whether the infrastructure is adequate to accommodate the required flow or not. Value allows governments and economists to assess patterns of international trade and balance of trade and balance of payments. Carrying capacity allows the shipping industry to assess how many tankers are required and on what routes. Transportation and storage play a critical additional role here. They are not just the physical link between the importers and the exporters, but between producers and refiners, refiners and marketers, and marketers and consumers; their associated costs are a primary factor in determining the pattern of world trade. These factors contribute to the smooth flow of crude oil.

3.2.7.2 Distance: The Nearest Market First

Crude oil and petroleum products flow to the markets that provide the highest value to the supplier. Everything else being equal, oil is traded and transported to the nearest market first, because that has the lowest transportation cost. It therefore provides the supplier with the highest net revenue, in oil market terminology, the highest netback. If this market cannot absorb all the oil, the balance moves to the next closest market and the next and so on. This will continue incurring progressively higher transportation costs, until all the oil is sold. The recent growth in dependence of the United States on its Western Hemisphere neighbors is an illustration of this 'nearer-is-better' syndrome. Western Hemisphere sources now supply over half of the United States import volume, much of it on voyages of less than a week. Another quarter comes from elsewhere in the area called the Atlantic Basin. Those countries are on both sides of the Atlantic Ocean. This oil, especially from the North Sea and Africa, takes just 2-3 weeks to reach the United States, and boosts the so-called short-haul share of U.S. imports to over three-quarters. Most North Sea and North and West African crude oils stay in the Atlantic Basin, moving to Europe or North America on routes that rarely take over 20 days. In contrast, voyage times to Asia for the nearest of these, the West African crude oils, would be over 30 days to Singapore, rising to nearly 40 for Japan. Not surprisingly, therefore, most of Asia's oil comes instead from the Middle East, only 20-30 days away. Mexico and Venezuela have consciously helped the trend toward short-haul shipments. They pro-actively took the strategic decision to make as large and as profitable market. They make it possible for poor quality crude oil also. Their reserves are unusually biased toward those hard-to-place grades. Both countries therefore targeted their nearest markets. They target U.S. Gulf Coast and the Caribbean for joint venture refinery investments. They began with refineries that had traditionally run their crude oil, and then with refineries that might be upgraded to do so. This policy has turned poor quality crude oil to be preferred at these sites. Western Hemisphere has significantly increased the crude oil self-sufficiency with this policy.

Shipping industry will get affected by a change in trade flow patern.A change in trade flow patterns can also be of critical importance to the shipping industry. For example, the Suez crisis of 1957 forced tanker owners back to using the much longer route around the Cape of Good Hope, and resulted in the development of Very Large Crude Carriers (VLCC) to reduce that voyage's higher costs. The shift to short-haul routes in the 1990's was also critical. Using the growth in world trade volumes as a proxy for demand, tanker owners had been expecting a return to a strong tanker market. The combination of the surge in short haul imports in the Atlantic Basin and the shift of Middle East exports from the longer United States to shorter Asian voyages led to a sharp decline in average voyage length. This decline was accelerated by the return of Iraqi crude exports, many of which move on the extremely short route from the Black Sea end of the Iraq-Turkey pipeline to the Mediterranean. The tanker owners' outlook was thus fading even before world trade volumes were undermined by the Asian crisis. In practice, trade flows do not always follow the simple 'nearest first' pattern. Three important factors that tie into profitability of a refinery are refinery configurations, product demand mix, product quality specifications, and politics can all change the rankings. Different markets frequently place different values on particular grades of oil. Thus, a low sulfur diesel is worth more in the United States, where the maximum allowable sulfur is 0.05 percent by weight, than in Africa, where the maximum can be 10 to 20 times higher. Similarly, African crude oils are worth relatively more in Asia, where they may allow a refiner to meet tighter sulfur limits in the region without investing in refinery upgrades. Such differences in valuing quality can be sufficient to overcome transportation cost disadvantages, as the relatively recent establishment of a significant trade in long-distance African crude oils to Asia shows. The cost of transportation of crude oil will change when the government policies such as tariff changes. The balance on transportation can be lost due to these types of changes in policies.

3.2.7.3 Crude versus Products

World oil trade is still dominated by the trade in crude oil. Quality changes in product are one of the main reasons. The risk-weighted economics clearly support positioning refineries close to consumers rather than close to the wellhead. This positioning policy takes maximum advantage of the economies of scale of large ships; especially as local quality specifications are increasingly fragmenting the product market. It maximizes the refiner's ability to tailor the product output to the market's short-term surges such as those caused by weather, equipment outages, etc. In addition, this policy also guards against the very real risk that governments will impose on selective import restrictions to protect their domestic refining sector. As noted in the section on, there are a limited number of refining centers that are at odds with this general rule, having been developed to serve particular export markets. These export refining centers give rise to some regular inter-regional product moves, but they are the exceptions. Major export refining centres are Singapore, the Caribbean, and the Middle East. The inter-regional products trade is largely a temporary market-balancing function. Some inter-regional flows are extremely short lived, as when extremely cold weather in Europe causes the United States to export heating oil. A longer-lived example arose when a large proportion of European drivers opted for diesel cars, leaving the region in the late 1990's with surplus capacity to produce gasoline for export to the United States. This gave a new product demand pattern and transport requirements in that scetor.

3.2.7.4 Tankers and Pipelines

Tankers and pipelines are the two modes used for transportation of inter-regional trade. Tankers have made use for intercontinental transport of crude oil. The major reasons for using tankers are, they are low cost, efficient, and extremely flexible. Pipelines are the mode preferred for transcontinental crude oil movements. All tanker trade routes do not use the same size ship. Each route usually has one size that is clearly work out the economics best. The size is selected on the basis of voyage length, port and canal constraints, and volume. Crude oil exports from the Middle East are moved mainly by Very Large Crude Carriers (VLCC's) typically carrying over 2 million barrels of oil on every voyage. Pipelines are critical for landlocked crude oils and they also complement tankers at certain key locations by relieving bottlenecks transport or providing shortcuts to certain other places. The only inter-regional trade that currently relies solely on pipelines is crude from Russia to Europe. Pipelines contribute main role in intra-regional trade. They are the primary option for transcontinental transportation in almost all part of the world. They are cheaper to a great extend than any alternative such as rail, barge, or road. The development in technology in manufacturing of large diameter pipelines during World War II allowed the development of the vast pipeline network that moves crude oil and product.

Fungibility is an important factor in transportation economics of crude oil and products. Fungibility is the ability to substitute one shipment for another, to exchange between regions. Because the oil is broadly interchangeable (fungible), it can be mixed without any significant change in value. Environmental mandates have required different regional and seasonal qualities of gasoline. The changes in mandates increased substantially in batching for transport and segregation for storage. Thus the logistics flexibility inherent in a product's fungibility has disappeared. This is invisible to consumers during normal times. This adversely contributes to market upheavals and price spikes in times of sudden changes in demand or supply, as during the early driving season in 2000.

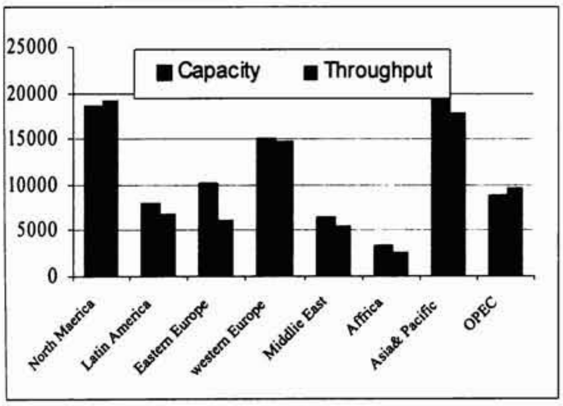
Table 3.3 World exports of refined products by region, 1996-2001(1000b/d)

Region names	1996	1997	1988	1999	2000	2001
North America	1203.6	1251.3	1174.2	1171.2	1360.3	1374.5
Latin America	1848.1	2002.2	2130.5	2079.2	2063.9	2131.7
Eastern Europe	1188.9	1220.7	1112.8	1143.8	1325.8	1512.3
Western Europe	4154.9	4246.3	4263.2	4252.7	4436.1	4454.1
Middle East	3197.3	3335.9	3284.2	3302.1	3140.3	2962.6
Africa	871.0	1049.4	957.6	1162.2	1142.7	1193.6
Asia and Pacific	2697.1	2970.8	2936.4	2852.7	2844.1	2869.8
Total World	15160.9	16076.7	15858.9	15963.9	16313.0	16498.5
OPEC	4411.7	4668.0	4580.2	4745.3	4506.8	4317.8
OPEC %	29.1	29.0	28.9	29.7	27.6	26.2

Source: OPEC Annual report,2001

The region wise analysis of refining capacity and throughput in the year 2001 is shown infigure3.2. The maximum installed capacity is in the Asia and Pacific region. The capacity utilization is the lowest in Eastern Europe and the highest in the OPEC.

Table 3.4 shows the details of region wise global crude oil exports. It can be observed that there is no appreciable increase in the export from OPEC countries during the period of analysis. Crude oil export by OPEC members to different destinations is shown in Table 3.5.



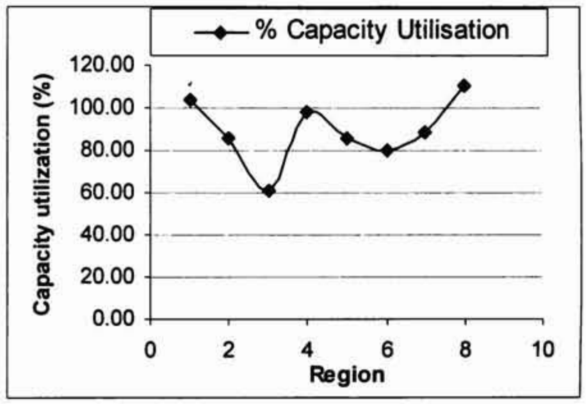


Figure 3.2 Comparison of capacity & throughput **Figure 3.3** Capacity utilization (percentage)

Table 3.4 World Crude oil exports by region, 1996-2001(1000b/d)

Region	1996	1997	1988	1999	2000	2001
North America	1182.3	1139.6	1258.7	1168.0	1226.7	1153.9
Latin America	4585.6	5061.7	5188.5	4715.5	5039.5	5060.9
Eastern Europe	2069.0	2177.9	2428.2	2565.0	3058.3	3346.1
Western Europe	4408.7	4569.2	4525.7	4670.5	4985.2	4904.9
Middle East	13820.0	14553.7	15597.9	15147.0	16016.5	15390.6
Africa	4876.0	5035.2	5226.1	4863.0	5172.4	5261.5
Asia and Pacific	2214.9	2275.6	2210.7	2222.1	2266.2	2214.8
Total World	33156.5	34812.9	36435.8	35351.0	37764.9	37332.7
OPEC	18372.0	19331.1	20586.9	19405.5	20526.7	19880.8
OPEC Percentage	55.4	55.5	56.5	54.9	54.4	53.8

Source: OPEC Annual reports,2001

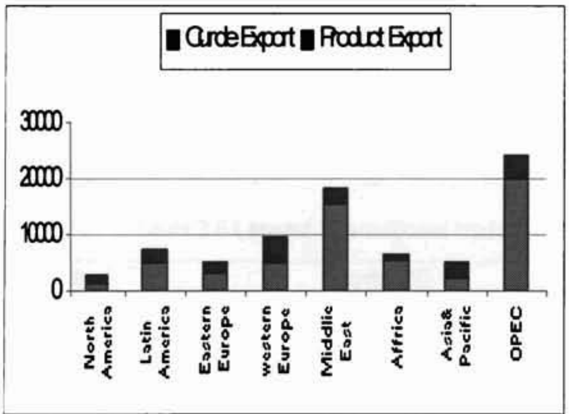


Figure **3.4** Comparison of crude and product export

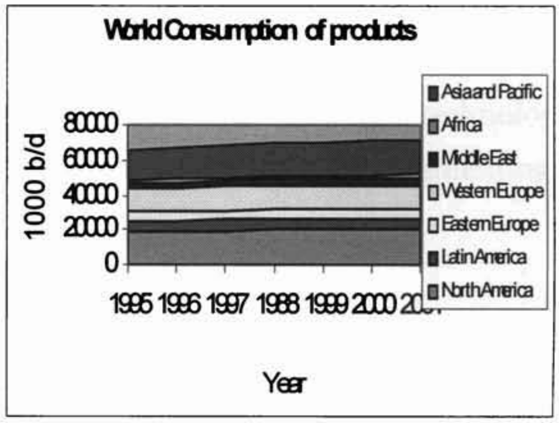


Figure **3.5** World Consumption of refined products

The consumption pattern is positively correlated with per capita income of the country. Consumption of petroleum products is more in urban and industrial areas. Consumption of crude oil is steadily increasing in all the countries in the world and it is expected to grow in the next fifteen years also. Due to the globalization all refineries are trying to reduce cost of competitive advantage and

Table 3.5 OPEC Members crude oil exports by destination, 1997-2001(1000b/d)

Destination	1997	1998	1999	2000	2001
North America	1557.3	1558.2	1223.2	1214.8	1236.7
Canada	92.8	102.9	108.6	96.9	85.7
United States	1464.5	1455.3	1114.6	1117.8	1151.0
Latin America	497.5	532.4	577.6	671.2	611.2
Brazil	na	na	na	na	na
Chile	na	na	na	na	na
Jamaica	na	na	na	na	na
Netherlands Antillies	na	na	na	na	na
Panama	na	na	na	na	na
Puerlo Rico	na	na	na	na	na
Eastern Europe	na	na	na	na	na
Western Europe	152.1	150.3	122.1	99.5	112.8
France					
Germany	49.3	49.7	38.4	26.2	28.7
Italy	9.6	2.6	1.3	2.0	2.8
Netherlands	9.1	13.0	12.6	7.4	9.3
Spain	18.9	31.3	24.4	22.5	32.7
United Kingdom	29.2	29.1	20.4	16.0	22.9
Middle East	-	-	-	-	-
Africa	-	-	-	-	-
Asia and Pacific	3.9	3.0			4.0
Japan					
Unspecified	-	-	-	18.1	-
Total World	2210.8	2243.9	1923.0	2003.5	1964.7

Source: OPEC Annual report,2001

a lot of improvement have been achieved in process technology. Even though seventeen percentage of the total cost is going to logistics operations, much study has not been carried out in this area. Improvement in information technology gave quantum leap in integration of logistics operations by way of implementing

Table 3.6 Largest International traders in Crude and Petroleum products

Product	Crude Oil		Petroleum Products	
Rank	Exporter	Importer	Exporter	Importer
1	Middle East 51%)	USA (26%)	Middle East (27%)	Asia Pacific (23%)
2	West Africa (10%)	W.Europe (25%)	Former USSR (13%)	USA (21%)
3	S & C America (7%)	Other Asia Pacific (18%)	S&C America (11%)	W.Europe (18%)

Source: BP Statistical Review,2002

SCM in other type of industries. Further major improvement in cost reduction in petroleum industry can be expected by applying SCM in existing and new refineries. This is more important for Indian refineries because India is in the process of complete decontrol of petroleum sector.

Table3.7. World Consumption of refined products by region, 1996-2001(1000b/d)

Region	1996	1997	1988	1999	2000	2001
North America	18929.9	19373.5	19701.8	20378.1	20463.1	20369.9
Latin America	5926.5	6197.9	6405.0	6239.6	6370.4	6240.7
Eastern Europe	5407.6	5543.6	5381.0	5144.4	4834.3	5009.0
Western Europe	13376.7	13450.1	13735.4	13802.8	13691.2	13911.3
Middle East	3469.0	3521.0	4004.8	3947.4	4046.9	4187.3
Africa	1972.0	2034.4	2092.6	2106.7	2059.8	2111.7
Asia and Pacific	17650.9	18475.3	17881.1	18815.5	19355.2	19312.7
Total World	66732.7	68595.9	69201.7	70434.5	70820.8	71142.7
OPEC	4436.0	4549.4	4979.0	4850.9	5053.8	5254.7
OPEC Percentage	6.7	6.7	7.3	7.0	7.2	7.2

Source: OPEC Annual report,2001

Crude Oil has been discovered in different parts of the world. 941 billion barrels in the OPEC region and 890 billion in the non-OPEC region, Major quantity of crude oil discovered so far are in the Middle East (742 billion barrels). Out of the 1831 billion barrels discovered, 854 billion barrels has been produced so far. Even though the production is concentrated in the OPEC countries, consumption is distributed through out the world. The consumption pattern is proportional to the per capita income of the country. Consumption of the petroleum products is seen to be more where the per capita income is more.

Crude oil consumption is treated as a parameter to measure the growth rate of a nation. Consumption of crude oil is steadily increasing in the countries of the world.

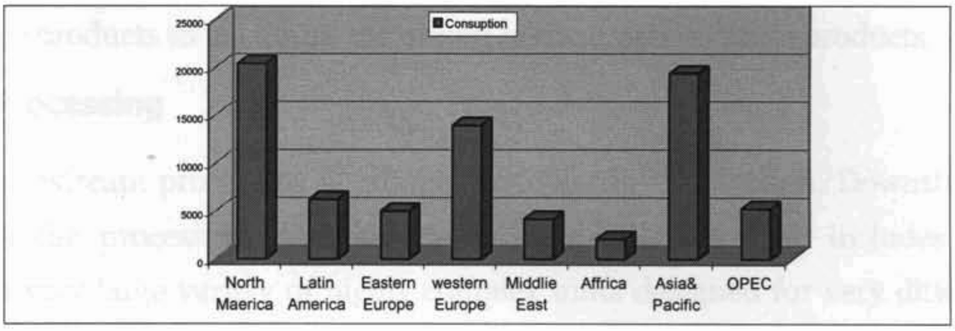


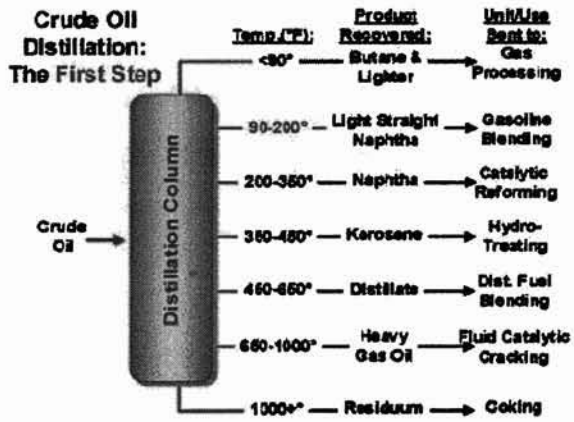
Figure 3.6. Consumption of refined products comparison

3.2.8 Refining of Crude Oil

Refining is a complex series of processes that manufacture finished petroleum products out of crude oil and other hydrocarbons. This section deals with discussion of refining. Refining begins as simple distillation but refiners must use more sophisticated additional processes and equipment to produce the products according to the market demands for different products. This effort minimizes the production of heavier, lower value products (residual fuel oil) in favor of lighter, higher value products (gasoline). This provides better profit for the refineries.

3.2.8.1 Simple Distillation

Core refining process is simple distillation. It is illustrated in the diagram shown at the right. Crude oil is made up of a mixture of hydrocarbons. Basic refining process is aimed at separating the crude oil into its 'fractions. Crude oil is heated and put into a still, a distillation column, and different products boil off and can be recovered at different temperatures. The lighter products (liquid petroleum gases (LPG), naphtha, and so-called 'straight run' gasoline) are recovered at the lowest



temperatures. Middle distillates (jet fuel, kerosene, distillates such as home heating oil and diesel fuel) come next. The heaviest products (residuum or residual fuel oil) are recovered as the last. The heavier fractions are processed into lighter products to maximize the output of the most desirable products.

3.2.8.2 Processing

Downstream processing is grouped together in this section. Downstream process is the process that follows crude oil distillation. This includes and requires a very large variety of highly complex units designed for very different upgrading processes. Downstream process makes some change in the molecular structure of the input with chemical reactions, and some with thermal reactions. Chemical reactions in crude oil are normally taking place in the presence of a catalyst. These processes are designed to take heavy, low-valued feedstock and change it into lighter, higher-valued output. A catalytic cracker uses the gas oil, heavy distillate, output from crude distillation as its feedstock and produces additional finished distillates (heating oil and diesel) and gasoline. Sulfur removal is accomplished in a hydrotreater. A reforming unit produces higher octane components for gasoline from lower octane feedstock that was recovered in the distillation process. A coker uses the heaviest output of distillation, the residue, to produce a lighter feedstock for further processing, as well as petroleum coke. The output from simple distillation of a crude oil like Arab Light would be about 20 percent of lightest, gasoline-like products, and about 50 percent of the heaviest. Further processing in the most sophisticated refinery can produce the finished product output in to about 60 percent gasoline, and 5 percent heaviest.

3.2.8.3 Crude Oil Quality

Crude oil with a similar mix of physical and chemical characteristics, usually produced from a given reservoir constitutes a crude oil stream. Crude oils are classified by their density and sulfur content. Less dense (lighter) crude oils generally have a higher share of light hydrocarbons. It is a higher value product. It can be recovered with simple distillation. The denser (heavier) crude oils produce a greater share of lower-valued products with simple distillation and require additional processing to produce the desired range of products. Some crude oils also have higher sulfur content. It is an undesirable characteristic with respect to both processing and product quality. For pricing purposes crude oils of similar quality are often compared to a single representative crude oil. This is the benchmark of the quality of crude oil.

Processing and re-processing necessary to achieve the optimal mix of product output is decided by the quality of the crude oil. Premium crude oil like West Texas Intermediate has a relatively high natural yield of desirable naphtha and straight-run gasoline. Nigeria's Bonny Light, has a high natural yield of middle distillates. Saudi Arabia's Arabian Light is a heavy residue (residuum) that must be reprocessed or sold at a discount to crude oil. West Texas Intermediate and Bonny Light have a yield of about one-third residuum after the simple distillation process.

The type of hydrocarbon molecules and other natural characteristics affects the cost of processing. The molecular structure of a crude oil also decides the suitability of a crude oil for the manufacture of special products such as lubricating oils. Refiners therefore try to refine the optimal mix of crude oils through their refineries, depending on the refinery's equipment, the desired output mix, and the relative price of available crude oil.

3.2.8.4 Other Refinery Inputs

A variety of other specialized inputs enhances the refiner's capability to make the desired mix of products. Among these products might be unfinished oil, or imported residual fuel oil used as input to a vacuum distillation unit. The world crude oil reserves are concentrated in a few countries, whereas the demand for petroleum products is almost universal. This leads to the need for distribution of crude and products obtained after refining to all over the world. International trade in crude oil and petroleum products is a large and active market. In 1997, about 1544 million tons of crude oil and 435 million tons of petroleum products were traded worldwide. Table 3.8. shows the world refinery capacity, region wise. An important observation made is that though the crude capacity of OPEC is about 77% in 2001 its refining capacity is only 10.9 percentage of the global refining capacity.

Table 3.8. World refinery capacity by region, 1996 – 2001 (1000 b/d)

	1996	1997	1988	1999	2000	2001
North America	17324.4	17627.6	17802.7	18452.6	18444.8	18508.4
Latin America	7457.9	7922.6	7606.3	7664.6	8106.7	7920.4
Eastern Europe	12125.4	11976.2	11294.4	11317.3	9972.2	10164.6
Western Europe	14672.2	14864.4	15065.0	14929.2	14982.5	15045.9
Middle East	5528.3	5781.0	6134.5	6353.9	6337.9	6409.2
Africa	2833.3	2888.3	2944.5	2982.5	3282.5	3247.3
Asia and Pacific	16604.3	16866.6	18681.8	19491.0	20130.0	20248.2
Total World	76545.7	77926.8	79529.2	89191.1	81256.6	81544.0
OPEC	7773.6	8035.1	8448.8	8656.3	8836.2	8882.7
Opec Percenatge	10.2	10.3	10.6	10.7	10.9	10.9

Source: OPEC Annual repor,2001t

There are 170 refineries in United States alone followed by 135 refineries in Asia Pacific region. Global distribution of refineries is given in Table 3.9.

Table 3.9. Number of refineries in the world

Region	No. of Refineries.
United States	170
Asia pacific	135
Western	115
Eastern	90
South	75
Africa	45
Middle east	40
Canada	25

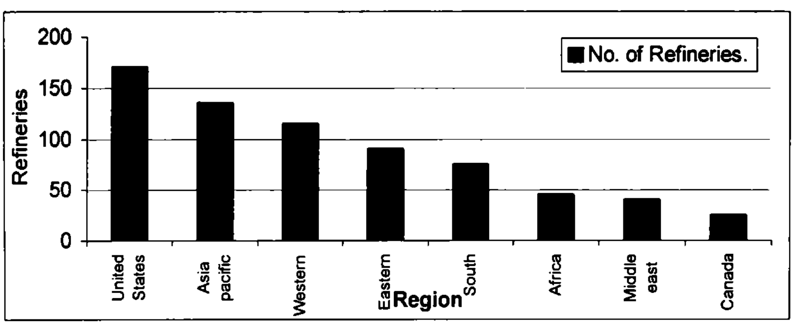


Figure 3.7. Number of refineries in the world

During 1980s average refinery capacity utilization in the world was only 70%, which resulted in the closure of less economic refineries.

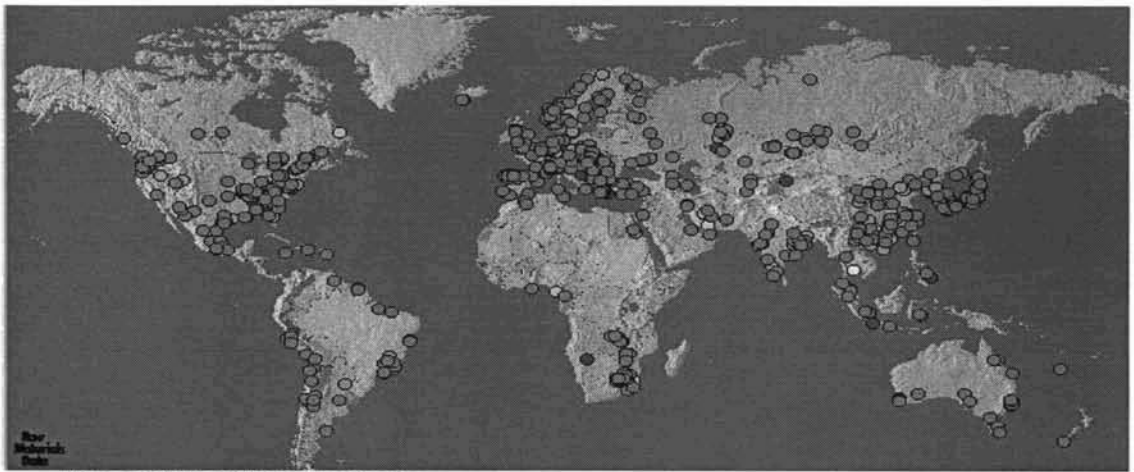


Figure 3.8. World map on refineries

Later years the situation improved substantially and world wide capacity utilization improved to 88% in 1994, which has further improved to a level of 90% in 2000. Considering this level of capacity utilization, 4350MMTPA of refining capacity must be there to meet the crude oil processing requirement by the year 2010. This necessitates an increase of 780MMTPA refining capacity. Although much of increase in capacity will come from expansion of existing refineries, many new refineries must be commissioned to meet the forecast demand of refined products. In Asia Pacific region, 75% of the region's refining capacity is concentrated in six countries i.e. in Japan, China, South Korea, India, Indonesia and Singapore. Asia's increasing Oil demand represents almost 70% of worldwide growth. To meet increasing demand in petroleum products, total refining capacity in Asia pacific is likely to increase from 15.30 million b/day (765MMTPA) in 1993 to 20.1 million b/d (1000 MMTPA) in 2005. It can be clearly seen from fig. 3.8 that refining is done nearer to point of consumption. As per estimates, 42 grass root refineries are under construction and planning stage in the region. Total capacity of these projects is about 175MMTPA. Out of this 65MMTPA capacity is considered firm and another 65MMTPA is expected to be installed by expansion in existing refineries. However the capacity utilization of OPEC is above 100 percent. The global refined out put is 7298.9 bb/d. Table 3.8 shows the detailed region wise out put of refined products It can also be observed that the lowest refining capacity is in Africa. Table 3.7 shows the world consumption of petroleum products by region. North America is the largest consumer (2036.99bb/d in 2001) followed by Asia and Pacific.

Table 3.10. Refining capacity in Asia Pacific (000bb/d)

Country	1993	2000	2005
Japan	5005	5500	5500
Korea	1675	2488	2488
Taiwan	600	720	900
Singapore	1085	1135	1135
Indonesia	856	1011	1131
Malaysia	230	450	450
Thailand	395	780	780
Philippines	296	399	399
India	1086	1598	2025
China	3200	3900	4400
Australia	732	807	807
New Zealand	92	92	92
Total	**15302**	**18880**	**20107**

Source: OPEC Annual report,2002

3.2.9 Stocks of Crude oil

This section discusses the availability and consumption of crude oil in the global, regional, and local scenario.

3.2.9.1 Why Stocks Are Important

There are 7.8 billion barrels of oil tied up with industry and government stocks. The reason for those stocks is to keep the global supply smooth. The oil is stored in pipelines from oil well, crude oil tanks, tankers, the pipelines to the refineries, rail wagons, road tankers, and tank to retail outlets. All these put together make the oil industry deliver the right product to the right location at the right time. Only 10 percentage of this sock is available to the industry according to the demand of the industry. When the level of stock reduces in a particular market, the price of crude oil will go up. It will lead to encourage extra supply and the prices will come down. When the stocks are high, the prices of crude oil come down in that region. Projected stocks are considered as an indicator of prices of crude oil in a market. So it is closely monitored. It is difficult to closely monitor the global stock due to the diversified market locations. The United States is the only country to publish comprehensive weekly stock data. They have the largest commercial stock (one billion barrels). Largest part of crude oil stock is in Gulf Coast. East Coast is having the greatest finished products inventories.

World's majority of the storage capacity is owned by the companies that produce, refine, or market the oil. Independent operators also store a small important portion. They are holding it at the world's main trading hubs. This small portion makes the hubs successful and viable. The independent storage volume is a key indicator to what is happening to discretionary stocks.

3.2.9.2 Stocks are Seasonal

Oil stock in the world follows a seasonal pattern. In the middle of winter it goes down and goes up in the spring. It leads to high price in winter and low price in spring. Reason for stock change is the demand for products. Heating oil, propane, and kerosene demand drive world oil seasonality. Crude oil stocks are also seasonal. When the refineries make maximum through put, the stock will come down and stock will go up when the refineries go for shutdown maintenance. Asia's refining system has its maximum output in winter and minimum in summer due to scheduled maintenance. Maximum through put in US is in summer and maintenance is in winter. So the stock fluctuation in crude oil in the global level is minimum. The product stock variation is more than that of oil stocks.

3.2.9.3 Strategic Stocks

Government controlled stocks are called strategic stocks. It is a buffer stock against interruption in supply of crude oil. The largest of the strategic stock is with US Strategic Petroleum Supply (SPS). The international Energy Agency's rule says that each participating nation must hold stocks equal to 90 days of imports. Most of the nations meet the requirement with industry owned stocks. United States, Japan, and a few other nations hold government controlled stocks.

3.2.9.4 Costs and Profits

Money is involved in building up stocks. Quantum of money depends up on the type of oil, quantity stored, ownership of storage facility, price of crude oil, and the opportunity cost of money. The cost inventory becomes significant to the margin of the stake holders. Every petroleum station, terminal, and refinery must have some inventory. This increases the quantity of stock in different stages. Through consolidation of industry this stock can be minimized. Stock need not be treated as a money spending area alone. Stocks can be used for making profit also. Stocks can be made when one company expects hike in oil price and if they have money to invest, they can stock oil to make profit through purchase.

3.2.10 Prices of Crude Oil

Demand for one product is also connected with demand for another product. Demand for each product in each region establishes a price level for crude oil and refined products. The price fluctuations in the products are small and it is the interest of buyers and sellers within the industry. The stability in prices can be affected by different reasons. They are sudden increase in demand, storage in refineries, and demand surges. Prices shoot up initially and then stabilizes when the fluctuation in demand stabilize. The crude oil price slashed in 1998 and price increased in 2000 took longer period to come back. These are exceptions in the oil price consistency pattern.

3.2.10.1 Overview: Costs plus Market Conditions

Like any other goods and services, price of crude oil is affected by products' underlying cost and market conditions. Price is also affected by the consumer behaviour.

The pre-tax price of gasoline (or any other refined oil product) reflects:

- Its raw material, crude oil
- Transportation from producing field to refinery
- Processing that raw material into refined products (refining)
- Transportation from the refinery to the consuming market
- Transportation, storage and distribution between the market distribution center and the retail outlet or consumer.
- Market conditions at each stage along the way, and in the local market

Crude oil is the raw material for petroleum products. Supply and demand conditions in the global market decide the price of crude oil. Global market is mainly based on the trades in Singapore, Northwest Europe, US, and Gulf Cost. Price of products is based on the price of crude oil. The refined products are marketed through main distribution centres. Products from the refineries in that area, shipments, and imported products form the product suppliers. These products are distributed to local retailers using barges, railways, pipelines, and finally trucks. Oil markets are inter-connected by the supply in one region from the other regions. So the products prices are affected by the prices abroad.

Many transactions are taking place for oil at different parts of the world. Price of oil based on those transactions. Production of oil is almost constant through control of OPEC countries. Oil prices are fixed on the basis of bidding in international market. When the demand is more and supply is less, the bidder will be forced to pay more. This is called strong market. When the demand is less supply is more, the bidder will be interested in paying less. This is called weak market. Bidders need not always compete. Depends on their stock position they may wait for the price to come down to their desired level. When the prices come down, they will come for bidding.

Transactions are also different types in oil market. The most common type is contract purchase. The price is fixed in advance for the delivery in a later period. Spot transaction is also prevailing in the oil market. When the contract quantity is not enough for a refiner, may go for spot transaction. Demand for different crude oil also leads to spot transaction. Oil is also traded in future markets. This is for covering risk due to price fluctuation. This is based on the expectation of price of oil in the market. In this market physical supply of oil is not common. Spot market gives a clear idea about the trend in demand and supply. Increase in price means more demand for the products and decrease in price indicates reduction in demand for crude oil. Majority of oil being traded in contract terms, the price changes are based on spot purchase. Futures market also gives indication on the trend in the demand and supply balance. Seasonal changes are the other important factors that affect the price of oil. In cold seasons the demand will be more and in hot seasons the demand will be less. This also will affect the price of oil in region. Regional demand can affect the consistency of price. Government policies are another factor that can affect the price of crude oil.

3.3 Indian Refinery Supply Chain

So far the discussion was on the world scenario of petroleum supply chain. Now the petroleum industry in India will be discussed.

3.3.1 Availability of crude oil in India

Despite the existence of other sources of energy like electricity, petroleum, and natural gas, sub-sector has witnessed a very rapid rate of growth. The limited resources of oil and natural gas and stabilization of indigenous oil production at around 33.682 MMT PA, the gap between oil production and consumption has widened over the years.

Table 3.11 Self reliance of Petroleum products

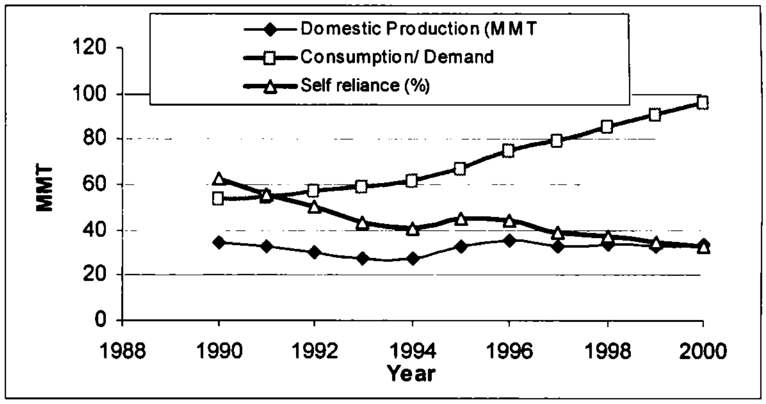
Year	Domestic Production (MMT	Consumption/ Demand	Self reliance (%)
1989-90	34.09	54.10	63
1990-91	33.02	55.04	56
1991-92	30.35	56.97	50
1992-93	26.95	58.90	43
1993-94	27.03	61.54	41
1994-95	32.24	67.45	45
1995-96	35.17	74.67	44
1996-97	32.90	79.17	39
1997-98	33.95	85.49	37
1998-99	32.72	90.80	34
1999-00	33.86	96.44	33

The production reached a level of 35.17MMT during 1995-96, which is the highest level reached by the country so far. However, subsequent years witnessed shortfall in the production of crude oil. It is clear from Table 3.11 that the production of crude oil is consistently reducing. The main reason is that India could not find new crude oil sources. The consumption was shooting up from 54.1MMT in 1990 to 96.44 MMT in2000. This increase of 78% in demand affected our self-reliance very badly to reduce from63% in1990 to 33%in 2000. So 2/3rd of our crude oil demand is met by import. The major reasons for comparatively low growth in oil production are

- No major discoveries of oil resources
- Most oil fields are entering the natural declining phase
- Reservoir management problems in Mumbai high, Nedam & Gandhar etc.
- Constraints in operating conditions in the North eastern region.

3.3.2 Indian Refinery Scenario

Indian oil industry can be divided into two distinct segments based on nature of activities, Upstream activity which involves exploration and production (E&P) of crude oil, and downstream sector i.e. plain refining and refining plus marketing (R&M).



The oil companies presence in the further down stream petrochemicals business had been so far restricted to minor aromatics complexes producing Benezene and Toluene. Till recently, exploration and production of crude oil, was only with Oil and natural gas Corporation Ltd. (ONGC) and Oil India Limited (OIL). OIL operates mainly in the north eastern sector (in the Assam oil fields) where as ONGC activities are spread through out the country. Over 60% of its production is in the Bombay High offshore area. In 1983, ONGC produced 93% and 90% of total domestic crude and natural gas production respectively of India. With the opening up of this field for private companies, major multinational oil companies like Shell, Amco, etc, and Indian Private companies are participating in the exploration activities. Refining and marketing is dominated by the public sector companies such as Indian Oil Corporation Limited (IOCL), Hindustan petroleum corporation limited (HPCL), Bharath Petroleum Corporation limited (BPCL). IOCL is also the canalizing agent for crude oil imports in the country.

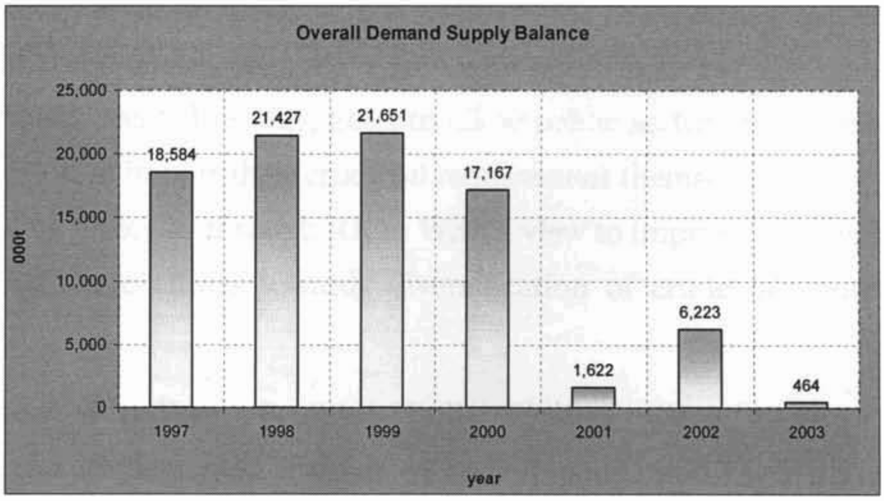


figure 3.9 Demand Supply Balance

It is clear from the figure 3.9 that India is leading to self-reliance in all the petroleum refined products. Graph is drawn by deducting production from demand of refined products. The refining capacity as on 1.4.2002 was 116.07Million Metric Per Annum (MMTPA). Availability of petroleum products during 2002-03 from domestic refineries was adequate to meet the domestic demand except for Liquefied Petroleum Gas (LPG).The availability of petrol and diesel is in excess of domestic requirement and the surplus quantity was exported during the year. At present, there are 18 refineries operating in the country, (16 in Public Sector, one in joint sector, and one in private sector). Out of the 16 Public Sector refineries, 7 are owned by Indian Oil Corporation Limited (IOCL), two by Chennai Petroleum Corporation Limited (subsidiary of IOCL), two by Hindustan Petroleum Corporation Limited (HPCL) and one each by Bharat Petroleum Corporation Limited (BPCL), Kochi Refineries Limited (KRL)(subsidiary of BPCL), Bongaigaon Refinery &Petrochemicals Limited (BRPL) (subsidiary of IOCL), Numaligarh Refineries Limited (NRL)(subsidiary of BPCL) and Oil and Natural Gas Corporation Limited (ONGC). There is one refinery in joint sector viz. Mangalore Refinery &Petrochemicals Limited (MRPL) and one refinery in private sector viz. Reliance Industries Limited (RPL).

Import and Exports: The quantity of crude oil imported (including JVC / private companies) between April and November 2002 was 55.609 MMT, valued Rs. 49,680 crore. Besides, 4.494 MMT of other petroleum products valued at Rs. 5,029 crore were also imported during the same period. Exports of petroleum products was 6.607MMT, valued at Rs. 6,364 crore during the same period. Import of crude oil has been made free with effect from 1 st April, 2001. Further, Government decided in May, 2001 to allow public sector oil companies to exercise the option to import their crude oil requirement themselves under the actual user licensing policy or through IOCL. With a view to improve oil security, the oil companies made efforts towards diversification of crude oil sourcing during 2002-03.

Refineries' Pipeline: Petronet India Limited (PIL) a non-PSU Company, has so far implemented Vadinar - Kandla pipeline and Kochi - Kurur pipeline projects. Mangalore –Bangalore pipeline project is at an advanced stage of implementation. To match the post APM scenario, MoP&NG vide notification F.No. P-20012/5/99-PP dated 20.11.2002 has issued guidelines for laying petroleum product pipelines. The new guidelines for grant of right of user (RoU) in land do not contemplate any restrictions or conditions for grant of ROU for crude oil pipelines. Product pipelines have been categorized as follows:

(i) Pipelines originating from refineries, whether coastal or inland, upto a distance of around 300 kilometers from the refinery; (ii) Pipelines dedicated for supplying product to particular consumer, originating either from a refinery or from oil company's terminal; and 23 pipelines originating from ports and pipelines originating from refineries exceeding 300 km in length, other than those specified in (i) & (ii) above. As per the guidelines, companies and investors will have complete freedom in respect of the pipelines originating from refineries or meant for captive use of companies for which RoU will be unconditional. As per the notification, the pipelines exceeding 300 km in length and those originating from a port location, grant of RoU will be subjected to the fulfillment of certain conditions, like:

- Oil companies/investors interested in laying a product pipeline originating from a refinery or a port would be required to publish the proposal inviting other interested companies to take capacity in the pipeline.
- Any oil company interested in sharing the capacity of the pipeline, will be able to do so on mutually agreed commercial terms and conditions.

The proposer would then provide capacity for such interested party also.

- The proposer company applying for the grant of ROU in land would need to provide atleast 25% extra capacity for others.
- The pipeline will be owned and operated by the proposer company.

The pipeline tariff will be subject to the control orders or the regulations that may be issued by the Government under the appropriate law in force. Internationally transportation of products by pipelines is preferred to other modes of transport for the reasons of safety, operational convenience and its environmental benefits.

Table 3.12 Refineries in India

Name of refinery	State	Year of establishment	Capacity in MMTPA
Mumbai Refinery	Maharashtra	1954	5.5
Bharat Petroleum	Maharashtra	1955	6.9
Vishakh Refinery	Andra Pradesh	1957	7.5
Guwahati Refinery	Assam	1962	1
Kochi Refinery Ltd.	Kerala	1963	7.5
Chennai Petroleum	Tamil Nadu	1965	6.5
Koyali Refinery	Gujarat	1965	12.5
Barauni Refinery	Bihar	1967	4.2
Bongaigaon Refinery	Assam	1974	2.35
Mathura Refinery	Uttar Pradesh	1982	7.5
Digboi Refinery	Assam	1991	0.65
Mangalore Refinery	Karnataka	1991	9.69
Crude Distillation	Tamil Nadu	1991	1
Numaligarh Refineries	Assam	1993	3
Panipat Refinery	Haryana	1998	6
Reliance Petrolium Ltd.	Gujarat	1999	27
Haldia Refineries	West Bengal	1991	3.75

In most cases, transportation of products by pipelines is cheaper in comparison to other modes like rail and road. In developed countries, around 60% of the total petroleum products are transported by pipeline. In India this percentage is presently around 32. It is estimated that the share of pipelines in product transportation may touch around 45% over the next 2-3 years.

3.3.3 Refining Capacities And Capacity Utilization

To meet the growing demand of petroleum products, the refining capacity in the country has been gradually increased over the years by setting up of new refineries in the country as well as by expanding the capacity of the existing refineries

- The refining capacity, actual crude throughput and capacity utilisation during the last five years are indicated in Table 3.13

Table 3.13 Refining capacity utilization in India

Sl. No.	Category	94-95	95-96	96-97	97-98	98-99
1.	Refining Capacity	53.4	56.4	61.1	62.2	62.2
2.	Actual Crude throughput (MMTPA)	56.5	58.7	62.9	65.2	68.5
3.	Capacity Utilisation (%)	105.9	104.2	102.9	104.7	110.1

3.3.4 Private Refineries

Government of India has welcomed proposal for private investments including foreign investment in the refining sector following liberalization of industrial policy. In pursuance of this policy, letters of Intent have been granted to 14 companies for setting up of refineries in the private sector for about 70 MMTPA capacity including EOU refineries.

3.3.5 Future of Petroleum Industry

Production from countries outside OPEC is expected to show a steady increase, from around 47 million barrels per day in 2002 to about 62 million barrels per day by 2025. Total world demand for oil is expected to reach 112 million barrels per day by 2020 and 133 million by 2025. Developing countries in Asia show the largest projected growth in demand, averaging 3.3 percent per year, led by China at 3.9 percent per year.

3.3.6 Persian Gulf Producers Took More Than Half of World Oil Trade

Considering the world market in crude oil exports, the historical peak for Persian Gulf exports (as a percent of world oil exports) occurred in 1974, when they made up more than two-thirds of the crude oil traded in world markets. The most recent historical low for Persian Gulf oil exports came in 1984 as a result of more than a decade of high oil prices, which led to significant reductions in worldwide petroleum consumption. Less than 40 percent of the crude oil traded in 1984 came from Persian Gulf suppliers. Following the 1985 oil price collapse, the Persian Gulf export percentage again began a gradual increase, but it leveled off in the 1990s at 40 to 45 percent when non-OPEC supply proved to be unexpectedly resilient.

Persian Gulf producers are expected to account for 45 percent of worldwide trade by 2007—for the first time since the early 1980s. After 2007, the Persian Gulf share of worldwide petroleum exports is projected to increase gradually to 66 percent by 2025. In the low oil price case, the Persian Gulf share of total exports is projected to reach 76 percent by 2025. All Persian Gulf producers are expected to increase oil production capacity significantly over the forecast period, and both Saudi Arabia and Iraq (assuming the lifting of United Nations export sanctions after 2003) are expected to nearly triple their current production capacity.

3.3.7 Asia/Pacific Region is Expected to Surpass U.S. Refining Capacity

The Asia/Pacific region was the fastest growing refining center in the 1990s. It surpassed Western Europe as the world's second largest refining center and, in terms of distillation capacity, is expected to surpass North America before 2005. While not adding significantly to their distillation capacity, refiners in the United States and Europe have tended to improve product quality and enhance the usefulness of heavier oils through investment in downstream capacity.

Future investments in the refinery operations of developing countries must include configurations that are more advanced than those currently in operation. Their refineries will be called upon to meet increased worldwide demand for lighter products, to upgrade residual fuel, to supply transportation fuels with reduced lead, and to supply both distillate and residual fuels with decreased sulfur levels. An additional burden on new refineries will be the need to supply lighter products from crude oils whose quality is expected to deteriorate over the forecast period.

3.3.8 Future Refining Capacity in India

Keeping in view the need of enhancing the refining capacity to meet the growing demand of petroleum products, a number of grass-root refineries as well as the expansion of the existing refineries are at various stages of implementation. As per the latest outlook, the refining capacity is expected to be about 129 MMTPA by the end of IX and about 167 MMTPA by the end of X plan(Planning Commission report 2001).

Table 3.14 Details of private parties granted letters of intent for setting up oil refineries in India

Sl. No	Name of the Party / Partner with Name of Company	Capacity of The Refinery	Location	Date of Issue of LOI
APPROVED PRIVATE SECTOR REFINERIES (DTA)				
1	M/s Reliance Petroleum Limited, Mumbai	9.00 MMTPA + 6 MMTPA	Jamnagar Gujarat	03.6.92 22.9.94
2.	M/s Ashok Leyland Ltd. GOTCO, USA	6.00 MMTPA Connected to 200 MMTPA Lube	Paradeep Orissa	14.8.92 03.7.96
3.	M/s Essar Investment Ltd.	9.00 MMTPA	Vadinar Gujarat	06.1.93
4.	M/s TCG Refineries Ltd.	6.00 MMTPA	Haldia	08.1.94
5.	M/s Nippon Denro (Ispat Industries)	9.00 MMTpa	Paradeep Orissa	05.6.96
6.	M/s Nagarjuna Oil Corporation Ltd.	6.00 MMTPA	Tamil Nadu Cuddalore	24.5.99
1.	M/s International Petroleum SA (BVI), Switzerland	5.00 MMTPA expandable to 10 MTPA	West Coast of Gujarat	14.8.92
2.	M/s Black Gold, Andhra Pradesh	2.5 MMTPA	Visakhaptnam A.P.	10.6.93
3.	M/s Petro Energy, Pondicherry	4.8 MMTPA	Pondicherry	26.6.95
4.	M/s Jindal Ferro, Andhra Pradesh	6.00 MMTPA	Andhra Pradesh	22.9.94
5.	M/s Aban Lloyd ,	3.00 MMTPA	Tamilnadu	13.2.95
6.	M/s Moplac Udyog, Haldia West Bengal	3.00 MMTPA	Haldia	14.3.96
7.	PRA Petrochemicals Ltd	9 MMTPA	Srikakulam	14.9.97
9	M/s Sterlite Industries (India) Ltd	3 MMTPA	Tuticorin Tamilnadu	27.10.97

3.3.9 Logistics for Petroleum Products

Transportation by ship and pipelines are the two modes used in India for

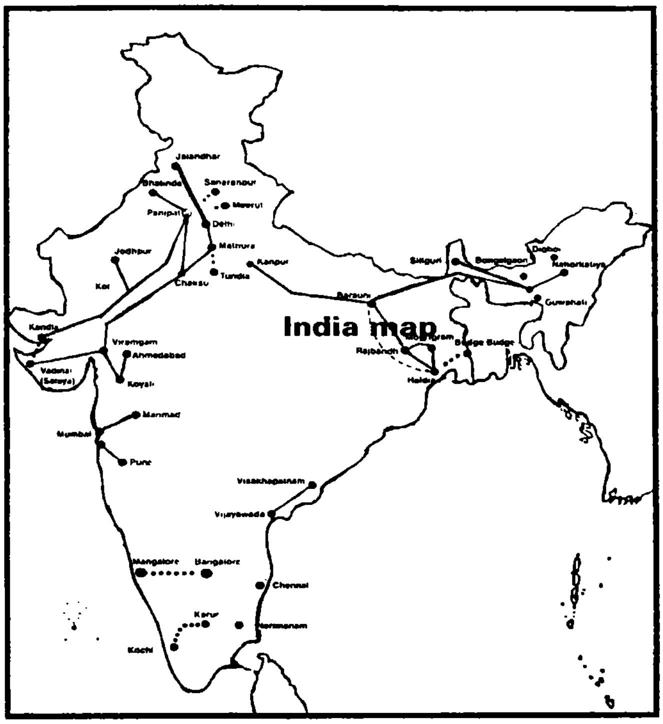


Figure 3.10 Indian petroleum map

the crude movement. Ship is the main mode of crude movement. Ship scheduling is not that accurate in any part of the country. So the crude availability at any refinery, which depends on ship transport, cannot be planned correctly. This sometimes disturbs production. The demurrages are also high due to unplanned arrival of ships. Ports are also not having most modern facilities. So unloading time is also higher at almost all the ports Rail, road, pipeline and sea are the modes of conveyance for transporting refined products. Railway and road gives maximum service. Pipeline supply is very limited. Pipeline is used for supplying to major industrial customers. Retail distribution is through road only. Rail wagons are used for bulk movement to areas where the direct supply by road is difficult because of distance. Wagons must be unloaded to tanks in the unloading yard and from there it is to be distributed by trucks to the retail outlets.

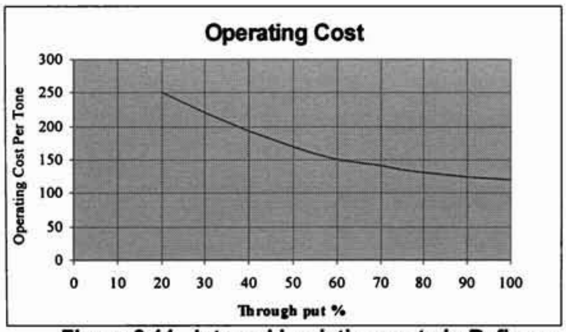


Figure 3.11 Internal Logistics costs in Refinery

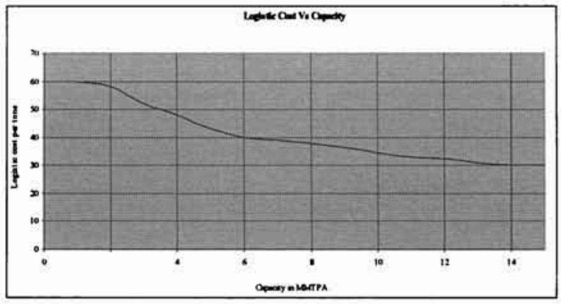
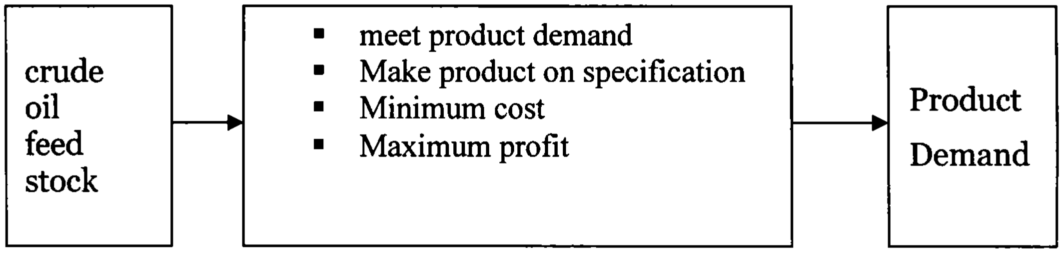


Figure 3.12 Logistics Costs Vs capacity

Ship can also be used to transport from refinery to coastal cities. This will be cheaper than rail and road transport. This facility is not being largely used in India. It may require modification or modernization of existing facilities. Reliability of supply is not very good due to the uncertainties in rail and road transport. Movement of small quantities necessitates the need for frequent trips of trucks and which in turn disturbs the scheduled movement. Operating cost of a refinery is depended on through put of refinery. Through put is the crude oil processed by the refinery. If the through put is less than 60% of its installed capacity, operating cost will almost double at 20% of installed capacity. Internal logistics costs are calculated by deducting operating costs from total production costs. Internal logistics costs are not available directly from any refinery data. So it is calculated as mentioned above and plotted against the capacity of refinery. As shown infigure 3.12 it is decreasing almost linearly with installed capacity. A refinery with 1.5 MMTPA has Rs. 60/tonne as logistics where as it is only Rs. 30 for a refinery with 14MMTPA as installed capacity. A refinery with high installed capacity will be enjoying better internal logistics costs.

3.3.10 Refinery Objective

Main objective of a refinery is meeting product demand by producing sufficient volume of products. The product must be meeting the specification laid by the Government. The interest of refinery will be in minimizing the cost of production to increase the profit. In the decontrolled environment reducing cost of production will be essential to compete with imported products. Supplying products at the site of customer to meet the demand is the ultimate objective of a refinery to maximize their profit. Selection of crude oil is important because transportation cost of crude oil is directly dependent on the distance of the loading port. Saving in transportation can be treated as profit.



Govt. of India is giving incentives for capacity utilization in full. So the refineries have been always trying to maximize their throughput. This resulted in achieving more than the designed maximum capacity. If a new product is produced or more volume of existing product is produced, it will be difficult to sell the product immediately after the production It will lead to unnecessary product holding. This is a difficult situation for many refineries because storage capacity is a bottleneck. More over it adds cost to the product. All these problems are arising because the companies are looking only on the volume of production and capacity utilization.

3.4 Refinery Location Selection Model

Location of a refinery is important as far as logistics is concerned. Many factors have to be considered for site selection. The general facility location problem is very well discussed in literature. Details are available in Khumawala [1971], Klassen [1994], and MacCormek [1994]. The factors considered in the general location problem have to be prioritised for refinery site selection and other relevant factors added. Here a four stage decision model for refinery site selection is presented. In the first stage alternative locations are generated, in the second stage a Pass/ Fail criterion is applied to eliminate sites not suitable, in the third stage a logistic cost comparison is done to rank the alternatives based on logistics cost. Finally a few top rank alternatives are compared using weighted factor method to arrive the site to be selected.

3.4.1 Generation of Alternatives

Location of the refinery can be anywhere in the world because crude is transported from few parts of the world to the rest of the world. Transporting crude oil is easier and cheaper than transporting refined products. To optimize the expense in transport, location of the refinery plays a vital role. Finding a location is the first step in the process. Important factors to be considered for the generation of alternatives for location for a refinery are :

- Near source of crude oil
- Port site
- Pipeline grid for crude oil
- Presence of bulk industrial customers
- Connectivity to rail
- Highway linkages

Nearness of port is very important because the bulk movement of crude oil and refined products can take place only through sea. Companies, which are planning to export products, will be able to do it through sea only. So the location must be near to the port. Crude oil has to be brought in large quantities to a refinery. Ship is one commonly used mode of transport but pipeline is much more cheaper. Laying a new line for refinery may not be economic and feasible. Setting up refinery near an existing crude oil pipeline will be a more economic alternative. So the nearness to the pipeline grid is an important factor for selecting the location for a refinery. Nearness or access to supply is essential. Similarly access to customers, especially industrial customers since they consume bulk quantities, is also important. Nearness to railhead also must be considered because it is the cheapest mode of conveyance on land. It will be essential to move the products in wagons also. Highway linkage is also vital for supplying to the customers in the nearby places.

3.4.2 Pass / Fail Criteria

Identification of alternative location process for a refinery will provide a lot of sites. For selecting the right location each location must be checked first against some critical factors like environmental regulations, taxes by Governments, availability of water, availability of land etc. Locations which are failing in these factors must be removed. If a government does not give license for refineries then any location in the state or the nation cannot be selected. So such location fail in the test and must be removed from the list.

3.4.3 Cost Comparison Using Spread Sheet

Major cost components in logistics are inbound logistic cost, production cost and outbound logistic cost. In the selection of location problem, processing cost can be avoided because it is constant. Minimum distance for transporting of refined products is taken as 50 km because the chance of complete distribution of refined products within 50 km is almost impossible. Expense for multiples of each fifty km is used for calculation. Sum of inbound logistic cost and outbound logistic cost for each location is calculated using spreadsheet and the list of location is made in the ascending order.

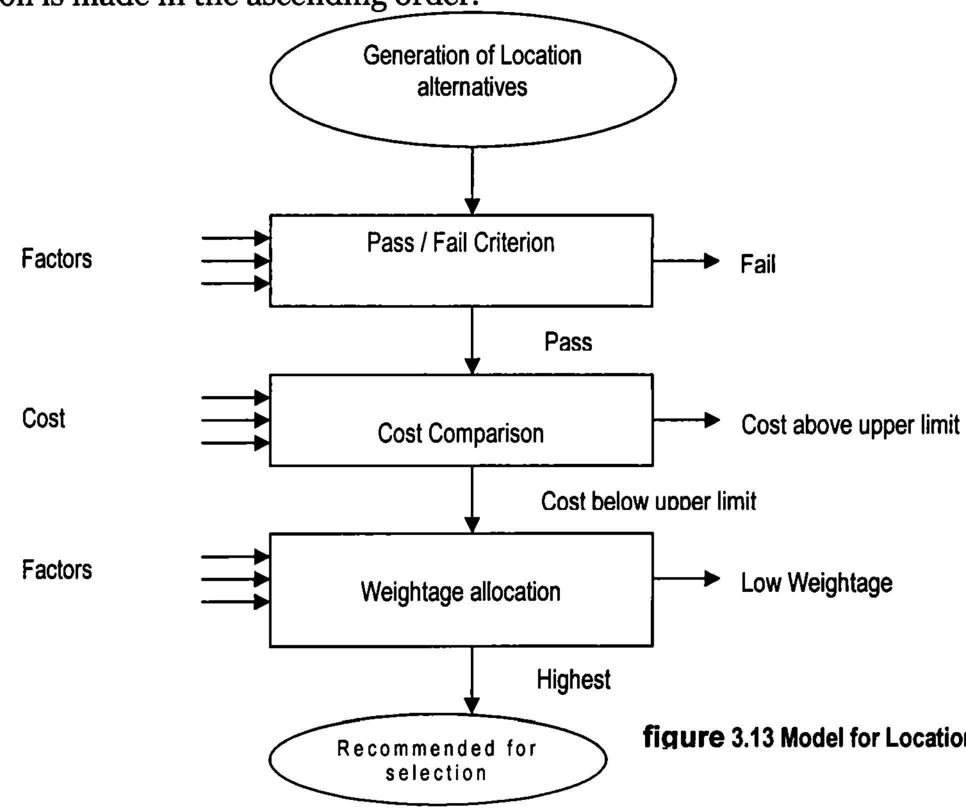


figure 3.13 Model for Location Selection

Cut off on the list can be 50% higher than the least cost. Reason for fixing the 50% higher is that it should not cross the least when other criterion is applied. Selection of alternatives at this stage can be made by selecting first n numbers. For example first 5 locations can be selected from the total selected locations. These five locations will be considered for further detailed analysis.

3.4.4 Scheme for Cost Calculation

Pipeline has only capital investment as the major component. Operating cost is the least. Transportation cost can be calculated in rupees per tonne per kilometer. Total cost of transportation can be taken as Rs.X. Shipping charges for crude as well as for refined products can be calculated on the basis of distance multiplied with rate in rupees per tonne per kilometer. Port charges per tonne must be added to it separately because port charges vary from port to port. Total of ship charges can be taken as Rs.Y. Railway charges can be calculated by adding fixed minimum charge for an order with the cost of transporting per tonne per kilometer. Total can be taken as Rs.Z for railway. Road transport cost can be calculated on the basis of distance transported per tone per kilometer. Minimum charge is fixed for transporting within 50 kilometers from the refinery. Total cost of transportation using truck can be taken as Rs.W. Using this method inbound variable logistic costs and outbound logistics costs can be used for the screening of locations primarily selected. Table 3.15 gives the method of calculation for each location. For example, a location in south will be having inbound and outbound logistics costs. Inbound logistic cost involves pipeline and shipping transportation costs (X+Y). Outbound logistics cost involves pipeline + sea + rail + road and the sum of all individual costs is the total outbound logistics cost. Grant total is the sum of inbound and outbound logistics cost. Total cost can be compared and decision can be taken for selecting the number of locations for detailed analysis.

Table 3.15 Cost comparison using Spreadsheet

Sl. No.	Location	Inbound Cost	Outbound Cost	Total Cost
1	South	X+Y	X+Y+Z+W	2X+2Y+Z+W
2	North	X+Y	X+Y+Z+W	2X+2Y+Z+W
3	East	X+Y	X+Y+Z+W	2X+2Y+Z+W
4	West	X+Y	X+Y+Z+W	2X+2Y+Z+W
5	Middle	X+Y	X+Z+W	2X+Y+Z+W
6	Middle East	X+Y	X+Z+W	2X+Y+Z+W
7	Middle South	X+Y	X+Z+W	2X+Y+Z+W
8	Middle West	X+Y	X+Z+W	2X+Y+Z+W
9	Middle North	X+Y	X+Z+W	2X+Y+Z+W

3.4.5 Factors for Selection of Location

Factor comparison method is commonly adopted for selection of location for industrial units. Francis [1992] and Ritzman [1990] have suggested procedures for identifying location. Same method with additional features is used for identifying important factors as far as a refinery is concerned. General Factors for location selection for an industry are discussed below.

- Availability of Land
- Cost of land
- Transportation facility
- Availability of labour
- Wages for labour
- Information Technology
- Availability of power and water
- Supporting industries
- Quality of life like school, hospital
- Nearness to market
- Building of site
- Availability of Skilled employees like manager
- Training for workers and foreman
- Security
- Expansion of site
- Taxes
- Government support
- Union problem and industrial relations
- Environmental relations
- Waste disposal
- Location of sub contractors, retailers etc.
- Incentives form financial institutions
- Climatic conditions

All these factors are not important for a refinery. Factors, which are important for the site selection of a refinery, are found out in discussion with senior people in refineries. Procedure is discussed in detail in next section. The selected factors are given in Table 3.16. The selected factors from the full list are reduced to nine and they are assigned with weightage in Table 3.17 and these factors are used for further analysis.

Table 3.16 Selected factors

Factor Code	Sl. No.	Factors
A	1	Nearness to raw material
B	2	Security
C	3	Availability of water and power
D	4	Climatic Conditions
E	5	Quality of life
F	6	Transportation facility like port
G	7	Availability of land
H	8	Nearness to market
I	9	Ancillary industries

Table 3.17 Guidelines for factor selection

Sl. No.	Factor	Grade	Weightage	Selection
1	Nearness to raw material	Within a days journey	100	
		One day journey	90	
		3 days journey	60	⇐
		5 days journey	40	
		More than 5 days journey	20	
2.	Security of organization	Highly secure	100	
		Medium Secure	70	⇐
		Less Secure	40	
		Risky	10	
3.	Availability of water/ power	High	100	
		Medium	80	⇐
		Low	60	
4.	Climatic condition	Very cold less than 15° C	30	
		Cold 15° C – 25° C	70	⇐
		Moderate 25° C – 30° C	100	
		Hot 30° C – 40° C	70	
		Very hot above 40° C	30	
5.	Quality of Life	Metropolitan City	100	
		Capital of State	70	⇐
		City	40	
		Township	10	
6.	Transportation facility	Availability of Air, Sea, Rail, Road & pipeline grid	100	
		Availability of Sea rail road and pipeline	90	⇐
		Availability of Rail Road & pipeline	60	
		Availability of Rail & pipeline	30	
7.	Availability of land	Cheaply available	100	
		Moderate	50	⇐
		Expensive	10	
8.	Nearness to market	Within a day	100	

		One day's journey	80	⇐
		2 day's journey	60	
		3 day's journey	40	
		More than 3 day's journey	20	
9.	Auxiliary Industries	Can take 60% of products	100	
		Can take 50% of products	80	⇐
		Can take 40% of products	60	
		Can take 30% of products	40	
		Can take 20% of products	20	

3.4.5 Procedure for Weighted Score Method

This method was used to identify the important factors out of the general 23 factors. Simple judgment also can be used for selecting the important factors. But, in such cases, the quality of decision will be poor. So the weighted score method was adopted for the selection of location for a refinery. Preliminary selection of factors was made by the opinion of managers and executives from KRL and IOC. 23 factors were thus brought down to nine. All nine factors do not have equal weightage in selection of location of a refinery. Finding out the weightage for each factor was the next step. Pair wise comparison was the method adopted. Each factor was compared with all the other factors and a relative score was given.

Table 3.18 Relative Scoring Procedure

Sl. No.	Relative Value	Score
1	Factor A is minor compared to B	A_1
2	Factor B is minor compared to A	B_1
3	Factor A is medium compared to B	A_2
4	Factor B is medium compared to A	B_2
5	Factor A is major compared to B	A_3
6	Factor B is major compared to A	B_3

Table 3.18 gives the procedure for finding out the score for each factor. After finding the relative score, the preference matrix was tabulated. Table 3.19 shows the preference matrix. Each column was filled as in the procedure given in Table 3.18. Opining of executives was considered for pair wise comparison. Five top managers and 21 senior managers in different sections were identified for this purpose. Opinions of all 26 were considered and factors which were opted by

more than 50 percentage of the participants were taken as score. In majority of the factors more than 90% were having the same opinion. There was a variation of 10% in the opinion collected from the participants. For the easiness of calculation it was neglected. Selection was made by the participant on the table given in Table 3.16. After consolidating the scores, codes were assigned to each factor. Code 'A' for nearness of raw material was assigned and 'B' for security. All the factors were given the codes as given in Table 3.16. Same group of people were assigned with the task of giving the pair wise comparison. In this case the variation was only 9%. Those values are tabulated in Table 3.19. Three choices were given for the selection. They are minor, medium, and major. As shown in Table 3.18, 'A' is compared with 'B' and the value will be entered in the column of 'B'. In the case the nearness of material is major when compared with security and 93% of the participants were of the same opinion. So 'A3" is assigned in column of 'B' against the row of 'A'. Similarly 'A' is compared with C,D,E,F,G,H, and I. Same procedure was continued in the case of all the factors. After making all the entries it used for calculating weightages. Number of corresponding values in each square against each factor was added up to get the value in column of score. Values of the same factor only were used for the calculation. In the row of 'A', values of 'A' only was considered for the calculation of score. Value of 'F' was not used for calculation. In the case of score for 'F', first values of 'F' in the column was added and that value was added with the sum values in the row of 'F'. Scores of all the factors are calculated in this way. Total of all those scores were calculated to find out the weightages. Total value of the scores of the factors was calculated as 78. Percentage weightage was calculated by dividing individual factor score with total factor score.

After the completion of allocation of scores in the matrix the total score (Si) against each factor score is calculated. Score values in the rows and columns are added to get the final score. For example

Score of C = [Sum of scores in Column= 2+Sum of row = 2+2+2 = 6]2+6=8 and

Score of F = [Sum of scores in Column 2+3+2+3 = 10+ Sum of raw=1+3=4]= 10+4 =14

Sum of scores (ΣSi) is calculated to find out percentage weight.

Percentage weight = Wi = Si / ΣSi

For example Percentage weight of factor A = 17/78 = 0.218

Table **3.19** Preference Matrixes

A	B	C	D	E	F	G	H	I	Score (Si)	% wt (Wi)
A	A3	A1	A3	A3	F2	A2	2	3	17	0.218
	B	C2	B1	B3	F3	G1	H2	I1	4	0.052
		C	C2	C2	F2	G2	H1	C2	8	0.102
			D	D3	F3	G2	H2	I2	3	0.038
				E	E2	G2	H3	I2	2	0.026
					F	F1	F3	I1	14	0.179
						G	H2	I1	7	0.090
							H	H3	13	0.167
								I	10	0.128
									78	1.00

After calculating Wi of each factor, the locations under consideration were tabulated as given in Table 3.19. Locations are considered with respect to each factor. Location I is considered for Factor A1 (nearness to raw material) and weightage is given on 100-point scale. For minimizing subjectivity, nearness to raw material is divided into five classes and weightages are given. Table 3.17 gives the detailed guide lines for assigning weightage for each factor. Selection of weightage was done on the basis of interviews and discussions with senior level people in the refineries. In this example the value of A is 70 (ai1), value of B is 80 (ai2) and so on. Then the value of A was multiplied by its percentage weightage (0.218).

Table 3.20 Weighted Score

Factor	A	B	C	D	E	F	G	H	I	Weighted Score
Wi	0.218	.052	.102	.038	.026	.179	.090	.167	.128	
Location 1	70	80	60	70	25	65	90	90	80	**73**
Location 2	90	60	50	30	40	65	80	80	60	**69**
Location 3	100	30	80	70	80	30	80	90	80	**74**

All the values are multiplied like that and the sum of the row was placed in weighted score column (ΣWi Aij). Similarly all the rows were calculated to get the weighted score of each location. A location with maximum weighted score was selected for the company. This will be the best location for that refinery from the available locations. In this example location 3 is the best suited one.

3.5 Identification of Flexibility for Refinery Configuration

Once the location is finalized, flexibility and configuration plays important role in the performance of logistics. Flexibility and technology must be considered while making the final layout of the plant and land. Next section discusses these two issues.

3.5.1 Supply Chain Flexibility for a Refinery

Flexibility can be defined as the ability to respond to changes in the environment (oxford dictionary). Flexibility is the ability to change the output in response to change in the demand, supply of raw materials, etc. In a supply chain the flexibility of one entity is highly depended on the flexibility of upstream entities. The overall flexibility of a supply chain will therefore depend on the flexibility of all the entities in a supply chain and their interrelations.

Flexibility for a refinery is essential because (1) demand pattern changes, (2)price changes, (3)possibility of developing substitute fuels, (4)possibility of new market like new solvent, and(5) political instability in some crude supplying countries. Demand pattern changes due to changes in climate or changes in production pattern in consumer industries or political reasons. Refinery must be able to adjust with changes in the market. This will reduce the inventory. If rigid production pattern is adopted, possibility for holding of refined products also will increase. Price of crude oil as well as refined products changes in the market. Refinery must be flexible to accommodate the changes and to increase the profit. Possibility of substitute fuels like alcohol or liquefied natural gas may lead to reduction in demand for refined products. To increase profitability, refinery must be able to change the product mix to cope up with the product demand. Demand for new products may come up in the market. Refinery must be competent to cater to the demand for new products also, or else some other refineries will supply the product. It is not good in a competitive market. Political instabilities also can change the crude supply. So refinery must have facilities to process variety of crude oil to withstand the changes in demand. Flexibility to the maximum possible level will increase the freedom to select crude oil and supply refined products to any market.

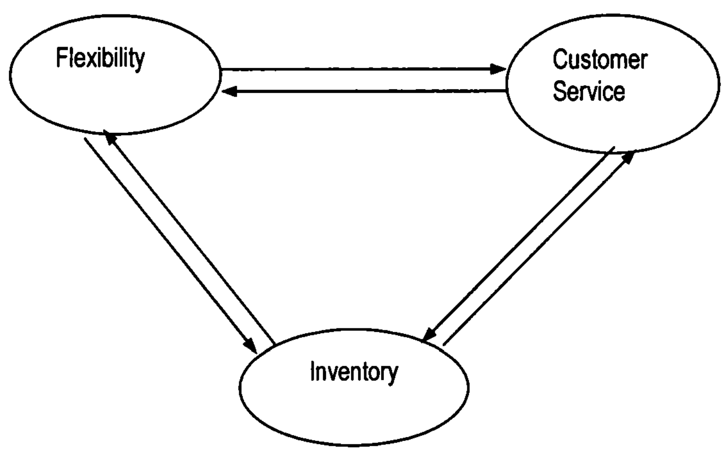


Figure 3.14 Relationship diagram

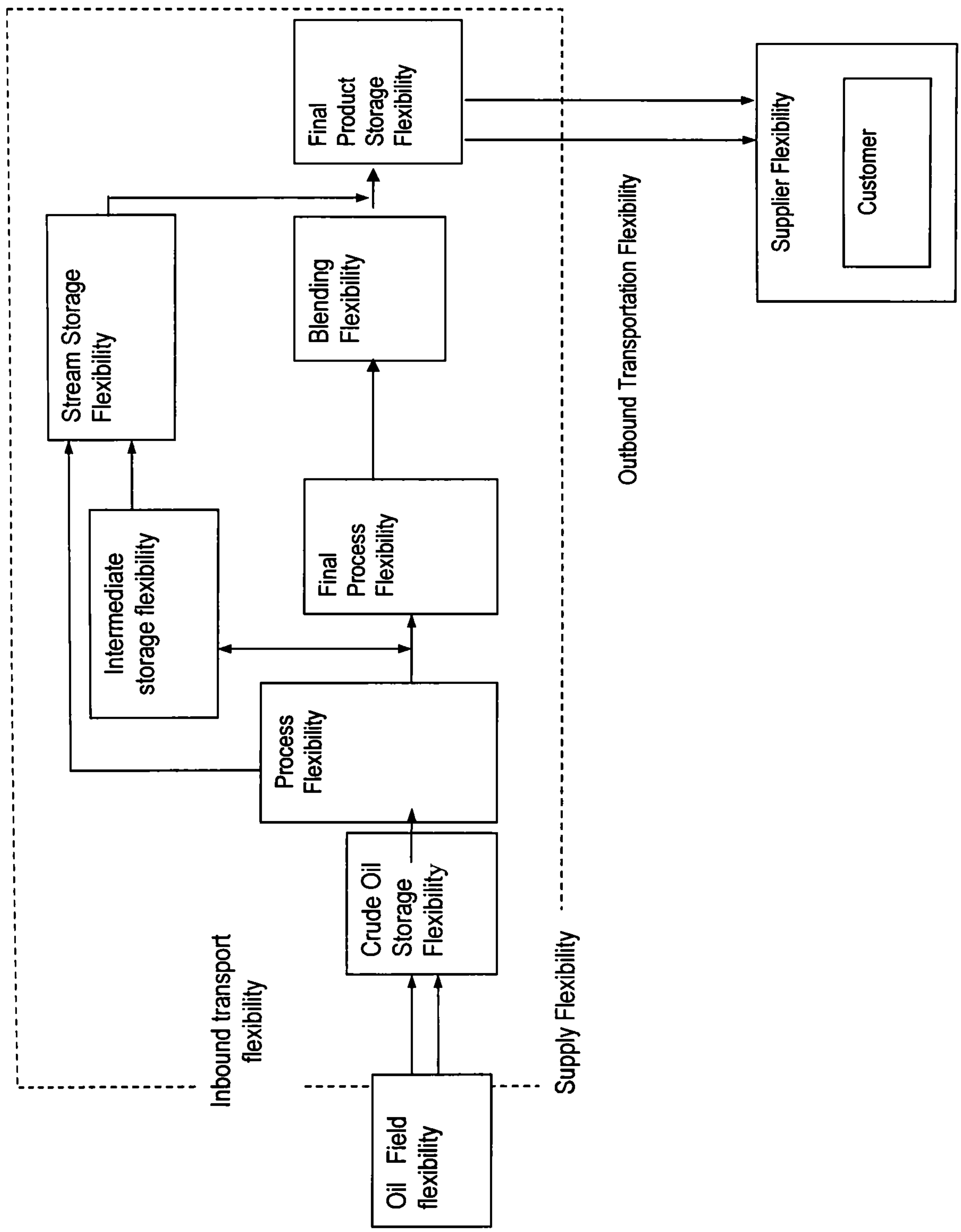


Figure 3.15 Components of logistic flexibility for a refinery

Figure 3.14 illustrates how flexibility, inventories, and customer service are interrelated. The components of manufacturing flexibility play an important role in supply chain flexibility. However, as the supply chain extends beyond the enterprise, supply chain flexibility must also extend beyond one firm's internal flexibility. Most of the responsibility for one type of flexibility lies within one functional area of a particular firm. In a refinery production department is generally responsible for volume flexibility, marketing is generally responsible for distribution flexibility, laboratory is responsible for new production introduction flexibility etc. By focusing on the flexibility from an internal perspective, much of the concentration on supply chain perspective is lost. Figure 3.15 shows the major components of logistic flexibility for a refinery from facility point of view. Each component is explained below.

3.5.2 Oil Field Flexibility

Crude oil is available in different parts of the world including India as shown in Table 3.21. Crude oil available at all the places are not of the same quality. Gravity and sulfur content of crude oil mainly decide quality. Table 3.19 shows the quality of crude oil at different oil fields.

Table 3.21 Oil and condensate in billion barrel

Region	Cumulative production so far	Total discovered
North America	238	277
Latin America	101	177
Europe	40	77
North Africa	43	88
C/S Africa	27	59
Middle East	218	742
Far east Australia/ Asia	59	144
CIS	128	297
Opec	330	941
Non –Opec	524	890
World	854	1831

Selection of crude is not only dependent on the quality but also the distance of oil field from the refinery, processing capability of the refinery and product demand in the market. For improving productivity and profit crude oil must be carefully selected. Since the numbers of variables are more, selection of crude oil must be with utmost care.

3.5.3 Inbound Transportation Flexibility

Transportation of crude oil is mainly done by ships and pipeline. Pipeline can be used for pumping crude oil to the refinery if the refinery is near by the oil field like Guwahati and Barauni. Ships are serving as a major transporting means for crude oil transport from the loading port near oil field to destination port near refinery. Ships are classified on the basis of capacity and draft requirement for ship to sail. Table 3.18 shows classification of ships. Carrying capacity of ship is represented by dead weight tonnage (dwt). This is the amount of cargo, fuel, water, and stores a vessel can carry when fully loaded. It is economic to bring crude oil using VLCC and ULCC but the refinery must have matching facilities at receiving end. Draft requirement is high for VLCC and ULCC. Suez –max ships are used to transport crude oil through Suez Canal. These ships do have good dwt but the draft requirement is less. So these ships can be utilized for ports with lesser drafts and shallow channels like Cochin port. Larger parcel size reduces transportation cost.

Table 3.22 Classification of ships

CATEGORY	TONNAGE RANGE
Medium range	25000-44999
Large range(LR1)	45000-79999
Large range(LR2)	80000-159999
Very large crude carriers	160000-319999
Ultra large crude carriers	320000-549999
Suez-max	150000 maximum

3.5.4 Crude Oil Supply Flexibility

Crude oil supply is depended on many factors. They are availability, prize, transportation cost, and facility at receiving port, storage tank capacity and processing capacity of refinery. Availability of crude oil is a major problem when sweet crude is considered. Sweet crude from Bombay High is good for Indian refineries but it is not available in sufficient quantities. Demand for crude oil is 90.80 MMTPA, but domestic supply is only 32.72 MMTPA. Sweet crude oil is available in South Africa but cost of transportation will be very high and bulk carriers must be employed for transportation. So standard types of refineries will not have capacity to receive and stock crude oil brought by Suez Max ships. Refineries can share this by lightering crude oil to small ships. So the flexibility in availability of different quantity can be enjoyed by small refineries.

Table 3.23 Crude oil properties at different locations

World Major Export Crude Oil Properties.			
Country	**Crude**	**Gravity ° API**	**Sulfur Wt%**
MIDDLE EAST			
Abu Dhabi	Murban	40.5	0.78
Abu Dhabi	Umm Shaif (Abu Dhabi Marine)	37.5	1.51
Abu Dhabi	Zakum (Lower Zakum/ Abu Dhabi Marine)	40.6	1.05
Abu Dhabi	Dubai (Fateh)	31.1	2.00
Divided zone	Hout	32.8	1.91
Divided zone	Khafji	28.5	2.85
Egypt	Suez Blend	31.9	1.52
Iran	Iranian Heavy	31.0	1.65
Iran	Iranian Light	33.8	1.35
Iraq	Basrah Light	33.7	1.95
Iraq	Kirkuk Blend	35.1	1.97
Kuwait	Kuwait Export	31.4	2.52
Oman	Oman Blend	36.3	0.79
Qatar	Dukkan (Qatar Land)	41.7	1.28
Qatar	Qatar Marine	35.3	1.57
Saudi Arabia	Arabian Heavy	27.9	2.85
Saudi Arabia	Arabian light	33.4	1.79
Saudi Arabia	Arabian light (Bern)	37.8	1.19
Saudi Arabia	Arabian Medium (Khursaniyah)	30.8	2.40
NORTH SEA			
Norway	Ekofisk	43.4	0.14
United Kingdom	Brent	38.2	0.26
United Kingdom	Flotta	35.7	1.14
United Kingdom	Forties	36.6	0.30
WEST AFRICA			
Cameroon	Kole Marine blend	34.9	0.30
Gabon	Mandji	30.5	1.10
Nigeria	Bonny Light	36.7	0.12
Nigeria	Bonny Medium	25.2	0.23
Nigeria	Brass river	40.9	0.09
Nigeria	Forcados Blend	29.7	0.29
Nigeria	Qua Iboe	35.8	0.12

Country	Crude	Gravity ° API	Sulfur Wt%
NORTH AFRICA			
Algeria	Saharan Blend	45.5	0.53
Algeria	Zarzaitaine	43.0	0.07
Libya	Amna	36.1	0.15
Libya	Brega	40.4	0.21
Libya	Es Sider	36.7	0.37
Libya	Sarir	38.3	0.18
Libya	Sirtica	43.3	0.43
Libya	Zueitina	41.3	0.28
ASIA			
China	Daqing		
Indonesia	Cinta	33.4	0.08
Sumatra	Duri	21.1	0.20
Sumatra	Minas	34.5	0.08
Common wealth of Independent states	Urals	32.5	1.38
LATIN AMERICA			
Colombia	Cano liman	30.8	0.47
Ecuador	Orienta	29.2	1.01
Mexico	Isthmus	32.8	1.51
Mexico	Maya	22.0	3.32
Venezuela	Tia Juana light	32.1	1.10
AUSTRALIA			
Victoria	Gippsiand	45.4	0.10

3.5.5 Crude Oil Storage Flexibility

Crude oil can be stored in storage tanks in the tank farm of a refinery. It can also be stored in floating tanks in outer sea also. Tanks can be connected to one tank to another so that crude oil can be pumped from each other. The flexibility in storage reduces the storage capacity requirement for crude oil, which in turn reduces capital investment.

3.5.6 Process Flexibility

Normal refineries cannot process all variety of crude oils in single distillation column. Minimum two distillation columns are required for processing low sulfur and high sulfur crude oils. A good refinery must have flexibility in processing a large variety of crude oils. Quality is the other area, which requires flexibility. Product demand decides the crude oil to be processed. This reduces the variety of crude oils that can be purchased. The flexibility for processing any type of crude in any quantity will improve the profitability of refinery.

3.5.7 Intermediate Storage Flexibility

Transferring from first distillation column to final processes is not always continuous. So intermediate storage tanks are essential to store the products waiting for further processing to upgrade the product. The flexibility can be improved by increasing the capacity and interconnection between tanks. Capacity increments can be in terms of number of tanks rather than a few number of large size tanks. Variety of products can be increased by increasing intermediate storage. This will improve productivity of refinery.

3.5.8 Final Process Flexibility

Technology for any process is available in the market. Selection of process like super oil cracking (SOC), Hydro cracking, reforming etc. decides the product variety and quality. The higher the variety and quality, the better will be the gain. By adding different processes, required type of products can be produced. All the variety of products produced need not have sufficient market. Increased flexibility in final process will make a refinery equipped to produce high value products in the desired volume. It will increase profitability of the refinery.

3.5.9 Stream Storage Flexibility

Products running out of distillation columns without any addition to it are called stream. Keeping them may help in varying the product specifications. Facility for storage of this stream will improve product variety, which will in turn satisfy customer in a better way. Different tanks must be provided for storing different streams and interconnectivity is desirable for better capacity utilization.

3.5.10 Blending Flexibility

In the short term, tightening fuel specifications may result in a business hedache, but in the long run it will open up new marketing opportunities.

Blending is the process of mixing different streams to get desired specification of a product. Product blending area is receiving much attention by many refineries around the world. Following are the main reasons.

Blending is the area that is best understood in terms of qualified benefits from improvement.

Traditional blending has required a significant number of dedicated tanks.

As demand pattern changes, opportunity sales may be very profiTable. Accommodating opportunity sales may well place severe strain on the finished product tankage and associated loading facilities.

Blending requires a significant amount of manpower support, both off site and laboratory manpower.

The major types of blending are batch blending and in line blending. Adding streams to a tank containing a product does batch blending. Quantity of addition of new stream as directed from the laboratory depends upon the specifications of the product in the tank.

In line blending is done at the time of either filling the tank or while pumping to the tanker. Four types of inline blending are in practice.

- Component to finished product
- Component to loading
- Rundown to finished product/ loading
- Rundown to base

Depending upon the demand for the variety of the product, any one of the above methods can be used for blending. Anyway batch blending can be employed if the marketing is limited to local market. Flexibility in marketing can be employed only through increase in the variety of product, which can be obtained by delaying blending.

3.5.11 Final Product Storage Flexibility

Blended stream with accurate specification is called final product. This is ready to market and will have assured demand. In the final product, quantity can be flexible. Fast moving items with standard specification can be stored as products to improve the speed of delivery. It is difficult to store all the variety products in the final product storage tanks. Less moving and special products can be blended at the time of loading to reduce the inventory level. Demand for number of tanks will be high for storing all the products as products. To increase flexibility the variety of final products stored must be the minimum. Maximize the volume of fast moving products to improve flexibility.

3.5.12 Outbound Transportation Flexibility

Transportation of products from refinery to retail outlet or customer is known as outbound transportation. Pipeline, ship, wagon, and trucks are the commonly used modes of transport. Pipeline can be used for supplying to customers who buy huge quantities on regular basis or to distribution station at a distant places. This is the most economic mode of conveyance. Pipelines are being used to supply LPG for domestic consumption also in metropolitan cities like Mumbai. Ship is used for transporting product to far off places in the country or for exporting. In India products are not exported because our domestic production is not even sufficient for internal use. Only constraint of ship transport is the need for port on both ends. So this is feasible for coastal refineries and coastal cities. Rail can be used for transporting petroleum products from refinery to another city, which is far off from sea or port. Quantities of movement will be less because of the capacity limits of locomotives and loading and unloading facility constraints. If the railway system is not efficient, it will take more time to move products when compared to ship. If ship is not accessible then rail is the best option for bulk transport. Trucks are mostly used to move the product from distribution center to retail outlet. 70km is normally seen as maximum limit for economic road transport. Profitability will be lesser if the distance is more than 70 km. The distance is a matter of demand also. If the demand is less, definitely road will be better option because the capital investment is minimum. A refinery must have flexibility in selecting any mode of transport. For better profitability a combination of all modes of transport must be possible in any refinery.

Table 3.24 Flexibility areas and their impacts

Flexibility area	Key factors	Impact
Oil field	Sulfur Content Specific Gravity	Less production cost Lighter products
Inbound Transport	Ship size Distance Pumping rate	Less cost Moe quantity Fast discharge
Crude supply	Availability Price Transport cost	Less cost Fast movement Less inventory
Crude storage	Tank connectivity Types of crude	Less inventory Better scheduling
Process	Variety of crude Availability of crude Capacity	More products Less inventory Better capacity utilisation
Intermediate storage	Connectivity between tanks Size of tanks Variety of products Quantity of products	Better utilization of tanks More products More flexible processing
Final process	Technology adopted Investment capacity	Flexibility in crude High value products Better netback
Stream storage	Connectivity between tanks Blending practice	More variety of products Less tankage
Blending	Type of blending Product specification Variety of products	Less tank capacity More variety of products Flexibilty in product specification
Product storage	Specification of products Type of blending Variety of products	Customer satisfaction Availability of more products Better process control
Outbound transport	Mode of transport available Cost of each mode Location of refinery Demand of quantity	Fast delivery Supply to any market Supply of any quantity
Supply	Blending procedure Product storage Transportation	Increased product variety Increased product quantity Supply to any location
Retailer	Storage capacity Service Information Technology	Increased customer satisfaction Faster information to refinery

3.5.13 Product Demand Flexibility

A good refinery must be able to supply any quantity of product as per the specification given by the customer. This can be attained only by the combination of flexibility in blending, final product storage and transportation. Supply flexibility will improve customer satisfaction and brand loyalty.

3.5.14 Distribution Channel Flexibility

Retail outlets-bringing product from refinery and distributes- is termed supplier. The supplier at each area must be able to sell products with specification suiTable for that area. For example the outlets at high ranges must be able to supply diesel with low cetane number to have better ignition but cetane number can be high in cities and level roads to reduce the possibility of fire at the time of accident. Facilities at each supplier must be similar so that the customer will not feel any difference between places. By using information technology customers can be given the freedom to enjoy card facility and help lines also. The flexibility will improve customer loyalty and in turn will improve profitability of a refinery.

3.6 Process Selection for an Oil Refinery in India

A refinery is a factory just as a paper mill, which turns lumber into legal pads or a glasswork, which turns silica into stemware. A refinery takes a raw material--crude oil--and transforms it into gasoline and hundreds of other useful products. A typical large refinery costs billions of dollars to build and millions more to maintain and upgrade. It runs around the clock 365 days a year, employs between 1,000 to 2,000 people and occupies as much land as several hundred football fields. Today, some refineries can turn more than half of every 42-gallon barrel of crude oil into gasoline. That's a remarkable technological improvement from 70 years ago, when only 11 gallons of gasoline could be produced from a barrel of crude oil. How does this transformation take place? Essentially, refining breaks crude oil down into its various components, which then are selectively reconfigured into new products. The complexity of this equipment varies from one refinery to the next. In general, the more sophisticated a refinery, the better its ability to upgrade crude oil into high-value products. Whether simple or complex, however, all refineries perform three basic steps: separation, conversion and treatment.

3.6.1 Separation: Heavy on Bottom, Light on Top

Modern separation, which is not much different from the "cooking" methods used at the Pico Canyon stills, involves piping oil through hot furnaces. The resulting liquids and vapors are discharged into distillation towers. The tall narrow columns give refineries their distinctive skylines.

Inside the towers, the liquids and vapours separate into components or **fractions** according to weight and boiling point. The lightest fractions, including gasoline and liquid petroleum gas (LPG), vaporize and rise to the top of the tower, where they condense back to liquids. Medium weight liquids, including kerosene and diesel oil distillates, stay in the middle. Heavier liquids, called gas oils, separate lower down, while the heaviest fractions with the highest boiling points settle at the bottom. These tar like fractions, called **residuum**, are literally the 'bottom of the barrel'. The fractions now are ready for piping to the next station or **plant** within the refinery. Some components require relatively little additional processing to become asphalt base or jet fuel. However, most molecules that are destined to become high-value products require much more processing. This is where refining's fanciest footwork takes place-where fractions from the distillation towers are transformed into **streams** (intermediate components) that eventually become finished products. This is where a refinery makes money, because only through conversion can most low-value fractions become gasoline. The most widely used conversion method is called **cracking** because it uses heat and pressure to "crack" heavy hydrocarbon molecules into lighter ones. A cracking unit consists of one or more tall, thick-walled, bullet-shaped reactors and a network of furnaces, heat exchangers and other vessels. **Fluid catalytic cracking**, or "cat cracking," is the basic gasoline-making process. Using intense heat (about 1,000 degrees Fahrenheit), low pressure and a powdered catalyst (a substance that accelerates chemical reactions), the cat cracker can convert most relatively heavy fractions into smaller gasoline molecules. **Hydrocracking** applies the same principles but uses a different catalyst, slightly lower temperatures, much greater pressure and hydrogen to obtain chemical reactions. Although not all refineries employ hydrocracking, Chevron is an industry leader in using this technology to cost-effectively convert medium- to heavyweight gas oils into high-value streams. The company's patented hydrocracking process, which takes place in the *Isocracker* unit, produces mostly gasoline and jet fuel.

Some Chevron refineries also have **cokers**, which use heat and moderate pressure to turn residuum into lighter products and a hard, coal like substance that is used as an industrial fuel. Cokers are among the more peculiar-looking refinery structures. They resemble a series of giant drums with metal derricks on top. Cracking and coking are not the only forms of conversion. Other refinery processes, instead of splitting molecules, rearrange them to add value. **Alkylation**, for example, makes gasoline components by combining some of the gaseous byproducts of cracking. The process, which essentially is cracking in reverse, takes place in a series of large, horizontal vessels and tall, skinny towers that loom above other refinery structures. **Reforming** uses heat, moderate pressure and catalysts to turn naphtha, a light, relatively low-value fraction, into high-octane gasoline components

3.6.2 Treatment: the finishing touch

A major portion of refining involves blending, purifying, fine-tuning and otherwise improving products to meet the requirements.

To make gasoline, refinery technicians carefully combine a variety of streams from the processing units. Among the variables that determine the blend are octane level, vapor pressure ratings and special considerations, such as whether the gasoline will be used at high altitudes. Technicians also add dyes that distinguish the various grades of fuel.

3.6.3 Classification of Refineries

Atmospheric distillation is the first processes in crude oil processing and different basic streams are separated from the crude oil. While the available crude oil becomes heavier (high sulfur) and there is decreasing demand for fuel oil, new technologies are to be adopted for reduction of the bottom of the barrel. The bottom of the barrel is low quality and less demanding products, three up gradation routes are available for bottom residue. They are

i. Carbon Rejection
   - Delayed cocking
   - Visbreaking
   - Fluid cocking
   - Flexi Cocking
   - Residue fractional catalyst cracking (FCC)

Table 3.25 Refinery up gradation options

Upgrading	Processes
i. Naptha	Isomerisation Catalystic Reforming Petrochemical option
ii. Distillate	Desulphurisation
iii. Vacuum Gas oil	Vacuum Distillation Vacuum gasoil desulfurisation FCCU Hydrocracking Lube oil base stocks
iv. Residue	Visbreaking Solvent Deasphatting Delayed cocking Flexi cocking Resid catalysitic cracking Hydro-treating (Atm & Vacuum) Vacuum resid Hydro-cracking Gassification Power generation
v. Light Oilfin	Alkalisation Poly Naptha Ethrification Petrochemicals Deep catalysitic Cracking

ii. Hydrogen addition
   - Hydro treating
   - Hydro refining
   - Hydro cracking

iii. Physical separation
   - Solvent Deasphalting

Table 3.25 shows possible refining upgradation options. No single optional configuration exists which can be directly adopted for all refinery configurations. The configuration is to be decided on the basis of market demand of products and supply of crude oil. For example in US, FCC units and cocker is considered as better option because of heavier crude slates and high gasoline and high residual fuel oil demand. In Europe, because of the availability of the fuel oil outlets, thermal cracking is substituted for coking. In Japan, hydro-desulfurisation capacity for long residue is substantial because of low sulphur fuel oil market. Factors affecting selection of residue up gradation technology are investment, product pattern, return on investment etc. These are the methods for maximum upgradation but it may not be economic to go for full upgrading of residue. The optimum processes configurations are given in Table 3.25

3.6.4 Classification of Refineries in Indian Context

From March 31, 2002 all petroleum products except LPG and Kerosene has been totally deregulated with the freedom to import refined products. In these years India is going to face huge deficit of petroleum products particularly middle distillates. To meet the large gap between supply and demand, Government of India has taken measures to expand the refining capacity in the country. The capacity is expected to increase from present 112MMTPA to 150MMTPA by 2010,which is a great challenge to the industry. Existing as well as new entrants, will have to expand and /or build refineries. Industry is also to face change of adopting newer technologies to meet increased requirement of middle distillates and environmental regulations for the refinery operations as well as product quality. In this regard, following aspects are important.

- Each refinery need to provide flexibility to process variety of crude oil i.e. both light as well as heavy with high sulfur content.
- Development of resid processing technologies viz. FCCU, hydrocracking etc. to upgrade heavier ends.
- Adoption of technologies like hydro-treatment, hydro-desulphurisation, summarization etc. to meet stringent product quality likely to be enforced in future. As can be seen from above, all new process technologies require substantial qualities of hydrogen for which dedicated hydrogen producing facilities will have to be installed.

In India the following refinery margins are there.

- High on stream factors of process units
- Low manpower costs
- Low cost of land
- Less stringent environmental regulation
- Less transportation cost due to long coastal belt

Existing refineries do have capacity to get useful streams from distillation columns. So the reprocessing requirement is minimum to sell the production in the domestic market. Indian manpower cost is cheaper when compared to many countries in Asia Pacific. Low cost of land makes the expansions cheaper and economical. Environmental regulations are liberal when compared to western countries. So many final expensive processes are eliminated in Indian refineries. This reduces the cost of production as well as capital investment. Flexibility for processing light as well as heavy crude with high sulfur content will be required to improve profitability. The environmental regulations will change in the near future. For example Delhi made a lot of changes in the regulations, which can be expected in other parts of the country also. To meet these challenges these optimum processes configuration in Indian context are as given in the Table 3.26. Technology up gradation has been a thrust area all along and technology upgradation plans are being continuously pursued in order to recover bottom of the barrel to the maximum extent. Technology upgradation has also been adopted in modernization and advance control energy conservation, product quality improvement, etc. apart from augmentation of crude processing capacities. Scanning and implementing technological advances is also evident in the plans of years to come.

Table 3.26 Optimum processes configuration in India.

Processes	Advantages
FCCU + Solvent Deasphalting	Low Investment Low return Maximum Gasoline Pitch disposal
Resid Hydrotreating + Resid Catalystic cracking	High investment Low return Least unwanted products Maximum Gasoline
FCCU + Delayed cocker (without VGO hydrotreatment)	Medium investment High return Maximum gasoline, Coke disposal
Hydrocracker + Solvent deasphalting	Medium investment Moderate returns Maximum middle distillation Pitch disposal.

3.6.5 Options for Types of Refineries in Future

Future refinery criteria is a critical subject which has many diversified opinions in each individual countries depending mainly on the socio-economic conditions, political environment, and close observations on environmental management issues. The countries which depend on imported crude, the crude quality of their requirement has limited choice because the exporter country naturally will try to deliver much sour and residuous crude, to the comparatively less predominant countries and will definitely use sweet crude for themselves or supply to the effluent countries.

In the above context, the day is not far when India has to consider the following refining options, though it may appear at the moment a more costly affair to revamp or reengineering the existing refineries, but when crude will decline or deteriorate further the options will be more realistic. Options available are:

- Sour crude refining
- Super Oil cracking(SOC)
- Deep catalystic cracking (DCC)
- Hydrocracking for producing high quality middle distillate
- Distillate dewaxing
- ISO dewaxing
- Modernisation of asphalt technology
- Vacuum gas oil Hydrotreating and mild hydrocracking
- Flexicocking
- Improvement in the catalyst design and concepts for vibreaking and FCC to accommodate more residue and contaminated feed and beheld positioning the catalyst for a reasonable period.
- Reforming units
- Diesel fuel upgrading: Hydroprocessing for deep desulfurisation and /or aromatics saturation
- Gasification of petroleum coke
- Integration of hydrocracking with residue upgradation, light cycle Oil (LCO) upgradation to premium products
- Moderate pressure hydrocracking as a conversion alternative

In this scenario the developing countries also have started to diversify their refining options into the areas like petrochemicals manufacture power plant set up basically to use the furnace oil because the demand for future furnace oil through out the world is on the decrease, keeping in mind the increase in quantity and quality of middle distillates for meeting the demand of transport fuels.

Demand for high sulfur residual fuels is in decline relative to the demand for refined products. This is largely due to environmental considerations, which are pushing the refinery's product barrel into lighter, low sulfur fuels. Gasoline demand growth in Europe and the United States is sluggish while the market for high quality distillates remain tight. As a result of these changes in the market place, refineries are seeking routes to a profiTable future. The integration of residue upgradation technology with gas oil conservation capability has the dual effect of following optimization of process parameters to satisfy products demand and of providing flexibility to meet new specification for higher quality transportation fuels.

3.7 Conclusion

A thorough understanding of crude oil drilling to the consumption of refined products is essential to find out the problems in SCM of a refinery. Detailed study of production, supply, pricing, consumption of crude oil, and refined products etc. was presented as an introduction to this chapter. On the basis of that information, the location of a refinery was studied because location has great impact on supply chain of a refinery. Factor comparison method was modified to cater to the needs of a refinery and a nine-factor method was developed for finding out the right location. This model will help in finding out location for a new refinery. Weighted scores for each location will be available from the model. Selection of technology is the important activity after selection of location. When competition increases, flexibility is a key determinant factor in deciding variety of products and reduction in inventory. Inventory reduction can improve into increased profitability. Thirteen areas of flexibility were identified for the performance improvement in a refinery. It was not tried to quantify the flexibility. This will help in improving the performance of supply chain. To minimize the movement of products, appropriate technology must be selected. Comparison and suitability of each type of technology was also discussed in the Indian context.

Demand for standard petroleum products is not increasing in the world market even though there is growth in the domestic market. After decontrolling and liberalization the Indian oil market also will face competition from imported products and international players. Existing refineries must be equipped to compete with high quality imported products and value added products from new generation Indian refineries also. Flexibility in all levels, starting from selection of crude oil to the blending at the latest possible point is considered for improving competitiveness of each refinery. Exporting products will be another option available to the refineries for increasing profitability. Flexibility in production must be designed to export products because each market specification will be different. In a nutshell, flexibility must be maximum for maximizing the profit of Indian refineries. Technology selection must be supplementing the flexibility. Technology available and suitable for India is identified. The tools used for location identification was found appropriate and the results are very encouraging. Methodology for flexibility and technology selection are found to be very useful. Next chapter discusses the supply chain planning procedure for a refinery.

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CHAPTER IV

Supply Chain Planning for a Refinery

4.1 Introduction

Over the last few decades governments around the world have been removing trade restrictions (EIA report 2001). It has resulted in a large increase in global trade. This increase in globalization has two main impacts on the supply chain. The first is that supply chains are now more likely, than ever, to be global. A global supply chain creates many benefits, such as the ability to a source from a global base of suppliers; get production done at different centers around the globe and to sell to global markets. However, globalization also adds stress to the chain because facilities within the chain are geographically farther apart, making co-ordination much more difficult. The second impact of globalization is an increase in competition, as once protected national players must now compete with companies from around the world. In the past, when there were not many companies offering service to satisfy customers' needs, the individual companies could afford to take more time for responding to their needs. Petroleum industry is not spared from competition. Earlier majority of the nations were importing crude and refining to meet their demand. Sudden increase in demand and increase in efficiency of logistics reduced the complexity of transporting different products. Above factors along with the liberalization in trade improved the competition in market in all countries in the world. Indian refineries are also facing similar competition. Products like LPG, Naphtha, Kerosene, etc are imported by Indian marketing agencies. Imported naphtha is cheaper than the domestically produced one. Refineries with high production capacity can sell at cheaper rate because of the reduced production cost. These refineries are exporting the products to many countries to maintain their capacity utilization. Now there are many more refineries aggressively marketing their products. This competitive situation makes supply chain performance a key to maintain growth in sales. Purchase planning and production planning can be done with expected demand for the products. Dependability of planning is based on the accuracy of product-demand calculation. Method for finding out the demand is also discussed in this chapter. Based on the demand for products and netback from refining, crude oil can be selected. A linear programming problem is formulated for selecting the crude oil.

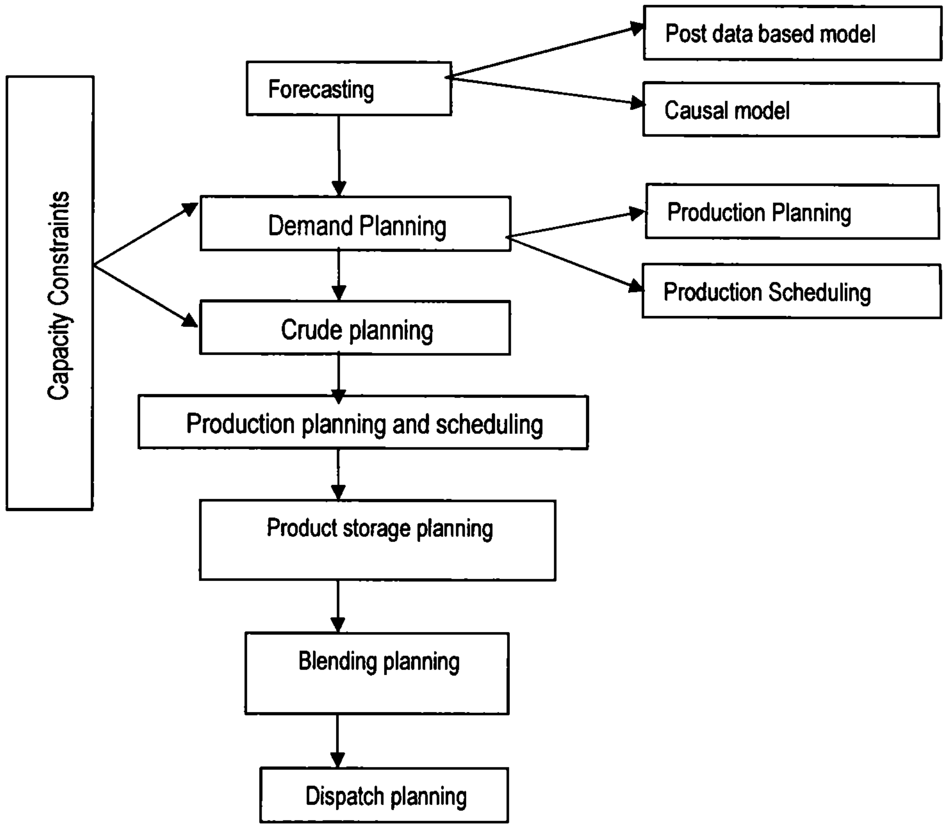


Figure 4.1. Production system (simplified)

Creating a successful supply chain strategy needs a lot of parameters such as good transportation facility for crude oil and refined products, sufficient facility at port for handling all types of ships, good information technology for data transfer. Once a good strategy is formulated, actually executing the strategy is also complex. Many highly talented and dedicated employees at all levels of the organization are necessary to make a supply chain strategy successful. Execution of a strategy can be very important as the strategy itself. Major obstacles to achieve strategic fit are increasingly demanding customers, and fragmentation of supply chain ownership. Overcoming these obstacles offers tremendous opportunity for firms to use supply chain management to gain competitive advantages.

As discussed in chapter 3 there has been increase in world trade of crude oil and petroleum products. Products that are largely traded are LPG, Naphtha, Kerosene, Diesel, and Petrol. World over refineries are working on cost reduction due to competition. In many countries installed capacity for refining is more than the demand in those countries. Those companies are prepared for export of refined products. Due to opening up of economy, India is also exposed to international competition. Cost reduction is essential for the Indian refineries also to withstand the competition from other multinational players. All the elements in the supply chain must be analyzed for maximizing the effectiveness of the system. In this chapter the problems of full supply chain in a refinery are analysed.

4.2 Problems in Indian Refineries Supply Chain

Major petroleum companies have many refineries at different locations in the country. Indian Oil Corporation is an example. Single refinery companies are also there in India. Multiple refining companies have their own advantages and some disadvantages. Main advantages are given below.

a. Sharing of key experts and expertise. Expertise in purchase of crude oil and marketing can be utilized for all the refineries in the group. Experience in refinery operation and refining can be transferred to newer refineries.

b. Single point decision will help in policy decisions. Corporate office will have competent team for formulating major policy decision for each refinery at different locations. The entire refinery will have uniform style of operation, so the performance of all the refineries can be better due to centralized decision making.

c. Bulk Purchase is possible for multiple refineries because the purchase is controlled centrally from the corporate office. The bulk purchase will have price advantage. Term purchase can be made for major quantity and spot purchase can be minimized. This will give better savings in purchase.

d. Sharing of crude is a gain for multi site refinery because bulk containers can be used for transporting crude oil from far off places like Egypt. So the price gain can be tapped by these groups.

e. Sharing of products and streams is possible for these refineries, if there is a demand for a product in the market of another refinery, then that product can be supplied from another refinery. Similarly if a product is held up in a refinery that can be moved to some other place where there is demand.

f. Specialized products can be manufactured in one unit and can be supplied to all the market. Specialized products normally require high capital investment, which will not be feasible with all the refineries. One refinery of a group of refineries can very well manage it.

g. Distribution grid can be developed by multi site refineries. Marketing is easy for these refineries because of the availability of products and capital required for the grid development.

h. Market Control is easier because of the grid. More number of outlets can be developed so that the entry of new marketing companies can be prevented to a greater extend.

Each refinery needs to concentrate in production only because all other elements of supply chain will be taken care by separate departments in corporate office. For example, purchase will be done by the purchase department of the corporate office. So each refinery can develop strength in refining and be normally very good in capacity utilization. Single site refinery has some advantages over the multi site refineries. Decision on all maters can be taken faster because all the offices are in the same site. Implementation of decisions will also be faster. So the response of the system will be faster than multi-site refineries. In our research we have selected a single site refinery for the study of supply chain management because all the data are available from a single source. First hand information is available on all operations from the same refinery. Operations and planning are similar in multi-site and single site refineries. In multi-site refineries different information are available at different geographical locations. The selected refinery is having very good operating efficiency. It is consistently above 100% for the years 1998 to 2002. It is processing both Indian and imported crude oil. So procedure for the purchase of imported and Indian crude is also available. All the information required for a detailed analysis of functioning of a refinery is available with the refinery selected for study. So the data collected represents the true picture of a typical refinery in India.

4.2.1 Logistic Problems

Complexity of logistic problem increases with variables such as limitation of distillation column, limitation of port facility for handling ships, etc. Logistics problem can be broadly divided into two stages namely design stage, and planning and operation stage. Operating problems are of less severe nature in refineries with lot of automation and control systems. Hence they are not discussed here in detail. Majority of the design stage problem cannot be rectified after installation. So the optimal solutions can be achieved mainly for new refineries. Existing refineries can look for alternative solutions for the problem. For example jetty facility cannot be improved beyond a certain limit for an existing port. But at the time of site selection port facility can be given due importance. Solutions for design stage problems are capital intensive and time consuming. Improvement in design will not be normally as efficient as a new design. So in this discussion the important design stage problems are dealt with. This will be useful for new refineries.

Table 4.1 Matrix of logistics problems

	Design Stage	Planning Stage		
		Annual Plan	Rolling Plan	Daily Plan
Inbound	-Jetty Characteristics -Mooring Types -Pipeline Selection -Crude Storage Tanks	- Quantity Of Crude - Comparison Of Rude - Rates Of Indian And Imported Crude	- Ratio of crude types - Ship selection - Sharing with other refineries	- Plan for ship receiving - Planning tanks - Planning pipeline for crude - Minimize demurrage
Internal	-Selection Of Process - Variety Of Products -Site Selection Products -Storage Capacity	- OEB -Products Demand - Availability Of Crude - Connectivity Of Tanks - Maintenance	- Ship scheduling - Availability of tanks - Products off take - Product demand - Product mix	- Processing of crude -Variety of products - Blending -Tank scheduling -Information generation
Outbound	- Transportation modes - Loading systems - Parcel sizes	- Ratio of each mode - Demand of products - Area wise demand	- Ratio of products - Mode of transport - Arranging transport	- Loading each mode - Information generation - Capacity utilization

The complex problem can be divided in to subgroups for easy and efficient planning. It is standard practice in logistics related studies to classify and study problems as inbound, internal, and outbound logistics problems, Lamming, et.al [2002]. We have also adopted this method.

4.2.2 Inbound Logistics Problems

Major classification is made as design stage, planning stage, and operational stage. In the case of refinery some major planning decisions must be taken in the design stage itself. Plans must be made in the solution space constrained by design. Major decisions of design stage in inbound logistics are jetty characteristics, mooring types, pipeline selection and crude storage tanks. Jetty characteristics involve draft in the jetty, discharging facility for crude oil, pilotage facility for day and night and turning radius for ships. Mooring is a bottleneck for many oil ports. Ships with high ullage cannot be brought to many of the ports in the country. The alternative for this is going for single point mooring (SPM). Inbound logistics deals with identification of supplier, purchasing, transporting, receiving, and storage of raw material and services. In the case of a refinery inbound logistics mainly deals with identification of crude oil, purchasing of crude oil, ship selection, ship scheduling, receiving of crude tanker at port, pumping of crude oil to the tanks in the tank farm. Crude oil received in tanks is to be checked for quantity by using either dip gauges or automatic level indicator or both. The verified crude oil is permitted for settling for two to three days and issued for refining using automatic values. Logistics also deals with the supply water to the refinery. Water from the natural source is brought to the refinery using pipeline. So the problems related to the logistics in water supply are minimum.

SPM is capital intensive so careful and detailed analysis is required before proceeding with this solution. Pipeline diameter and number of pipelines is a factor to be considered in the designing stage. Growth of the surrounding area may become a limiting factor for the expansion in a later stage. Proper long term planning is required in the capacity requirement of pipelines. Number and size of crude oil storage tanks is another important factor to be considered at the time of design. Number of tanks has a bearing on the types of crude the refinery is planning to process. Lesser variety reduces the number of tanks. Tank construction and maintenance is also capital intensive and time consuming. Space for setting up new tanks at the time of expansion must be provided in the designing stage. Time for maintenance of a tank is seen to be two years. So storage capacity must be calculated with time required for maintenance in mind. Operational problems are sub divided in to annual plan, rolling short plan and daily plan for the better analysis. This division will make the problem more clear also. The division on sequence of attending the problem also will be better.

Annual planning is required in deciding the quantity of crude for the year. Not only the total quantity the ratio in which each type of crude is brought. It must consider the availability of domestic crude oil. Importing crude also can be low sulfur and high sulfur. Crude selection problem has many variables and linear programming problem has been developed and used for solving the problem. Details of crude selection problem are given in this chapter.

Rolling short-term plan is required in the areas of ship selection, quantity requirement and ratio of each crude. Ratio of crude oil can be decided on the basis of market demand of products and availability of domestic crude oil. Ship selection depends on the quantity requirement. Quantity can be shared between two or three refineries if they all require same imported crude oil. Higher quantity carrier ships will reduce transportation cost. So selection of ship depends on many factors. Detailed analysis is done in chapter 6.

Daily Plan in inbound logistics will make the arrival and storage of crude oil. Smooth ship scheduling is the most important activity in this. By proper ship scheduling demurrages can be minimized and storage tanks can be properly utilized. Since pipeline is a bottleneck for the refinery, scheduling will help in better utilization of pipeline also. A simulation model for ship scheduling is developed.

4.2.3 Internal Logistic Problems

Internal logistics generally deals with the issues of transporting, value additions, and storage of finished products. In the case of refinery internal logistics deals with the delivery of crude oil from tanks in the tank farm, transporting through pipeline to the distillation columns, distillation, transferring refined streams to different tanks, blending to make final products, and storage in tanks for marketing. Selection of process, variety products, site selection, and products storage capacity are the important facilities to be considered in the design stage of a refinery; technology for many process are available. Selection of technology is very important because availability of crude oil and products demand has high impact on the processing of crude oil. Site of the refinery is important as far logistics is concerned. Details are given in Chapter 3. Options for selection of site and factors to be considered are all discussed in detail. The areas where annual planning is required are given below:

- Demand for products
- Availability of crude
- Oil economic budget
- Connectivity of storage tanks-using design flexibility

Oil economic budget (OEB) is the budget estimate of crude for a year. Demand for products is estimated for the year. On the basis of the estimated demand the OEB is prepared.

Rolling short plan deals with the following areas.

- Ship scheduling
- Availability of tanks
- Products demand
- Products off stake
- Product mix

Ship scheduling can be done for a month and it needs monitoring also. Monitoring is essential to avoid starving and blocking in the refinery operation. If the supply is not enough, then there will be starving in the refining process. If the supply is more, it will block the delivery due to unavailability of tanks in the tank farm. In refinery the stages are tightly coupled with limited inter-stages. So it is difficult to manage if starvation or blockages take place. This can be overcome with proper short term planning. Solution for ship scheduling problem is given in this chapter. Tank availability for storage of crude oil and refined products must be planned in advance because all tanks cannot be used interchangeably. Connection between tanks is important in utilizing tanks to the full capacity. All tanks are not interconnected. This increase in interconnection needs planning and time for doing the connection. Tanks used for certain products cannot be used for some other products, for example tanks used for furnace oil cannot be used for storing motor spirit. Products off take also must be planned in advance. It is normally based on the prediction of the demand. Solution for the problem of error in products demand is discussed in this Chapter. Products demand in the market can be monitored exactly and which will lead to better planning of products movement. Product mix also can be determined in a better way by the newly suggested information system (chapter 5). This will reduce the level of inventory.

Daily planning involves the type of crude and quantity of crude to be processed in each distillation column. Operational planning is necessary because there can be variation in inventory and flow rate of crude oil. Buffer inventory can vary from three months rolling plan. So adjustments in flow rate become necessary. This may lead to adjustments in daily planning of capacity and interconnection of tanks. Availability of products is dependent on these decisions. Variety of products also will be a function of daily planning of crude oil processing. Blending is done for achieving the correct specification of products. It is based on the demand from the market. The blending decision is also taken daily. Problems and solutions of blending are given in chapter 6. Tank scheduling is also done on daily basis. This problem cannot be generalized because the connectivity among tanks is unique in each refinery. Information generation also must be monitored on daily basis. Inbound logistics generates a lot of data. Detailed data collection model is also discussed in Chapter 5.

4.2.4 Outbound Logistics Problems

Refineries use pipeline, ship, railway wagons, and truck for movement of refined products. The quantity varies with respect to the location of the refinery and target market. Mode of transport must be decided at the time of design itself to build up infrastructure facility as per the demand and supply. Selection of mode can be made on the basis of information available in Table 4.2. Loading system of each mode is different and the deign of the system depends on the quantity to be handled. For example if more products have to be transported by ship, more pipelines to port will be required. Out of all the loading system, truck loading is the most complicated and it is discussed in detail in chapter six.

Annual Planning required areas are total quantity to be transported, modes of conveyance to be selected, and quantity in each mode to be transported. Quantity to be transported to each mode of conveyance must be planned in advance to have smooth movement of products. This can be one on the basis of demand forecast. Demand forecast for each product is done on the basis of consumption pattern of the previous year. This is made on all India bases. Area wise demand is also calculated to have a better decision on product movement and crude oil selection and purchase.

Table 4.2. Modes of product movement

Modes of Transport and their characteristics		Applications
Pipeline	▪ High Initial cost ▪ Low operating cost ▪ Low flexibility ▪ Low maintenance cost ▪ High quantity transfer	Good for regular supply in large quantity of one or a few compatible products
Rail	▪ Special unloading terminal ▪ Storage facility required ▪ High rolling stock ▪ High initial investment ▪ Low flexibility ▪ Medium maintenance ▪ Low operating cost	Good for long distance Medium quantity and multiple products
Road	▪ Low investment ▪ High flexibility ▪ High maintenance ▪ High operating cost	Good for small quantities to different places 2 or 3 products in a load maximum
Sea	▪ High initial investment ▪ Low operating cost ▪ High infrastructure demand ▪ Limited locations	Good for port cities High quantity 1or 2 products in a vessel
Air	▪ High infrastructure demand ▪ Limited location	Good for emergencies Small quantity One product /parcel

Rolling short term planning is to be made keeping the product demand ratio in mind. Product demand is dynamic in nature, annual planning data will not be correct but it can be taken as a guideline for rolling plan. Seasonal changes, local activities etc. can affect the demand for each product. So ratio of products is a variable over a period of time. Change in ratio of products will affect the mode of transport also. Final planning can be made only in a month time. Transport can be arranged only after the decisions on mode of transport.

Daily planning is needed in the areas of product dispatch, selection of sequence of trucks, allocating manpower to each section, etc. Final scheduling of loading of each mode and each product is taken on daily basis. Correct planning cannot be done in advance because small quantities demand will not be intimated in advance. They will be directly coming to the loading place with required document. So information generation is important on each day for the planning of next day. Data generated must be converted to information. Scheduling for each day can be done on the capacity of the refinery. So delivery plans must be made on the basis of installed capacity. Daily planning strategy is given in Figure 4.2.

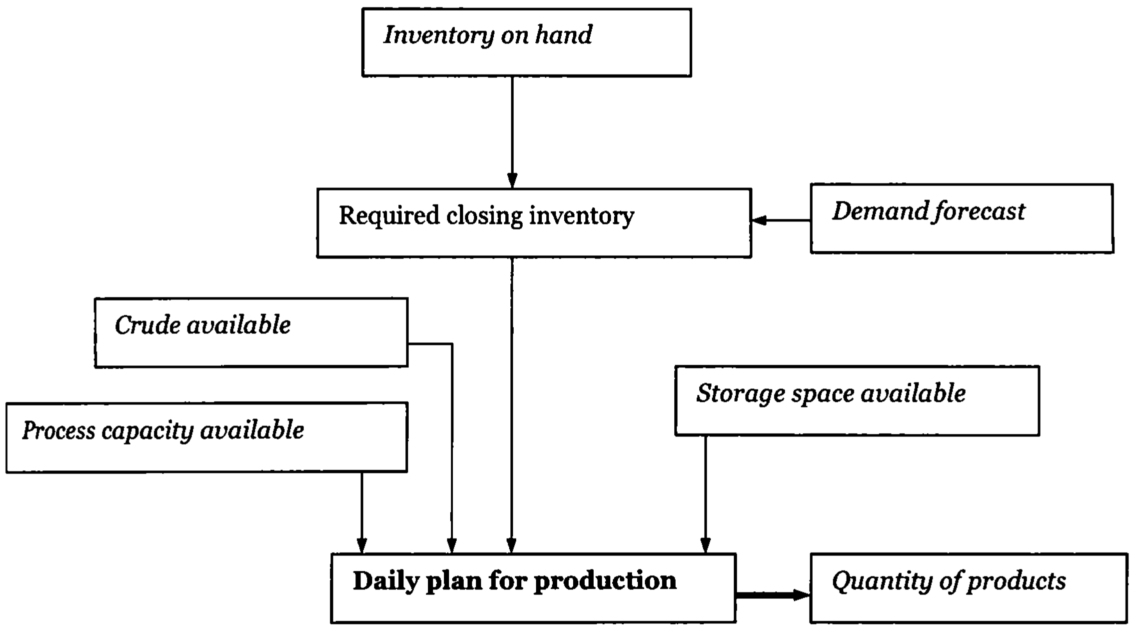


Figure 4.2 Daily planning strategy

Analysis of logistics problem indicates the importance of overall planning cannot be done in single stage. Bechtel [1993] reveals the importance of hierarchical planning for better and easier performance of an organization. So a hierarchical planning model has been developed for a refinery in the next section.

4.3 Hierarchical Model for Planning

Like any other industry, petroleum refineries also need to have planning for different time periods. In refineries it is found to be effective with annual planning, three months rolling planning, one months firm planning, and daily planning. Splitting of planning to different time zones make it more effective and efficient. The information available at annual planning stage is more aggregate and inaccurate. With the availability of better quality forecasts at three months level the same can be used to make more accurate plans. The variations are lesser at monthly and daily levels making it possible for the planners to make adjustments in the plan. Figure 4.3 shows a box diagram of the planning model developed for application.

4.3.1 Hierarchical Model Stage 1 → Annual Planning

Major decision for the industry is made in this planning. Factors to be considered for the annual planning are as follows:

- Annual Maintenance
- Refining technical characteristics such as capacity and routing requirements
- Logistics facility available
- Storage capacity
- Availability of crude oil

Annual shutdown of the refinery and its duration must be considered for the annual planning. Product storage or alternative arrangements must be made for making the products available for the customers. Refining capacity of a refinery must be considered for the annual planning. Selection of crude oil can be made on the basis of technical characteristics of the refinery. Logistics facility like port capacity to handle ship, availability of large ships, nearness to pipeline grid for both crude oil and products, loading facility for products, storage facility for both crude oil and refined products, nearness to railway lines and information flow must be considered for the annual planning. Storage facility available in the refinery is another important factor to be considered because the stock building up of crude oil and variety and product storage depends on the storage capacity of refinery. Availability of crude oil with required specification at the nearest source are also important because the timely arrival of crude oil depends on the availability and distance of the price of material. Information and constraints are there for the annual planning. Major constraints are:

- Oil economic Budget (OEB)
- Predicted demand
- Refining capacity

Annual planning brings out two main things namely netbacks (forecasted) and import of crude – Planning gives the price expectation, production requirement and off takes of product. From these information the netback for the refinery can be calculated. Netback is the profit for the refinery. So in the annual planning effort must be taken to improve the netback. Annual plan must give the quality of crude to be imported. Indigenous crude oil is available for the refineries in India but in limited quantity. To meet the capacity requirement and product demand almost all refineries have to import crude oil. Ratio of each type of crude oil to be imported is dependent on the product demand and availability of Indian Crude oil. Decision on percentage of each crude oil must be made in the annual planning for proceeding to purchase crude oil from the international market.

4.3.2 Hierarchical Model Stage 2 → Three months rolling planning

Implementation period in refinery is three months. A lot of meetings are to be held in national level before the execution of any suggestion for change. It will take three months for the change to get implemented. That is why refinery requires a three months planning period in addition to the annual and monthly planning inputs for monthly planning is similar to that of annual planning. Here the information available is more data based when compared with annual planning. The inputs considered for planning are:

- Refinery technical characteristics
- Shutdown maintenance of refinery
- Logistics facility such as ships, discharge rates, tank capacities available
- Availability of Indian Crude oil
- Constraints from annual planning are:
- Variety of crude oil to be bought
- Term purchase quantity
- Purchase price

Term purchase quantity is the quantity bought in the long-term contract. This can be made only for the confirmed demand. When a refinery is revising its purchase quantity in every three months, it must consider the contract obligation made after annual planning. Term contract is good for price gain. Purchase price will be given by the Government of India to each refinery. In India purchase is characterized through Indian Oil Corporation only. Forecast of supply plan and netbacks are the main output from three months planning. Variety and quantity of each product to be supplied will be available from the planning.

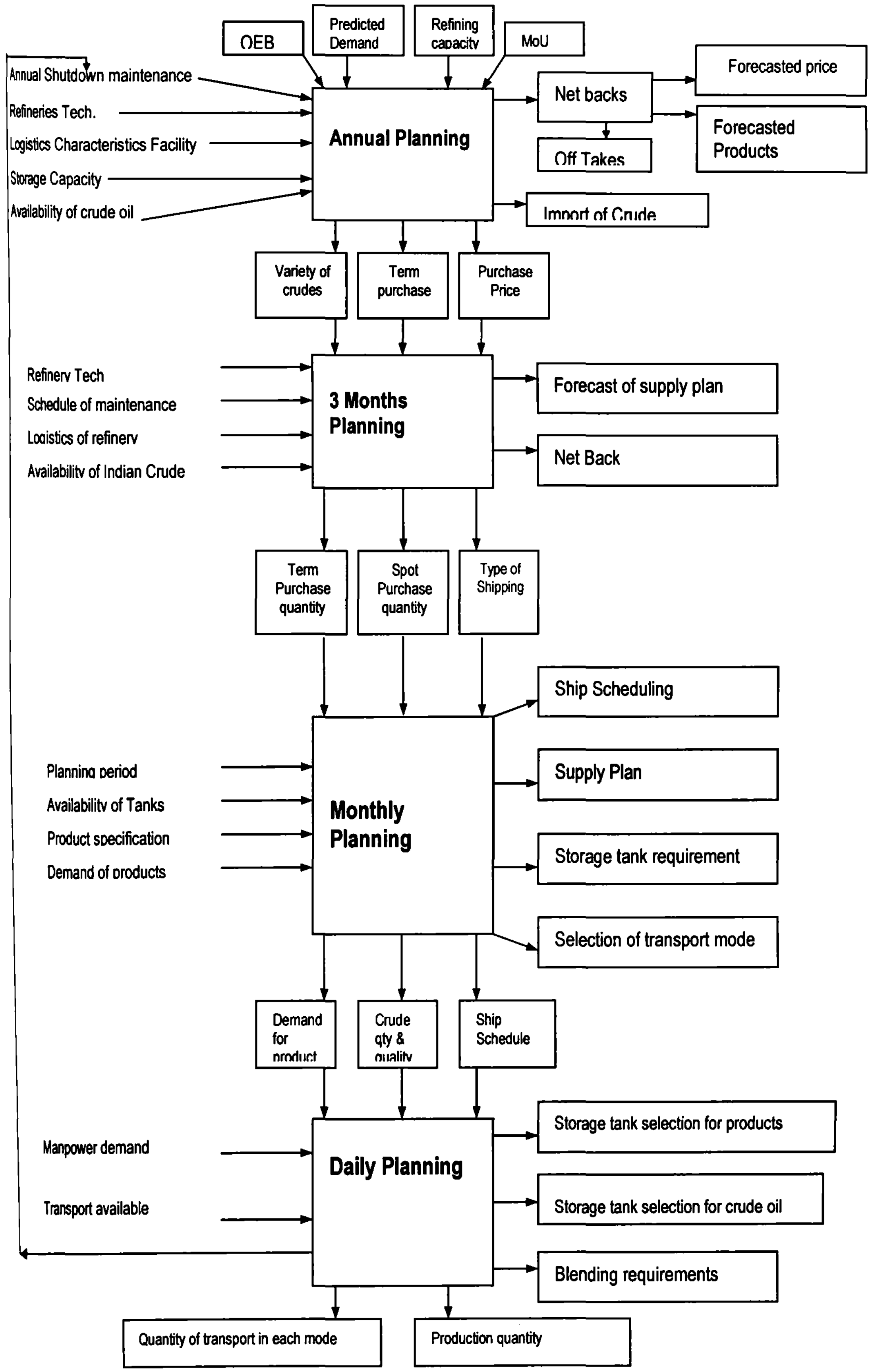


Figure 4. 3 Hierarchical model for planning

4.3.3 Hierarchical Model Stage 3 → Firm planning

Firm planning is done for a period of one month in a refinery. Monthly planning is done on the basis of the following input from refinery.

- Routine maintenance
- Availability of storage tanks
- Product specification needed
- Demand for products

Routine maintenance of facilities like pumps etc. will affect the production. So it must be considered for the monthly planning. Availability of tanks for storage of crude oil and refined products will be clear and a firm decision can be taken in monthly planning. Demand for each product quantity, type of products required and specification of each product can be decided accurately within a period of one month. Product specification of all products need not change in all months but some products can change in all months and some other products can change especially when going for export. Specification of diesel for all the nations in the world is not the same. This will be true in the same country also in the near future. Climatic conditions and road conditions affect the performance of an engine. To get best performance the diesel specification must be suitable for the condition. So different types of diesel will be required for different markets. This information will be clear in a month's time only.

- Gains of monthly plan are:
- Ship scheduling
- Supply plan
- Storage tank utilization plan
- Allocation of products to mode of transport

Supply plan of products is made by the refinery for the month to decide up on the movement of products. Movement of products planning includes quantity, quality and mode of conveyance. Mode of conveyance selection depends on distance to be transported and flexibility in quantity.

4.3.4 Hierarchical Model Stage 4 → Daily Planning

Main variable inputs for daily planning are manpower and transport facility. Reporting of manpower cannot be planned in advance because it will vary due to absenteeism. Transport facility like arrival of trucks and rail wagons cannot be planned in advance due to the uncertainty in arrival.

Tentative demand for products will be available from the monthly planning. This can be used for daily planning for production. Along with that, the stock available with the refinery also must be considered for the daily planning. Crude oil available for refining can be planned according to the information from monthly plan. Both quantity and quality of each type of crude oil is planned in the monthly plan. Arrival of ships is available from the ship schedule programmed and it is dependent on the ullages at destination. Planning for receiving ships can be made on daily basis. Information on ship arrival must be passed to the port for infrastructure facility providing. Storage of products in tank is decided on daily basis only because it depends on the product uplift. Product movement and production cannot be planned in advance. For better and correct performance, daily planning will be better. Same is true for the crude oil storage also. Blending is also planned according to the customer specification streams available and product demand. Normal practice for blending is making correct specification in each tank. So blending can be planned only on daily basis.

Planning sequence discussed in this section provides better and smooth flow of information from annual planning to daily planning. This makes the refinery operations smooth and the efficiency of the system will improve. It will also help in removing the bottlenecks in operation and planning.

4.3.5 Planning Comparison

Hierarchical planning shows the stages of planning. It will be useful for a refinery to compare the present practices and the system demand in SCM. Planning zones are subdivided into three for convenience of analysis namely annual planning, rolling planning, and daily planning. In this comparison three months plan and monthly plan are merged together because the same tools are used for both plans and they overlap very much in majority of areas. Table 4. 3 shows the present practices in annual planning zone and proposes tools for performance improvement

Table 4.4 shows rolling plan which covers both three months and monthly planning and Table 4.5 shows daily planning. Different tools are given in the Tables. Each tool can be modified to send and refinery. Data for the tools is taken from a standalone refinery. Performance of the refinery was analyzed in detail and is given in Chapter 6.

Table 4.3 Annual planning

	Function	Data Used	Decision to be taken	Model	
				Present	Proposed
Inbound	Crude type Selection	Quantity, Quality and cost of crude, Assays, capacity constraints and netback	Grades of crude to be purchased each month	Data based using 'what if'	LP
	Crude Purchase	Quantity, Quality and cost of crude, logistics cost, Assays, capacity constraints and netback	Crude to be purchased each month from each supplier	Data based using 'what if'	LP
	Ship size Selection	Size of ships, Per day costs, travel, load and journey times, demurrage rates	Selecting optimum size ship from each load port	Thumb rule	Spread sheet
	Port facility	Size of ships, parcel size, draft, number of berths, unloading facilities, discharge rates, port charges	Selection of the Port facilities to go for during expansion	'What if' expert opinion based	Spread sheet and simulation
Internal	Process automation	Product Quality demand, Automation costs, Flexibility and control requirements, manpower costs	Degree of automation to use in process control in the Refinery	Automated	No change
	Maintenance	Maintenance history, condition data, Production schedules	When to do planned maintenance for what	Experience based	Spread sheet
	Oil Economy Budget	Product demand, Crudes available, capacity, netbacks	How much of which crude to process when in each refinery	All India data	Refinery data focus
Outbound	Terminal design for transport	Demand for products at different location, Cost per ton of mode, Flexibility required	Capacity and expandability of each type of terminal	All India demand	Demand forecasting model
	Transport mode	Rate of transport, Terminal capacity, customer preference	Mode of transport	Thumb rule	Spread sheet

Rolling plan time zone also is divided into inbound logistics, internal logistics, and outbound logistics. Analysis is done on the basis of function, data presently used, and decision to be used. Tools used for each type of decision making at each level are analyzed and proposals for new set of tools are suggested wherever required. General practice of refineries is thump rule based decision making except in critical areas like crude selection, blending, etc.

Table 4.4 Rolling planning

	Function	Data Used	Decision to be taken	Model	
				Present	Proposed
Inbound	Crude Purchase	Quantity, Quality and Quotations of crudes, logistics cost, Assays, capacity constraints and netbacks	Crude to be purchased each month from each supplier	Data based using 'what if'	LP
	Ship selection and scheduling	Quality of crude from each supplier, ships available and alternate possible schedules	Deciding which ships to hire from which ports and when	Thumb Rule and experience	Ship schedule evaluation Simulation based DSS
Internal	Tank maintenance Planning	Ship schedules, production schedules, tank yard capacities, major maintenance plans, time for maintenance of tank	When to take which tanks for de-sludging and minor maintenance	Thump rule	Gantt based evaluation of alternative
	Plant maintenance Planning	Production and dispatch schedules, Product tank yard capacities and inventory, major maintenance plans, time for maintenance of equipment	When to take which equipment for and minor maintenance	Departmental Planning using experience	Gantt based evaluation of alternative
Outbound	Transport mode selection	Distance to move, Qty moved, frequency of movement, cost, ullage	Apportioning into rakes, ships and lorry	Thump rule	Spread sheet
	Transport Planning	Product demand, mode selection results, costs, capacities of transport	How much of transport facility needed and when and where?	Gross level aggregate/approximate	Spread sheet based with 'what if facility'

Daily planning also requires keen attention for improving the performance of supply chain in a refinery. Majority of decisions can be taken with the help of spreadsheet. Decision like ship scheduling requires sophisticated tools like simulation. Daily planning in refinery is not normally considered as very important because it goes in flow because it is a process industry. Proper daily planning can reduce both semi finished and finished goods inventory.

Table 4. 5 Daily planning

	Function	Data Used	Decision to be taken	Model	
				Present	Proposed
Inbound	Ship Receiving	Ships waiting, crude type, demurrage rates, Stage at Berthing facility	Decide order in which ships will be received	Spread sheet	Simulation
	Tank allocation	Tank capacity, condition, pipeline connectivity, crude storage capacity required, production plan	Allocating tanks to crude	Thumb rule	Modified thumb rule
Internal	Processing of crude	Product demand, assay and plant technical characteristics	Which crude to process in which facility and when	Spread sheet	Spread sheet (not modified)
	Blending	How much of What product of what specs required, how much of what are the blending streams available	How much of which blending streams to blend to which products	Experience and based on batch lab chemical tests	LP
	Storage tank selection for products	Tank capacity, condition, pipeline connectivity, product storage required, dispatch plan	Allocating tanks to different products	Thumb rule using centralized tank yard data	Modified thumb rule
Outbound	Dispatch transaction processing	Waiting orders, urgency requests, status of loading stations, transport availability	To select order to take and process from waiting customers	Rule based	Rule based - modified
	Dispatch of goods	Pending orders, waiting transport for dispatch, clearance for dispatch	To select order to fill from waiting orders	Rule based	Rule based - modified

4.4. Planning Demand

All supply chain decisions are based on an estimate of future demand. The forecast of future demand forms the basis for all strategic and planning decisions in a supply chain. Consider the push/pull view of the supply chain discussed in section 4.4.5. All push processes are performed in anticipation of customer demand, and all pull process is performed in response to customer demand. For push processes, a company must plan the level of production. For pull process, a company must plan the level of capacity to make available.

4.4.1 Characteristics of Forecast

The following characteristics must be known to forecasting department. Long term forecasts are usually less accurate than short term forecasts, i.e. long term forecasts have a largest standard deviations of error relative to the mean than short term forecasts. Aggregate forecasts are usually more accurate than desegregate forecasts. Aggregate forecasts tend to have a smaller standard deviation of error relative to the mean. For example – it is easy to forecast the gross domestic product (GDP) of India for a given year with less than a 2 percent error. It is much more difficult to forecast yearly earnings for a company with less than 2 percent error, and it is even harder to forecast demand for a given product with the same degree of accuracy. The key difference between the three forecasts is the degree of aggregation.

4.4.2 Components of a forecast

A Company can create useful forecasts, if it interprets the past correctly. Customer demands be influenced by a variety of factors and can be predicted if a company can determine the relationship between the current value of these factors and future demand. For good demand forecasting, company must identify the factors that influence future demand and then ascertain the relationship between these factors and future demand.

Before a refinery selects a forecasting method, it must clearly know what the supply chain's response time is as this information determines when the forecast need to be made. A refinery must also know about numerous factors that may be related to the demand forecast, including the following:

- Past demand
- State of the economy
- Competitors volumes
- New competitors
- Government policies

A refinery must understand such factors before selecting an appropriate forecasting methodology.

4.4.3 Forecasting Method for Supply Chain

Forecasting Methods can be classified according to the following four types.

Qualitative: They are most appropriate when there are little historical data available or when experts have market intelligence that is critical in making the forecast. Such method may be necessary to forecast demand several years into the future in a new industry.

Time series: Time series forecasting methods use historical demand to make a forecast. They are based on the assumption that past demand history is a good indicator of future demand. These methods are most appropriate when the environmental situation is stable and the basic demand pattern does not vary significantly from one year to the next.

Causal: Causal forecasting methods involve assuming that the demand forecast is highly correlated with certain factors in the environment (e.g. the state of the economy) Causal forecasting methods find this correlation between demand and environmental factors and use estimates of what environmental factors will be to forecast future demand. For example, product pricing is strongly correlated with demand.

Simulation: Simulation forecasting methods imitate the consumer choices that give rise to demand to arrive at a forecast.

Time series methods are most appropriate when future demand is expected to follow historical patterns. When a refinery attempts to forecast demand based on historical information, the current demand, any historical growth patterns, and any historical seasonal patterns will influence that company's future demand. Moreover with this forecasting method, there is always a random element that cannot be explained by current demand, historical patterns or seasonality. Therefore, any observed demand can be broken down into a systematic and random component.

Observed demand (O) = Systematic Component(s) + Random Component(s)

The systematic component measures the expected value of demand and consists of level, the current depersonalized demand, trend, the rate of growth or decline in demand for the next period, and seasonally, the predictable seasonal fluctuation in demand.

The objective of forecasting is to filter out the random component (noise) and estimate the systematic component. The difference between the forecast and actual demand is forecast error.

Out of these methods time series forecasting is most suitable for a refinery. Adaptive category of time series method is ideal for a refinery. In adaptive forecasting methods, companies update their estimates of the various parts (eg. Level, trend, seasonality) of the systematic component of demand after they make each demand observation. Adaptive methods assume that a portion of the error is attributed to incorrect estimation of the systematic component with the rest attributed to the random component. This method updates the systematic component after each demand observation. Adaptive methods include moving averages, simple exponential smoothing and exponential smoothing with corrections for trend and seasonality. Exponential smoothing is most suitable for a refinery because the demand changes are gradual and it will be reflected in the calculation. The demand has no observable trend or seasonality.

In this method, estimate the level in period t as the average demand over the most recent n periods. Let α be the weightage of the past data on the demand forecasted. In this calculation the value of α is taken as 0.5.Exponential Smoothing for four years demand is calculated as follows.

$$\bar{X}_1 = X_1$$
$$\bar{X}_2 = \alpha X_2+(1-\alpha)\ \bar{X}_1$$
$$\bar{X}_3 = \alpha X_3+(1-\alpha)\ \bar{X}_2$$
$$\bar{X}_4 = \alpha X_4+(1-\alpha)\ \bar{X}_3$$

Demand for five years of three products is taken for the purpose of comparing three different tools. It is compared with the actual demand in the forecast year. Error for each method is compared and exponential smoothing is found to be better than other two methods. This comparison is given in Table 4.6 and 4.7

Table 4.6 Consumption of products

	Consumption				
Product	**1997**	**1998**	**1999**	**2000**	**2001**
MS	129780	129800	130970	132150	133210
LPG	56980	56970	57190	57220	57180
Bitumen	9775	9680	10440	9260	10080

Table 4.7 Comparison of forecasts using different tools

Product	Actual demand for 2002	Forecast with different Tools					
		Average	*Error*	Moving average	*Error*	Exponential smoothing	*Error*
MS	133210	131182	**2028**	131533	**1678**	132239	**971**
LPG	57185	57108	**77**	57140	**45**	57165	**20**
Bitumen	9980	9847	**133**	9865	**115**	9870	**110**

Error in each method is calculated and compared to come to a conclusion. In this set of data it is found that the exponential smoothing method is most suitable for the forecasting of product demand in a refinery.

4.4.4 Six-step approach to demand forecasting.

All departments in the supply chain should reach consensus regarding forecast assumptions, techniques, and final forecast numbers. The following basic, six step approach to forecasting helps an organization perform effective forecasting.

4.4.4.1 Understand the Objective of Forecasting

The first step a refinery should take is to clarify the objective of the forecast. The objective of every forecast is to support decisions that are needed for the forecast. All parties affected by a supply chain decision should know the link between the decision and the forecast. For example, as per the forecast the diesel demand is going to be more in December. All parties must thus come up with a common forecast for a shared plan of action based on the forecast. Failure to make decisions jointly may result in either too much or too little product in various stages of the supply chain. At this stage the refinery must specify whether it wants a forecast based on geography, products or aggregate plan. Forecast horizon is the time lag between the point at which the forecast is made and the event being forecast. For example, the crude purchase planning starts two months in advance. So the forecasting for the month of December must be over at least by September.

Integrated Demand Planning and Forecasting. A refinery should link its forecast to all planning activities within the supply chain that will use the forecast. This includes capacity planning, production planning and purchasing. This link should exist at both information system and the human resource management level. As a variety of functions are affected by the outcomes of the planning process, it is important that all of them are integrated into the forecasting process. Ideal method for a refinery to have a cross functional team, with members from each affected function responsible for forecasting demand. A refinery should also involve the people responsible for executing a plan in the forecasting and planning process to ensure that all operational issues are taken into consideration during the forecasting and planning phase.

4.4.4.2 Identify major factors that influence the Demand forecast

A proper analysis of these factors is central for developing an appropriate forecasting technique. The main factors influencing forecasts are demand, supply and product related phenomena. A refinery must ascertain whether demand is growing consistent or has a seasonal pattern. These estimates must be based on demand not on sales data. On the supply side, a refinery must consider the available supply sources to decide on the accuracy of the forecast desired. If alternate supply sources with short lead-time are available, a highly accurate forecast may not be especially important.

4.4.4.3 Understand and Identify Area of supply

The area must be selected on the basis of convenience in conveyance, proximity of another refinery or mode of transportation. Number of industrial customers and their percentage consumption also will affect forecasting.

4.4.4.4 Determine the Appropriate Forecasting Techniques

In selecting appropriate forecasting techniques a refinery must first understand the dimensions that will be relevant to the forecast. These dimensions include geographical area, product groups and customer groups. The refinery should understand the differences in demand along each dimension. At this stage a firm selects an appropriate forecasting method from the four methods discussed earlier.

4.4.4.5 Establish Performance and Error Measures for forecast

Refineries must establish clear performance measures to evaluate the accuracy and timeliness of the forecast. These measures should correlate with the objectives of the business decisions based on the forecasts.

All supply chain design and planning decisions are based on a forecast of customer demand. These decisions include investment in plant and equipment, production-scheduling sales force allocation, and workforce hiring. Good demand forecasts have a significant impact on supply chain performance.

4.4.5 Push Vs Pull

Push systems generally requires information in the form of elaborate material requirement planning (MRP) systems to take the master production schedule and roll it back, creating schedules for suppliers with quantity and delivery dates. Pull systems require information on actual demand to be transmitted extremely quickly through out the entire chain so that production of products can accurately reflect the real demand.

Oil refineries are working on push system. Major disadvantage of push system for a refinery is the product variety. All the products may not have sufficient demand, so the holding capacity and time will increase. The present practice is to select crude oil suitable for the process so that the distillates with high margin will be the maximum. Processing quantity is decided on the basis of installed processing capacity. In both the cases demand for product variety and quantity are not considered. So the inventory holding will be more and it will lead to increase in working capital.

4.5 Linear Programming for Selection of Crude Oil

In the analysis it is clear that many factors must be considered for the selection of crude oil. Maximizing profit being the objective of the complex decision on crude selection, the ideal method is developing a linear programming model for selection of crude oil. The model can be used for selecting different crude oils for a refinery.

Maximizing net back is the objective function for the problem. It is calculated by summing up net backs of each type of crude oil suitable for the refinery.

Maximize $\sum$ Net back from each type of crude oil

Subject to the following conditions

I. Upper limit and lower limit of crude processing capacity must be fixed
   Upper limit ≥ Σ all crude oil types ≥ lower limit
II. Upper limit and lower limit of low sulfur crude processing capacity must be fixed
   Upper limit ≥ Σ all low sulfur crude types≥ lower limit
III. Upper limit and lower limit of Bombay High crude processing capacity must be fixed
   Upper limit ≥ Σ Bombay High crude oil≥ lower limit
IV. Upper limit and lower limit of product demand must be fixed
   Upper limit ≥ Σ Quantity of LPG available from each crude ≥ lower limit
   Upper limit ≥ Σ Quantity of MS available from each crude≥ lower limit
   Upper limit≥ Σ Quantity of diesel available from each crude ≥ lower limit
   Upper limit ≥ Σ Quantity of bitumen available from each crude≥ lower limit
   Upper limit≥ Σ Quantity of ATF available from each crude ≥ lower limit it
   Upper limit ≥ Σ Quantity of Hs-Distillates available from each crude ≥ lower limit
   Upper limit≥ Σ Quantity of FO available from each crude ≥ lower limit
1. Commitments due to term contracts also must be considered for solving the problem
   Upper limit of crude with limited supply
   Lower limit of term contracted crude

A sample model is developed for the refinery at Kochi. It is having two distillation columns. So it can process two different crude oils. One distillation column can process only low sulfur crude and second distillation column can process both. In this problem net back from each crude is calculated and used for calculation of profit of the refinery. Net back is the net profits the refinery gaining by processing one MT of crude. Seven such crude oils are considered for the formulation of the problem. The number of crude variety can be increased depending upon the availability. By processing one metric tonne of Bombay high (BH) the refinery will get Rs. 898 and by processing Labuan the refinery will get only Rs. 395. Refineries will not get BH for its full demand. The maximum availability of BH is 325000 MT. To meet the products demand, the refinery must process different types of crude oil. For example to meet the demand for Aviation turbine fuel (ATF), the refinery must process Iranian Mix (Ir. Mix.) Kuwaity and Basrah light (Basrah Lt.) Names of crude and its yield of each product is calculated for the constraints. Crude oil selected for the refinery are Bombay High(BH),Qua Iboe (QI), Labuan (L), Miri(M), Iranian Mix (IM), Kuwaity (K), and Basrah Light (BL) . The problem is discussed below.

The company, from were the data was collected, did not permit to reveal actual values of the coefficients and constraints in the LP hence, similar values are used in thesis. The values used for solving LP are only realistic but not real these values provided in this problem must not be used as secondary data for any further studies.

Refinery crude oil optimization

PROBLEM DATA IN EQUATION STYLE

```
Maximize
     + 898 BH + 797 QI + 393 L + 410 M + 245 IM + 804 K + 657 BL
Subject to
   CONSTR 1
     + 1 BH + 1 L + 1 M + 1 IM + 1 K + 1 BL <= 75000000
   CONSTR 2
     + 1 BH + 1 L + 1 M + 1 IM + 1 K + 1 BL >= 705000
   CONSTR 3
     + 1 BH <= 325000
   CONSTR 4
     + 1 BH >= 31500
   CONSTR 5
     + 1 BH + 1 QI + 1 L + 1 M <= 440000
   CONSTR 6
     + 1 BH + 1 QI + 1 L + 1 M >= 410000
   CONSTR 7
     + 0.046 BH + 1 QI + 1 L + 1 M + 1 IM + 1.2 K + 1.143 BL
           <= 756000
   CONSTR 8
     + 0.046 BH + 1 QI + 1 L + 1 M + 1 IM + 1.2 K + 1.143 BL
           >= 736000
   CONSTR 9
     + 0.12 BH + 0.026 QI + 0.026 L + 0.026 M + 0.031 IM
           + 0.031 K + 0.028 BL <= 30000
   CONSTR 10
     + 0.12 BH + 0.026 QI + 0.026 L + 0.026 M + 0.031 IM
           + 0.031 K + 0.028 BL >= 26000
   CONSTR 11
     + 0.547 BH + 0.026 QI + 0.06 L + 0.06 M + 0.07 IM + 0.07 K
           + 0.07 BL <= 83000
   CONSTR 12
     + 0.547 BH + 0.026 QI + 0.06 L + 0.06 M + 0.07 IM + 0.07 K
           + 0.07 BL >= 6300
   CONSTR 13
     + 0.522 QI + 0.575 L + 0.56 M + 0.297 IM + 0.267 K
```

```
        + 0.313 BL <= 350000
CONSTR 14
   + 0.522 QI + 0.575 L + 0.56 M + 0.297 IM + 0.267 K
         + 0.313 BL >= 330000
 CONSTR 15
   + 0.05 IM + 0.05 K <= 13000
 CONSTR 16
   + 0.05 IM + 0.05 K >= 1000
 CONSTR 17
   + 0.02 IM + 0.02 K + 0.02 BL <= 12000
 CONSTR 18
   + 0.02 IM + 0.02 K + 0.02 BL >= 6000
 CONSTR 19
   + 0.005 IM + 0.025 K + 0.018 BL <= 2780
 CONSTR 20
   + 0.005 IM + 0.025 K + 0.018 BL >= 0
 CONSTR 21
   + 0.293 IM + 0.323 K + 0.27 BL <= 100000
 CONSTR 22
   + 0.293 IM + 0.323 K + 0.27 BL >= 80000
 CONSTR 23
   + 1 QI >= 0
 CONSTR 24
   + 1 L >= 0
 CONSTR 25
   + 1 M <= 5000
```

The problem was solved using a commercially available software package named STROM. Solution of the problem is given below.

Refinery crude oil optimization

OPTIMAL SOLUTION - SUMMARY REPORT

	Variable	Value	Cost
1	BH	44690.3100	898.0000
2	QI	4152.7340	797.0000
3	L	391107.0000	393.0000
4	M	50.0000	410.0000
5	IM	259900.0000	245.0000
6	K	100.0000	804.0000
7	BL	82111.1200	657.0000

Slack Variables

8	CONSTR	1	74222040.0000	0.0000
9	CONSTR	2	72958.3800	0.0000
10	CONSTR	3	280309.7000	0.0000
11	CONSTR	4	13190.3100	0.0000
13	CONSTR	6	30000.0000	0.0000
14	CONSTR	7	4761.5490	0.0000
15	CONSTR	8	15238.4500	0.0000
16	CONSTR	9	4000.0000	0.0000
18	CONSTR	11	11029.2400	0.0000
19	CONSTR	12	65670.7600	0.0000
20	CONSTR	13	20000.0000	0.0000
23	CONSTR	16	12000.0000	0.0000
24	CONSTR	17	5157.7780	0.0000
25	CONSTR	18	842.2221	0.0000
27	CONSTR	20	2780.0000	0.0000
28	CONSTR	21	1646.9950	0.0000

29	CONSTR	22	18353.0000	0.0000
30	CONSTR	23	4152.7340	0.0000
31	CONSTR	24	391107.0000	0.0000
32	CONSTR	25	4950.0000	0.0000
34	CONSTR	27	209900.0000	0.0000
35	CONSTR	28	109900.0000	0.0000
37	CONSTR	30	82111.1200	0.0000

Objective Function Value = 314870100

Refinery crude oil optimization

SENSITIVITY ANALYSIS OF COST COEFFICIENTS

	Variable	Current Coeff.	Allowable Minimum	Allowable Maximum
1	BH	898.0000	-Infinity	4776.0210
2	QI	797.0000	453.0667	Infinity
3	L	393.0000	257.2369	786.7452
4	M	410.0000	-Infinity	507.3396
5	IM	245.0000	-2376.7240	Infinity
6	K	804.0000	-Infinity	5138.1720
7	BL	657.0000	-3243.7550	10095.2100

Since the values are not real, trying to read meaning from the numerical result is of less importance and hence it is not done. It has been shown that the problem given both optimal results and sensitivity analysis. This is indented to give the mode of selection of crude oil for maximizing the profit of a refinery by selecting proper combination of crude oils. The LP is developed for 100% efficiency. But refinery like KRL is working on more than 100% efficiency. Another LP must be developed for the refinery if it is working more than 100% efficiency. The same LP will not be suitable because some crude oils are being processed in the maximum capacity. So the variability is limited to a few varieties. That is why another model is developed for the purpose.

4.6 Ship Scheduling Model

The crude oil brought to the jetty in sea tankers is pumped to refinery through pipeline. This pipeline passes through the heart of the city. In 1971, when the pipelines were laid the city was small but now because of the growth of the city, the capacity expansion of the pipelines is almost impossible. If the capacity of the input pipeline has to be expanded the expenses will be exorbitantly high. So it will not be economical to go for it. The pipelines for pumping crude oil is therefore one of the major bottlenecks of the refinery.

The port under consideration is not having the facility for receiving all types of vessels because of the draft and turning circle limitations. Due to limitations in port facility and draft, COT cannot receive Suez-max and VLCC vessels. So the crude brought in big vessels need to be shared with other near by refineries. While sharing crude oil, the measurement as well as the quality of the crude changes. This refinery being at the southern end of India will be getting only the last part of the crude, which will be having a large part of the sediments and water. The depth of the channel to the port is not enough to bring ships at all times of the year. In monsoon time the draft will be low and the crude oil supply will be very much disturbed due to the draft problem. They can bring only small ships in the monsoon season. So weather is another bottleneck for the refinery. Under the above constraints as a short-term solution the existing facilities had to be made best use of. A good schedule of ships carrying crude with minimum overlap would be the best. The demurrage charges to be paid to ships under these conditions would be the minimum.

4.6.1 The Problem Characteristics

The objectives of a good crude ship schedule should be two fold, the first being able to meet the crude oil requirements of the refinery and the second doing the above at the least cost. The variable costs are the ones needing control, and in this case it is the ship charges for the unloading days. (The total days of the ship spends at unloading port is taken as unloading days and this includes time spent waiting for the free berth). In the DSS model that we have developed, only the ship cost/ton for unloading days is taken to find the minimum. The ship schedules that do not meet the refinery crude need satisfaction criteria should not be considered for evaluation by this model. The monthly ship demurrage paid to crude tankers now is in the range of 20 lac /month. It is the huge demurrage costs that we propose to reduce by selecting good ship schedules.

This meeting is held after the ICM every month with Oil Coordination Committee (OCC), Indian Oil Corporation (IOC) (Shipping), Shipping Corporation of India and the representatives from each refinery attending it. The aim of this meeting is to finalize the Crude allocation to each refinery by deciding the crude type and parcel size for different tankers, allotting them to different refineries and scheduling their arrivals at discharge ports. The crude requirement for next month of each refinery projected in the ICM is after consolidation by OCC (Technical) given to IOC (IT). They obtain quotes for crude. The initial crude shipping schedule is then made in consultation with IOC (Shipping). Here, a model that takes as input, data regarding crude and crude tanker availability from load ports, crude requirement of each refinery and lay days available at load and discharge ports and gives as output an optimum crude allotment schedule is used. This schedule gives the type and quantity of crude allotted to the tanker schedule to reach the discharge port for the refinery. This Crude allocation, and tanker schedule forms the basis for the Crude Slate Meeting.

4.6.1.1 The Crude Slate Meeting

Inbound logistics is discussed in this section as shown in Figure 4.4.

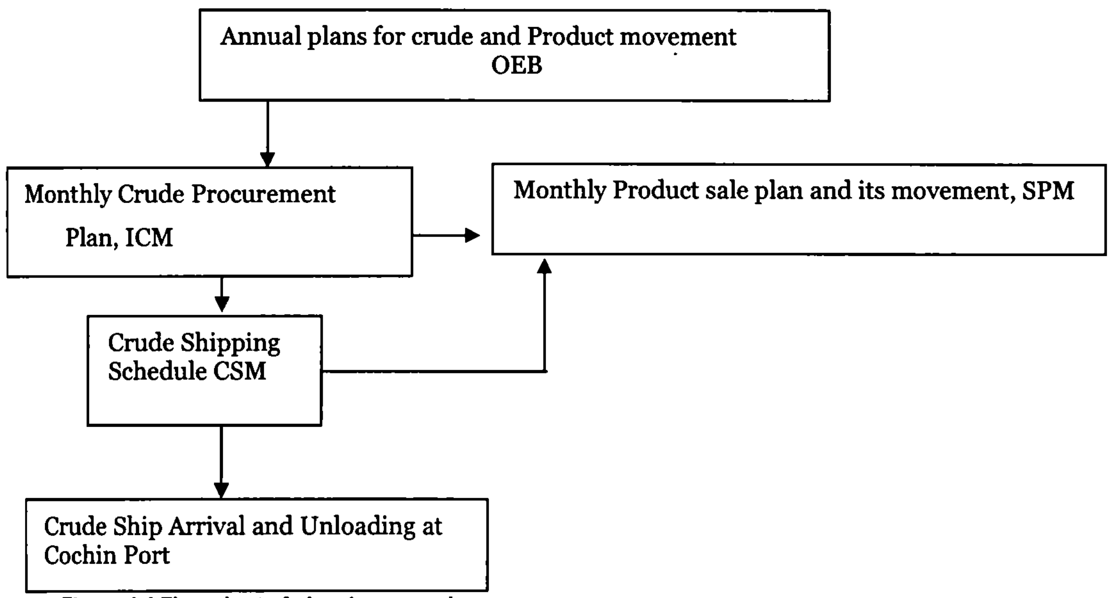


Figure 4.4 Flow chart of planning procedure

The purpose of the crude Slate meeting is to provide opportunities for the following:

- Exchange of crude between two refineries
- Move one tanker scheduled for one refinery to another to take care of emergencies
- To cancel or postpone certain tanker schedules
- To allot certain unallotted crude available to the refineries that can process them
- The result is the allotment and tanker schedule of crude
- The Bill of Lading holder for all parcels for the month is also finalized

4.6.1.2 Port facilities for crude ship handling.

Kochi refinery uses Kochi port for getting all its crude. The port handles on an average of about 17 crude tankers per month (minimum of 4 tankers in May to maximum of 24 tankers in December). The parcel size of these tankers varied from 24,918MT to 59,932MT with the mean at 38,927MT.

When the ship arrives at the outer sea it contacts its shipping agent and KRL personnel at the jetty. If no vessel is there at Cochin Oil Terminal (COT) instructions are given to bring the tanker for berthing with the tide rising. The in pilot boards the ship in outer sea and navigates it through the channel to the berth. At the mouth of the channel off fort Kochi two or three tugs approach the tanker to move it through the channel and berth it at COT. The mooring crew fastens the tanker at the jetty then the tugs and in pilot leaves. The loading arms or chicksuns are then fastened and the crude is unloaded through pipelines by the ship pumps. This takes about 24hrs normally. On completion of discharge and formalities the out-pilot boards the vessel, three tugs help the vessel cast off after the mooring have been removed. The vessel is then turned with the help of tugs and out-pilot and then it sails off through the channel to the outer sea.

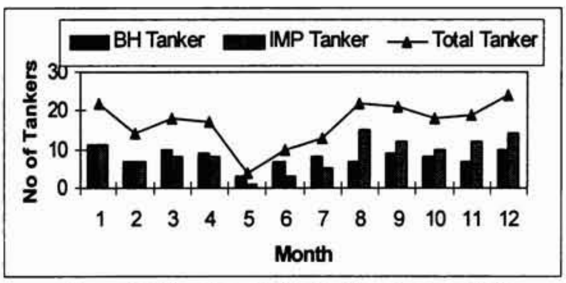


Figure 4.5 Number of Crude oil tankers arrival

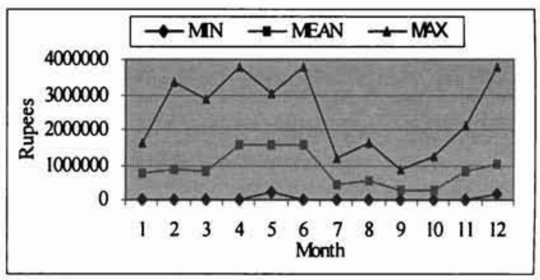


Figure 4.6 Demurrages paid in an year

As is expected from the data of crude arrivals the number of ship arrivals during each month also follows a similar pattern (figure 4.5). It is however worth noting that the average parcel size during monsoon drops to about 33,000 tons from the otherwise normal of 43,000 tons. This is due to loss of draft in the navigation channel due to monsoon siltation, this results in about 25% loss of cargo carrying space for each tanker trip which further aggravates the monsoon crude build up requirement

The Figure 4.6 shows the demurrage payable by CRL for tankers overstay beyond 36 hours for unloading crude. An hourly charge of Rs. 20,000 per hour has been taken for the calculation. This chart is of the financial year 1998-99. It can be clearly seen that there is wide variation between the minimum, mean and maximum Figures in most months. This indicates the problem due to clubbed arrival of ships, which is more in January to May, leading to higher demurrage during these months.

4.6.2 Objectives

The primary objective of this part of the study was to develop a simulation based Decision Support System to select the best monthly ship schedule from amongst alternatives available during DSM. The evaluation criteria for best schedule selection were the average cost per tone for unloading days for ship in a given month.

4.6.3 Solution Methodologies

The complex nature of this problem requires a model that can effectively take into account, the queuing of Ship at sea, and the times for which a Ship will have to wait for the tide for movement, for optimization of the system. Mathematical models fail to capture such complexity. A survey of literature shows that computer simulation is a widely used tool for port related studies. We have used simulation as a tool for solving this problem. The steps followed by us are given below:

(1) Understanding the crude oil movement system from the ships at high sea to the refinery.

(2) Detailed understanding of various subsystems such as Ships, tugs, port formalities, etc

(3) Finding out various constraints of the system.

(4) Time and other data collection for various Ships such as draft required empty and full, travel times, ships unloading times etc., and processing them for the use in simulation.

(5) Developing a simulation model, verification and validation of the same.

(6) Develop the DSS interface with the user and making the reporting system.

4.6.4 Simulation Model

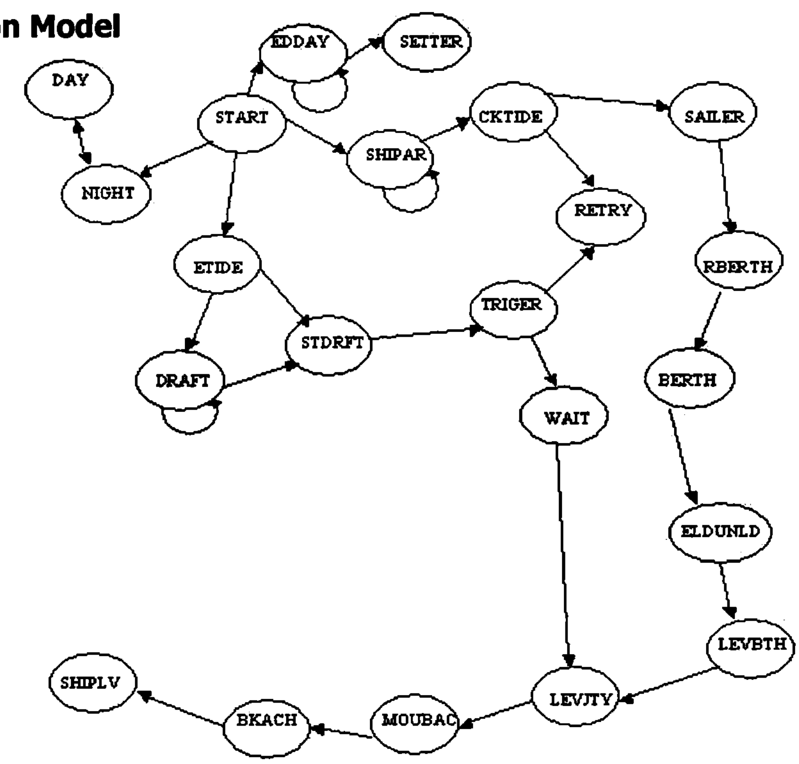


Figure 4.7 Event graph

A simulation model is developed using SIGMA, details of which are available in Schruben, a commercially available discrete event simulation package based on event graph representation of models, converted it into Pascal, modified it and incorporated the Ship loading and unloading rules to get a basic crude ship unloading simulation model that formed the base of the DSS model used to find the monthly cost/ton for a given ship schedule. The event graph for the basic ship-scheduling model is given in Figure 4.7. A brief description of the events represented by the nodes of the event is given in Table 4.8 . The model uses following assumptions:

- The tide data used has been taken from the tide Table of 1999.
- The pilot and tugs are available at any time.

Table 4.8 Description of events in event graph of the simulation model

Node Name	Description
EDDAY	Marks end of day and writes daily statistics in output file
SETTER	Resets the variables used for collecting daily statistics
ETIDE	Locates the appropriate starting low and high tides for the day
DRAFT	Reads the subsequent low and high tide values at appropriate times
STDRFT	Sets the movement times in creek for all Ships depending on tide
SHIPAR	Represents arrival of a ship at an anchorage location
SHIPLV	Ship leaves the Anchorage if completely empty
CKTIDE	Check for tide for sailing into creek
SAILSTR	Start sailing through Creek towards Jetty if Tide permits
RHBRTH	The loaded Ship reaches the Jetty and prepares to berth
BRTH	Ship berths at Jetty and starts unloading
EDUNLD	Unloading of Ship is over
LEVBTH	The Ship is ready to leave the berth after unloading
LEVJTY	Check if tide if favorable to leave the Jetty
MOVBAC	Ship starts sailing back
BKACH	Back to High Sea Anchorage
TRIGER	Trigger RETRY and WAIT nodes when favoring tide occurs
RETRY	Trigger movement of waiting full Ship through channel when tide favors
WAIT	Start movement of waiting empty Ship through channel when tide favours
NIGHT	End of Night
DAY	End of daylight occurs

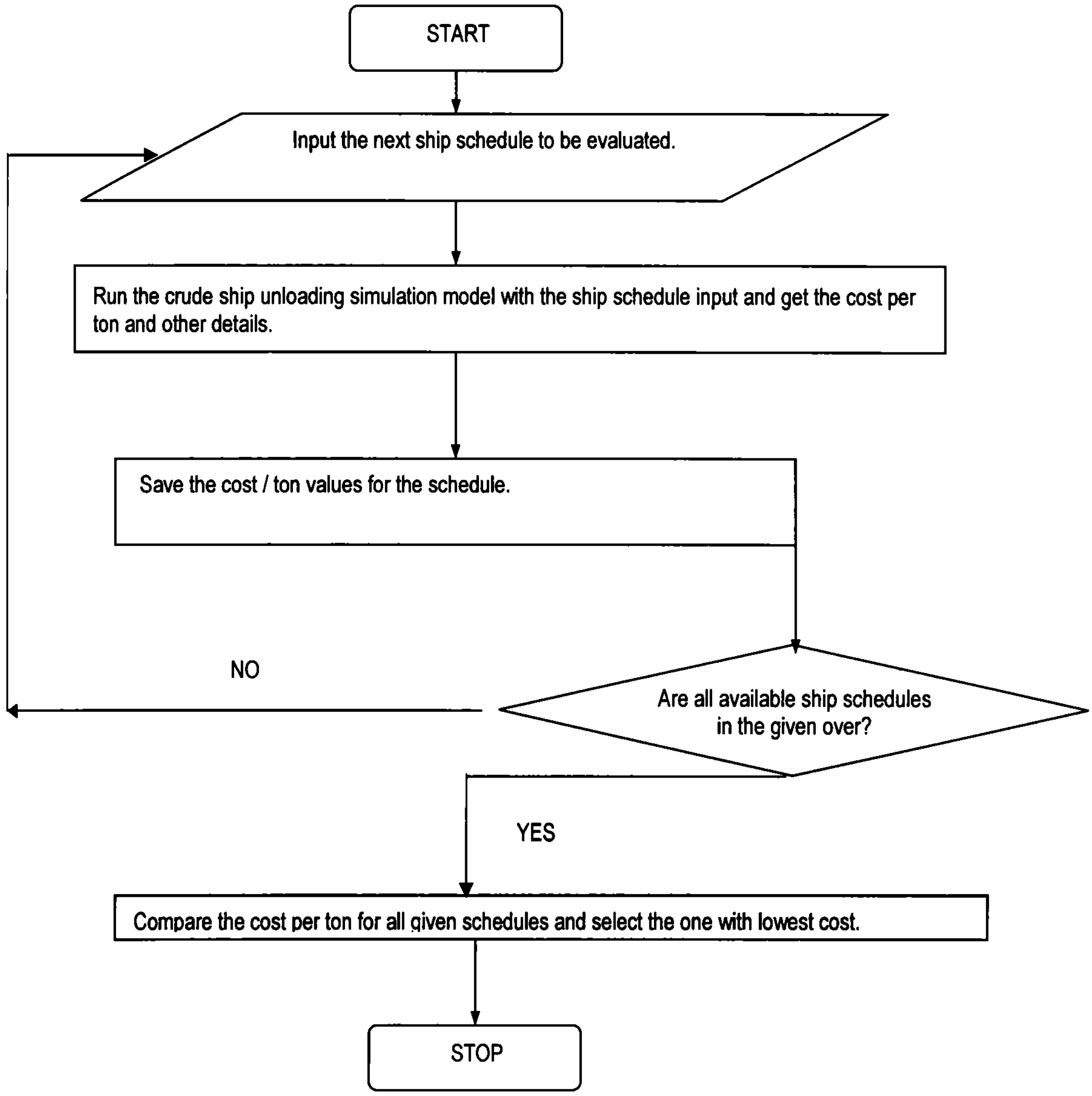


Figure4.8. Flow chart showing logic used in ship scheduling optimization model

4.6.5 Model Validation

We have used the white box method of validation. In this method the actual logic of operation was compared with that followed in the simulation model to make them the same. For this the detailed schedule of ship unloading for the month shown below was compared with what would happen in reality for both sequence of events and their times of occurrence and the model was validated.

K O C H I   R E F I N E R I E S   L I M I T E D

CRUDE TANKER WISE UNLOADING OPERATION DETAILS FROM THE SIMUATION MODEL

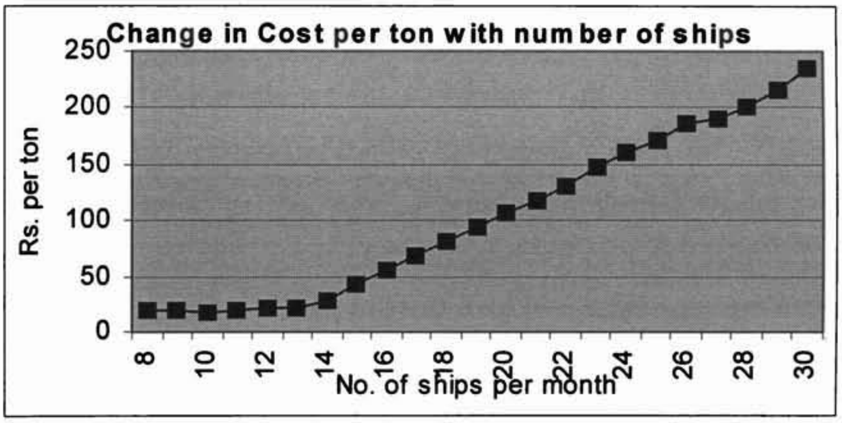
```
A DECISION SUPPORT SYSTEM (DSS) FOR EVALUATING CRUDE TANKER SCHEDULES
   Developed by: Kemthose P. Paul
  School of Management Studies, Cochin University of Science and Technology
Ship  1 has arrived on DAY  1 at time 12 hours   0 minutes
Ship  1 has started sailing in  on DAY  1 at time 13 hours  54 minutes
Ship  1 has reached the berth  on DAY  1 at time 18 hours  45 minutes
Ship  2 has arrived on DAY  2 at time 13 hours   2 minutes
Ship  3 has arrived on DAY  2 at time 13 hours  28 minutes
Ship  1 has finished unloading  on DAY  3 at time  2 hours   5 minutes
Ship  1 has sailed off on DAY  3 at time  6 hours  17 minutes
Ship  2 has started sailing in  on DAY  3 at time  6 hours  22 minutes
Ship  2 has reached the berth  on DAY  3 at time 10 hours  41 minutes
Ship  4 has arrived on DAY  3 at time 16 hours  36 minutes
Ship  5 has arrived on DAY  3 at time 16 hours  57 minutes
Ship  2 has finished unloading  on DAY  4 at time 17 hours  21 minutes
Ship  6 has arrived on DAY  4 at time 18 hours  28 minutes
Ship  2 has sailed off on DAY  4 at time 21 hours  23 minutes
Ship  3 has started sailing in  on DAY  4 at time 21 hours  28 minutes
Ship  3 has reached the berth  on DAY  4 at time  2 hours  37 minutes
Ship  7 has arrived on DAY  5 at time 15 hours  39 minutes
Ship  3 has finished unloading  on DAY  6 at time  9 hours  17 minutes
Ship  3 has sailed off on DAY  6 at time 13 hours  35 minutes
Ship  4 has started sailing in  on DAY  6 at time 19 hours  53 minutes
Ship  4 has reached the berth  on DAY  6 at time  0 hours  36 minutes
Ship  4 has finished unloading  on DAY  8 at time 7 hours 16 minutes
Ship  4 has sailed off on DAY  8 at time 11 hours  13 minutes
```

4.6.6. Results

Table 4.9 Relationship between ship hire cost per ton and number of ships per month

Number of ships per month	Total ship hire cost for unloading days	Total of Crude tonnage unloaded	Cost per ton for crude unloading
8	7200000	360000	20
9	8160000	405001	20.15
10	8160000	450001	18.13 <<
11	9120000	495000	18.42
12	11040000	540000	20.44
13	12000000	540000	22.22
14	16320000	585001	27.9
15	24480000	585000	41.85
16	32160000	585000	54.97
17	39840000	585000	68.1
18	47520000	585000	81.23
19	55200000	585000	94.36
20	62880000	585000	107.49
21	69120000	585001	118.15
22	75840000	585001	129.64
23	85920000	585000	146.87
24	93600000	585000	160
25	99840000	585000	170.67
26	108480000	585000	185.44
27	109440000	630000	190.71
28	118080000	585001	201.85
29	125760000	585000	214.97
30	137280000	585000	234.67

From Figure 4.9 and Table 4.9 it is clear that with increase in number of ships per month the total number of ship days at Cochin port increases resulting in increased cost per ton for ship hire for just the unloading days of the tanker trip. The total quantity of crude oil unloaded is the same when the number of ship arrival is more than 16 because of the facility constraint in the port. Ships will be forming a queue for unloading. The result shown no increase in unloading tonnage with increase in number of ships because though more ships come they have to wait in a queue and do not get unloaded because of unloading constraints. Refinery has to demurrage for the waiting time. It can be seen that up to 16 or 17 ships per month, the cost is Rs. 60 per ton or below. This is within the



tolerable limit. We have in the above model scheduled ship arrivals in equidistant intervals in time; this is not true in real case where clubbed ship arrivals do take place making the situation worse.

Figure 4.9 Transporting cost

The result of the simulation model is given below.

KOCHI REFINERIES LIMITED
RESULTS FROM THE CRUDE TANKER UNLOADING OPERATION SIMUATION MODEL
A DECISION SUPPORT SYSTEM (DSS) FOR EVALUATING CRUDE TANKER SCHEDULES
Developed by: *Kemthose P. Paul*
School of Management Studies, Cochin University of Science and Technology

SLTATED FOR KOCHI (DAY)	CRUDE PARCEL (in tons)	ACTUAL ARRIVAL (DAY)	ACTUAL BERTHING (DAY)	ACTUAL LEAVING (DAY)	UNLOADING DAYS AT KOCHI (DAYS)
1.0	45000.0	0.5	0.8	2.0	1.5
2.0	45000.0	1.5	2.4	3.7	2.1
2.0	45000.0	1.5	4.0	5.3	3.7
3.0	45000.0	2.6	5.9	7.1	4.5
3.0	45000.0	2.7	7.5	8.7	6.1
4.0	45000.0	3.7	9.1	10.4	6.7
5.0	45000.0	4.5	10.7	12.0	7.4
8.0	45000.0	7.5	12.3	13.6	6.0
10.0	45000.0	9.7	13.9	15.2	5.5

12.0	45000.0	11.8	15.8	17.0	5.2
13.0	45000.0	12.7	17.4	18.6	6.0
17.0	45000.0	16.7	19.0	20.3	3.5
17.0	45000.0	16.7	20.6	21.9	5.1
18.0	45000.0	17.9	22.2	23.5	5.5
22.0	45000.0	22.0	24.1	25.3	3.3
24.0	45000.0	23.6	25.7	26.9	3.4
26.0	45000.0	25.8	27.3	28.6	2.8
28.0	45000.0	27.9	28.9	30.2	2.3

Summary of the statistics of this SIMULATION run

Number of Crude Tankers that arrived =18

MINIMUM stay of a crude tanker at Kochi was for 1.5 days

AVERAGE stay of a crude tanker at Kochi was for 4.5 days

MAXIMUM stay of a crude tanker at Kochi was for 7.4 days

TOTAL COST of ship hire for unloading days Rupees 40800000.00

AVERAGE ship hire cost per ton for the period is Rupees 50.37 per Ton

It is demonstrated in this section how a simulation model run with different parameters and coupled with a search technique can be used as an optimizing decision support system. Such models can be of great help in taking complex decisions such as the optimal ship scheduling. The models made for such specific tasks can also be modified to evaluate different alternative changes or improvements proposed in the system studied. The analyst has however to be very careful in the verification and validation of the models used on which all the results depend. A word of caution is necessary at this stage, the results presented in this paper are case specific because of the cost, time, logic and other case specific data in the model. What is more general and of interest to practitioners in the field should be the methodology and the models used by us, which can be replicated and used in similar cases elsewhere.

4.7. Internal Logistics Planning

Internal logistics deals with the delivery of crude oil from storage tanks, processing of crude oil, intermediate storage of streams, final storage of products and blending of products. Maintenance plans of all the equipment will affect the performance of internal logistics.

4.7.1. Flexibility of storage tanks

The production planning decides what types of crude to be processed on each day and depends on the planning as discussed in this chapter. Tanks are grouped together for the purpose of storage of products. The grouping is mainly on the basis of connectivity.

All tanks are not inter connected. For example HSD cannot be stored in all the tanks. One reason is the product specification. Second reason is the connection to the HSD stream is limited to a set of tanks. Those connections are made on the basis of demand of HSD at the time of commissioning. The demand may vary according to time but the connectivity will remain the same. Due to this limited connectivity some set of tanks will be under utilized and some other sets will be always full. To overcome this problem the tanks, which store similar products, must be better connected so that utilization of tanks will be better.

All refineries use tank on thump rule. Because of this the under utilization of tanks in some farm and in other farm tanks will be full. So the problem can be solved by optimizing the storage tank usage. A model can be developed for this purpose to streamline the usage of storage tanks.

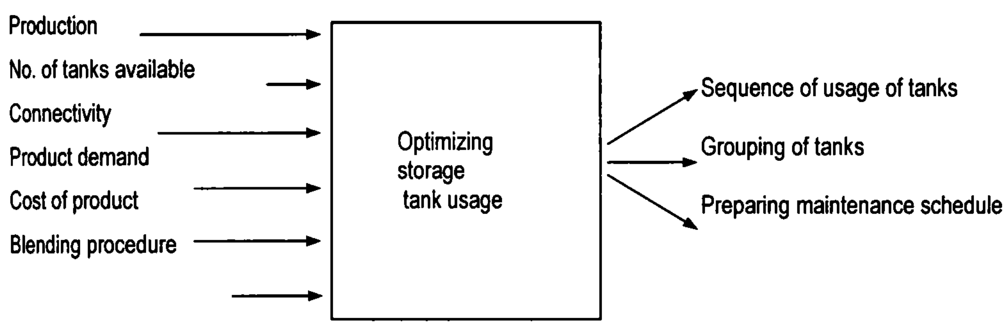


Figure 4.10 Storage tank allocation decision

The following inputs can be considered for the development of the model.

Production planning must be considered for the quality details of each product. This information is available on a predetermined period. For example, it can be taken on daily basis, weekly basis, biweekly basis or monthly basis. It will give the storage demand for each product.

Number of tanks available is another constraint for storage. The maximum requirement and minimum requirement can be found out from the records of the refinery. Connection between tanks and with processing units is another constraint for the decision-making tank optimization. Products supply to customers is also a factor in deciding the tank capacity. For individual customers it is almost on line. The supply is continuous. So the storage demand is minimum. The desirable outputs are:

Sequence of utilization of tanks, which tank must be filled first and which must be the second and so on. This information will reduce the operation effort as well as easy discharge of products as shown in Figure 4.10.

It also must give desirable number of tanks to be grouped for easy operations. It will also take care of fluctuation in the product demand.It must also give maintenance schedule for the tanks. Maintenance of tanks is time consuming processes. So it must be planned in advance for less disturbance to the supply chain system.

4.7.2 Processing of crude oil

Decision on processing of crude oil is dependent on the quality of crude, quantity of crude, ratio of each crude products planned, availability of storage capacity for each product and product specification.

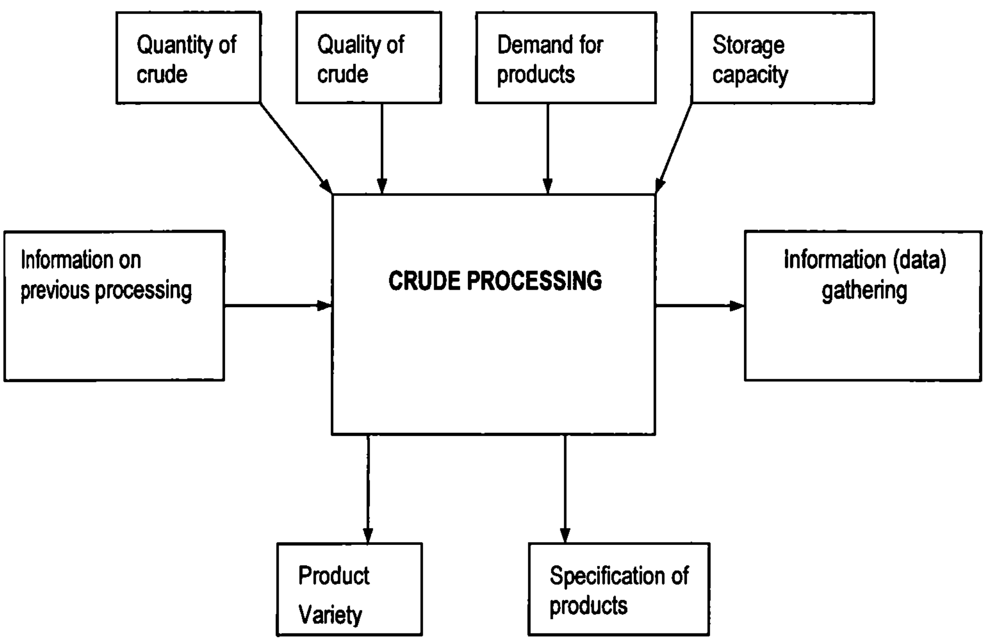


Figure4.11 Crude processing procedure

Almost all refineries have automatic process control. All the controls can be made from the control room. In the supply chain angle, improvement of process will yield comparatively lesser returns. So in this study improvement in process is not considered. As per records of the refinery (Annual report, KRL, 2002) it is working at more than 100% rated capacity for the last few years. This also indicates that the scope for improvement in process will be limited.

4.7.3 Blending of products.

Distillates with correct specification cannot be directly obtained from distillation streams. Specification varies with customer and use. Specification of products changes with many parameters and they cannot be corrected directly in the distillation column. Solution to this problem is blending of streams to get the correct specification. The commonly adopted blending procedures are given below.

- Batch blending
- Partial in-line blending
- Continuous in line blending
- Off unit blending
- Base stock blending

Batch Blending is done in tanks. One tank will be filled up to 90% of its capacity from the distillation column. Specification of the products will be tested in the laboratory. Laboratory will suggest the streams to be added to the tank for getting the correct specification. Blending is done separately for each tank and its control is manual.

Partial in line blending is done by controlling the flow to the collection tanks. Initial blending is done by adding multiple stream products to the blending tank and correcting the in-line blend after final lab analysis with small quantities of final touchup streams. This is also a manually controlled system.

Continuous in-line blending is done by controlling the flows of streams from different process or tanks to get the specification. This is normally done in the time of delivery of products. Products from distillation columns will be stored in tanks and their specification will be noted. Depends on the demand for the final product, the volume of each ingredient will be admitted to the flow. Blending is taking place in the pipeline. Final product, which is delivered, will be with correct specification. This is good for products with variation in specification. When the products are supplied to different markets, in-line blending will be ideal. Such complicated blending systems are best controlled fully by computer.

Off unit blending is done at distant location where the product specification is not sure. For example export of product is taking place from port. Storage facility is provided near the port. Refinery will not know when the shipment will take place and to which destination. Destination and customer decides the specification. It will be difficult to keep products with specification suitable for all customers. So basic streams will be stored in the tanks and the blending will take place only at the time of loading to ship or it will be blended in to a different tank before loading.

Base –stock blending is the blending of different types of crude oils to get products with required specification. This method will not give the correct specification still minor corrections will be good enough to have the required specification. The process of blending is easier in this method. The major disadvantage is the base stock variety requirement.

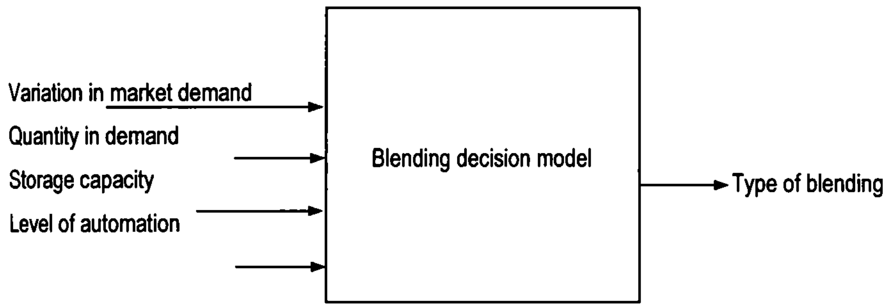


Figure 4.12 Blending decision making model

Blending method cannot be changed very easily after selecting one. So the selection must be made very carefully. The major factors to be considered are given below. Variation in Market demand: Variation in specification of products is major factor to be considered for the selection of blending technique. If the company is planning to supply markets in different areas then the product specification will be different. Frequent changes in specification also may be required. Then on line blending will be ideal but level of automation affects the consistency of specification.

Quantity in demand: If large quantity of product is required for a longer period, then batch blending also will be enough. Blended products can be stored because the demand is assured.

Storage capacity: storage capacity requirement will be more if the blended products are stored in the refinery. It will require less storage capacity if basic streams are stored. Again it depends on the demand, quantity and variety.

Level of automation: Level of automation is to be considered for types of blending. Batch blending requires less automation where as in-line blending high level of automation is required for better performance.

A decision making model will give a better solution because many blending methods are available and a variety of constraints are also available.

4.8 Outbound Logistic Planning

Outbound logistic planning involves the planning of transport including the selection of mode of transport, total quantity to be moved, quantity to be moved in each mode of transport, and types of products to be moved. Loading system selection is a design problem. The performance of the system depends on the efficiency of the system. Region wise demand of products must be decided on the basis of the consumption in each retail outlet. The consumption decides the quantity to be transported to the location. This necessitates the selection of mode of transport, which is discussed in the next section

4.8.1.Transport Mode Selection Model

Selection of mode for movement of refined product is another area, which can contribute to profit. Selection must be made from the commonly used modes- pipeline, ship, wagon and truck. All modes except pipeline have a minimum charge for transporting the product.

Truck transporting can be taken as an example.

Table 4.10 Calculation cost in truck transport

Minimum charge	A	Rs.500.00
Quantity Transported	B	12,000 kilograms
Distance transported	C	100 kms (assumed)
Rate per kilometer	D	Rs. 0.9023/lit
Total (A+ B x C x D)	E	**Rs. 1082/-**

Table 4.11 DSS for transport model selection

Mode	Min. Cost	Qty.	Dist.	Rate	Total
Pipeline	A	B	C	D	E
Ship	A	B	C	D	E
Wagon	A	B	C	D	E
Truck	A	B	C	D	E

Total cost of all the modes of transport can be calculated like this. Calculation can be made accurately by the help of spreadsheet as given in Table 4.9. Decision to select mode of transport can be taken very easily by comparing the total cost and selecting the mode with minimum cost. So this model can be taken as a DSS in the outbound logistics.

A few places are considered for establishing the feasibility of the transportation mode selection model. Product supplying refinery is situated at Kochi. Places considered for study are Thiruvanathapuram, Kollam, Chennai, and Kolkata.

Thiruvanathapuram needs supply of veriety of products like MS, diesel, bitumen, etc. Distance from Kochi is taken as 340 km. Requirement of quantity of all items added together is 600000 liters. This must be distributed to different outlets. Central

Table 4.12 Cost to Trivandrum

	Min. Cost	Rate/ Km	Total
Pipeline	------	-----	-----
Ship	300000	250	351000
Wagon	200000	320	265280
Truck	500	.9023	184570

storage facility is not available at Thiruvanathapuram. If railway wagons have to be used, then the distribution to retail outlets will incur additional cost. Model gives the solution as truck transport through road because that is having the minimum total cost.

Kollam needs supply of naphtha in bulk quantity for the power plant and small quantity of MS and diesel. MS and diesel can be transported using trucks because the distance is small and delivery is at different locations. Quantity requirement of all the items except naphtha is 596000 liters and the distance transported is 285 km. From Table 4.13 it is clear that pipeline is the economic mode for naphtha transportation. Single point delivery and large quantity regular supply makes the pipeline transfer viable. Cost for installation of pipeline is distributed for 10 years for the purpose of calculating the cost of transfer through pipeline.

Table 4.13 Cost to Kollam

	Min. Cost	Rate/ Km	Total
Pipeline			50000
Ship	300000	250	342500
Wagon	200000	320	254360
Truck	500	.9023	153800

Chennai needs supply of all type of products in large quantities at times. The demand is not consistent. Chennai has the port facility also to handle ships. Bulk storage facility is also available at chennai. So any mode of transport is technically feasible for Chennai. Demand from Chennai is dependent on supply from local refineries. Average consumption is 600000 litres and the distance to chennai is taken 650 km. When they cannot meet the demand, the refinery at Kochi must meet it. From the Table 4.14 it is clear that both sea and railway wagons are better options for Chennai.

Table 4.14 Cost to Chennai

	Min. Cost	Rate/ Km	Total
Pipeline			------------
Ship	300000	250	397500
Wagon	200000	320	324800
Truck	500	.9023	353400

Kolkata also requires supply of refined products from Kochi occationally. A permanent set up like pipeline will not be feasible. It is clear from the Table 4.15 that the most economic mode of transport to Kolkata is ship. Kolkata is also having seaport and unloading and storage facilities at port. Distance from Kochi to Kolkata is taken as 3000 km for calculation and the quantity to be transported is taken as 500000 liters.

Table 4.15 Cost to Kolkata

	Min. Cost	Rate/ Km	Total
Pipeline			------
Ship	300000	250	675000
Wagon	200000	320	680000
Truck	500	.9023	1353950

4.9 CONCLUSION

Logistic problem was divided in to two stages namely design and planning. Areas, which can not be improved after installation, are design stage problems. Planning is done for both facility deign and operation. For improving the effectiveness of planning, it is again sub-classified in to annual plan, rolling plan, and daily plan. Decisions to be taken at each level were identified in the plan zone with respect to inbound logistics, internal logistics, and outbound logistics. A hierarchical planning model was developed for giving a clear picture of decisions to be taken at each stage. This will also give an idea about the source of input data for planning. Source of information can be either from previous plan period or from outside the planning system. Model developed will help in maintaining the sequence in planning. Tools required for planning at each stage were identified and separated in to annual planning, short term planning and daily planning. These are given in Table form for the easy reference. Demand forecasting is the first stage in planning. Demand for refined products is not the same every month. It changes with seasons and socio-economic conditions. So a model was developed to make the forecasting better and more reliable. In the model consumption of products in the previous years was taken as the input data. A six-step approach to demand forecasting is developed for the implementation of the model in a refinery. Linking of forecast with all planning areas of supply chain is essential to have better planning. This six-step approach will help in achieving it. Crude selection and purchase is another important function in a refinery. Due to the linear nature of the problem an LPP was developed to solve the problem. Maximizing net back was the objective function. Each refinery will have different set of constraints. An example of Kochi Refinery Limited (KRL) was taken for verifying the applicability of the model. Bringing crude oil to the refinery is the next important function. This function is also having a number of variables like tide in the port. A simulation model was developed for ship scheduling. The model will give number of ships to be brought and the associated cost for bringing crude oil. This model can be used as DSS for ship selection with minimum demurrage payment to the shipping company. Internal logistics planning procedure was also discussed in this section to reduce starving and blocking of facilities in the refinery. In a refinery, the facilities are tightly coupled so the freedom for flexibility was limited for logistic purposes. Modes of transport for product in outbound logistics are also analyzed and a model is developed for selecting transport mode to a particular place for definite quantity and variety of products. These models will help in developing systematic planning procedure in inbound, internal, and outbound logistics.

CHAPTER V

Supply Chain Management and Information Technology

5.1 Introduction

Supply chain management system has three major components. They are information flow, material flow, and cash flow. SCM systems are used to improve the speed and accuracy of information flow to make system effective and efficient, and to make fast and reliable cash flow. Functional requirements to achieve the above are discussed in this chapter.

Information Technology is the backbone of success of any SCM system, Cachon and Fisher [2000]. The development in cost reduction started from efficient utilization of facilities using statistical tools. With the predicted demand it sub-optimizes at different levels to minimize the cost of production planning and scheduling of everything on the basis of product consumption in the market, [Pinto and Grossmann, 1998]. Consumption of customer is monitored on real time basis and that information is used for planning and rescheduling of production, [Sahinidis and Grossman,1991]. Movement of material from supplier retailer is on the basis of the new schedule. A strong support of computer network is essential for the success of SCM. Intranet, extranet and Internet can be used for the data collection and converting it into useful information. Suggestion for using these technologies in a refinery is given in this chapter. Data generation is another important area where refineries need a lot of impertinence. Same data is reproduced at different functional levels and this reduces the authenticity of information. Once data is generated, data must be used from the source itself at all functional levels, [Thonemann,2002]. It will reduce redundancy of data. Main data generation is production department and planning, operation and control departments use it. Data generation and flow management in planning operation and control is discussed in this chapter.

5.2 Problem and objective

Management in the Petroleum Refining industry is dominated by Engineers, mainly chemical Engineers. Since they are technically trained their focus is mostly on refining operations and its improvement. Logistics is sidelined. Therefore Supply chain related data collection, recording, and information generation are the weak areas in a refinery. Data collection and entry in to the computer is not made at the place of supply chain operation. Repetition of data collection and entry by different agencies is also common. This creates problems specially when there is difference between the values of the same data collected by different agencies. Lack of common standard norms of data collection and insufficient networking and data sharing is the main reason for this type of error.

Developing an information flow model for making SCM software for a refinery is the main objective of this chapter. Detailed study is made on the data collection methods at all stages from customer to the crude oil supplier and converting them to information to be used for decision making at different levels of management in a refinery. Main features required for the software are also discussed. Information flow at each module level must be developed and they must be integrated to get a complete information flow model. Different Information System tools and Technologies used in Supply chain Management are also presented in this chapter. The areas where each of these can be used in a Refinery supply chain are also pointed out here.

5.3 Supply Chain Management Components.

The nature of business enterprise is changing. Today's business is increasingly "boundary less" meaning that internal functional barriers are being eroded in favour of horizontal process management. The separation between suppliers, manufacturers, distributors, and customers is reducing. This is the idea of extended enterprise, which is transforming organization to complete in the market. According to Bowersox and Daugherty (1995), characteristics of modern supply chain are flexibility, quick response, reliability, and adaptability.

Information highway is the backbone of extended enterprise, sharing of information makes cross function and horizontal management possible. Characteristics of useful information are complete, reliable, timely, understandable, and verifiable, Marshel and Paul (2002). Information sharing between partners in the supply chain enables the responsive flow of product from raw material to the final customer.

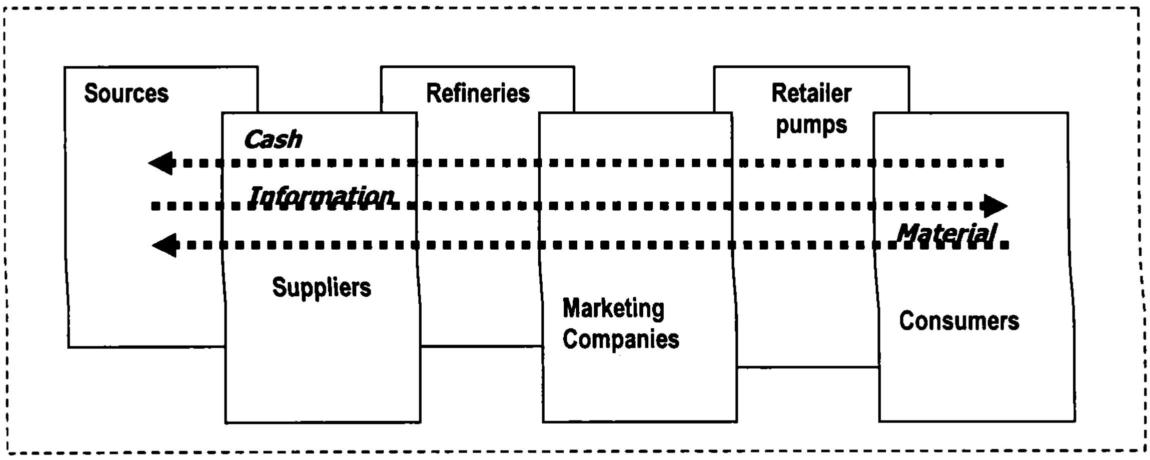


Figure 5. 1 Supply chain components

Supply chain is the effect of a series of relationships between partners. This is based on the value – added exchange of information. Figure 5.1 illustrates this concept. Fund flow and material flow are the commercially significant part of supply chain. All these interactions should ideally take place in a healthy business environment, which is conducive for the growth of industry. These components are discussed in the sections that follow.

5.3.1. Materials Flow

Earlier the focus in industry was on process improvement alone to improve productivity. The process improvement will not directly increase profit as logistics does.

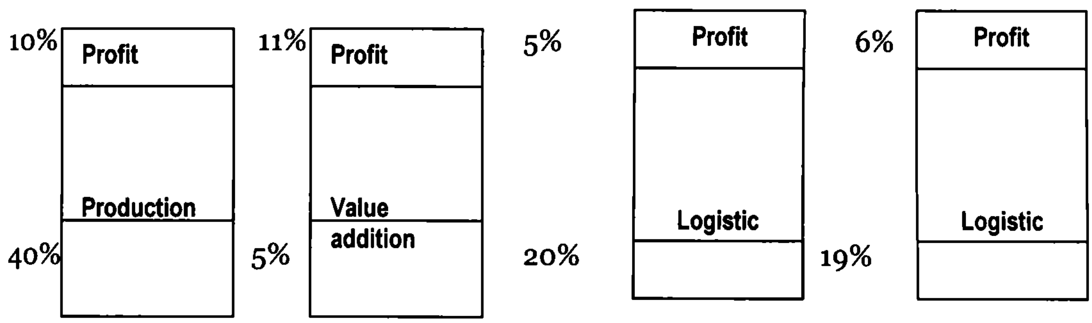


Figure 5.2 Effect of saving in logistic on profit compared to output improvement

There is considerable scope in many refineries for better management of logistics costs and hence for profit leverage. Figure 5.2 highlights the possibility of improving profit when profit margins are low relative to distribution costs. A hidden cost of logistics is the interest charged on inventory, tanks, and pipelines. Because this is rarely separately identified by most management accounting systems. Any reduction in hidden cost will directly increase profit. So improvement in efficiency of logistics is easy and urgent area for competitiveness in the market.

The value chain activities (Figure 5.3) can be categorized as inbound logistics, internal logistics, outbound logistics, and marketing and sales. To gain competitive advantage over its rivals, a refinery must deliver value to its customer through performing these activities more effectively than its competitors or by performing the activities in a unique way that creates greater differentiation. Logistic management has the potential to assist the organization in the achievement of both cost/productivity advantage and a value advantage

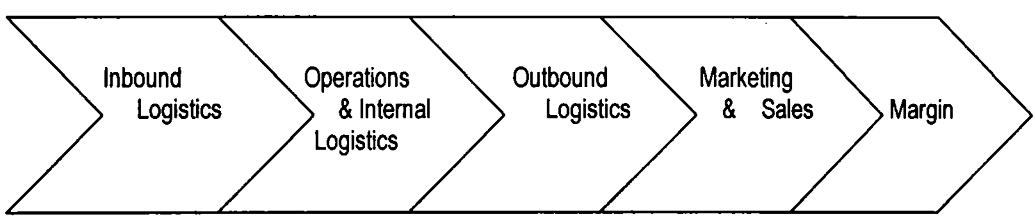


Figure 5.3 The value chain

5.3.1.1. Inbound Logistics

Inbound logistics in a refinery involves locating crude oil supplier, making the contract, and arranging shipment from supplier to the purchaser, facility management in the unloading port, and transporting from unloading port to refinery and storage at refinery.

Published data is available to get details on quality of crude oil of each location in different part of the world. Suitable and economic crude can be selected and the refinery can enter into purchase agreement. Purchase agreement can be either long term or spot purchase. Once purchase is made schedule of delivery can be obtained and shipping companies can be contacted for transporting. Many shipping companies are doing this crude oil transporting in different capacity ships. Depending on the crude demand and facility at unloading port, the refinery can select the right type of ship through shipping agents. Managing facilities at unloading port includes checking of draft with port trust, availability of port facility, pilots, and availability of tugs. Normally these arrangements are done through shipping agents. Refineries do not directly involve into shipping activities, they will entrust clearing and forwarding agents with the schedule of ship arrivals. Follow up of ship arrivals also will be done by clearing and forwarding agent at unloading port. Transporting from port to refinery is usually through pipeline. These will be exclusive pipelines for crude oil transporting from port to refinery.

Logistic management has the potential to assist a refinery in the achievement of both cost and productivity advantage and value advantage. Figure 5.4 suggest ways in which productivity can be enhanced through logistics and the prospects for gaining a value advantage in the market place through customer service. In short the refineries that will be the leader in the market of the future will be those that have sought and achieved the twin peaks of excellence: they have gained both cost leadership and service leadership.

The under lying philosophy behind the logistics concept is that of planning and co-ordination, the materials flow from source to user as an integrated system rather than managing the goods flow as a series of independent activities. Thus under the logistics management regime the goal is to link the market place, the distribution network, the manufacturing processes, and the procurement activity in such a way that

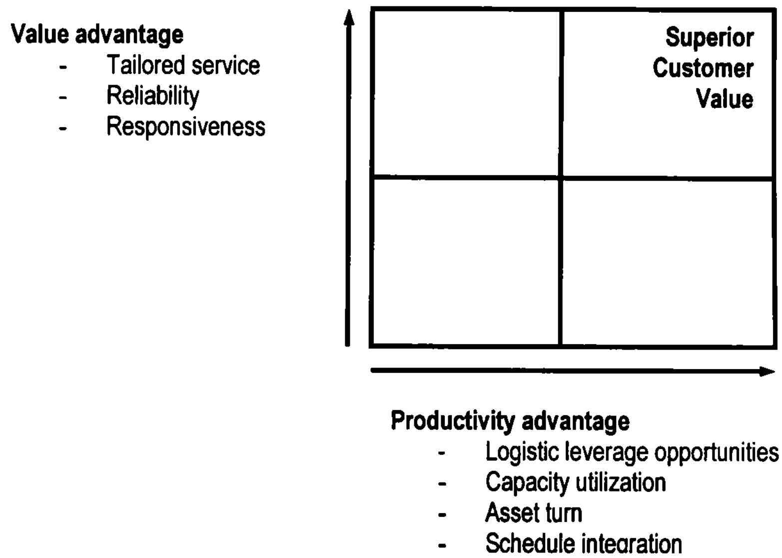


Figure 5.4 Gaining Competitive advantage through supply chain

customers are serviced at higher levels and yet at lower cost. In other wards to achieve the goal of competitive advantage through both cost reduction and service enhancement.

5.3.1.2 Operational and internal Logistics

In this thesis refining operations in a refinery is termed as operations. Main Functions involved in operations are the control of delivery of crude oil from storage tanks to initial distillation columns, storage of distillates or streams in tanks, treatment of streams for converting into products, selection of processes for getting products, and blending operations.

To improve operations management and flexibility, logistics management must be improved. Flexibility in feeding from any crude oil tank to any distillation column and distillation column to any stream tank must be possible. As on today Indian refineries are designating certain tanks to store a set of fixed tanks and normally those tanks are kept filled with blended products. Storage of blended products reduces flexibility and increases storage cost. If streams are stored in tanks, designation of tanks can be minimized and delivery from distillation columns can be less complicated. This will intern reduce number of trunks required for storage of products. Moreover a variety of products can be supplied to customers as per their varying demand. Internal logistics is a neglected area in almost all refineries. But internal logistics only can improve flexibility. So in the near future all Indian refineries will realize the importance of internal logistics.

5.3.1.3 Outbound Logistics

Outbound logistics involves the movement of refined products from refinery to customer. Two methods are in practice in India. One is refinery directly supplying to the retailer and the other is refinery supply to marketing companies and they distribute to retailers. For example Reliance Petrochemical Limited (RPL) is not having their own outlets instead they are selling to Indian Oil Corporation (IOC). IOC is doing their own refining and marketing. Indo-Burma Petroleum (IBP) is having only marketing no refinery. Refinery like KRL is having very few own outlets and marketing is mainly done by Hindustan Petroleum Limited (HPL).

Transportation can be using pipeline, ship, rail or road. As discussed in chapter 3, pipe line is the cheapest for bulk transporting but can not be easily used for small quantities. Small quantities in remote places can be supplied only through road. Coastal cities can be supplied through sea. The last option for main cities is rail.

5.3.1.4 Marketing and Sales

Marketing and sales were not treated as important activities in petroleum industry in India because the market was protected and supply was just sufficient to match the demand. Import of refined products were restricted by Government of India (GoI). April 2002 onwards Indian market is not price controlled and not free from competition. So far companies like RPL were not permitted to market their products in India. But now any company can market their own products or import for marketing. This will necessitate extensive market surveys and sales promotion techniques. Till April 2002, companies were doing market research and sales promotion only for lubricating oil. Branding was also very well done in lubricating oil. Market analysis and research will be essential in the near future to compete with other companies by way of optimizing the inventory and inventory movement. Sales promotion through increased flexibility of products will be essential to retain customers. Increasing flexibility in product specification is branding of petroleum products. That is why refineries must be equipped to stock streams instead of blended products. Blended products reduce flexibility in addressing customer demand. Dealers in different locations in the country will demand diesel or petrol of different specification to satisfy their customers to perform better. So Marketing and sales will play an important role in the years to come.

5.3.2 Information Flow

Information is not considered as a major supply chain driver because it does not have a physical presence in the company. Information affects all parts of the supply chain in many ways. Information serves, as the connection between the supply chain's various stages, allowing them to co-ordinate their actions and brings about many of the benefits of maximizing total supply chain efficiency. Information is also crucial to the daily operations of each stage in a supply chain. The main considerations for information flow are for planning, for operations, and for management control.

Supply chain co-ordination occurs when all the different stages of a supply chain works towards the objective of maximizing total supply chain profitability rather than each stage devoting itself to its own profitability. Lack of co-ordination can result in a significant loss of supply chain profit. Managers must decide how to create this co-ordination in supply chain and what information must be shared in order to accomplish this goal. Co-ordination between different stages in a supply chain requires each stage to share appropriate information with other stages. For example, if the arrival pattern of ships is given in advance, the stock and oil department can take steps to receive oil in a structured manner and production department can schedule their operations as per the availability of crude oil.

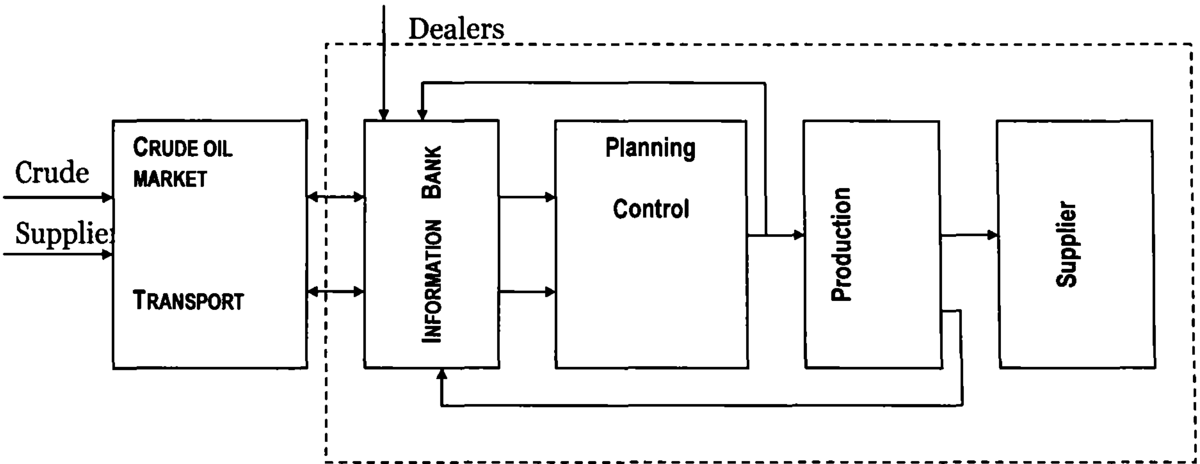


Figure 5.5 Information flow within a refinery

Information flow can be separated into two. One is information flow within the refinery and the other is information flow from outside. Figure 5.5 explains information flow within a refinery, Information bank receives information from all the departments and supplies information to all departments for the better co-ordination among departments. Centralized information reduces redundancy and improves reliability. All the data must be collected from the source of data generation. Centralized information storage enforces better control on authenticity and privacy of data. In many refineries compartment data storage and retrieval is in practice. Transfer of data is either through floppy disc or through printouts. In both the cases possibility of error is high and timely availability and storage are major problems. Major partners in information flow in a refinery are Planning, operations, and control. Co-ordination among these departments is essential for the efficient running of a refinery.

5.3.2.1 Information flow for forecasting and planning

Forecasting is the art and science of making projections about what future needs and conditions will be. Obtaining forecasting information frequently means using sophisticated techniques to estimate future demand or market condition. Managers must decide how they will make forecasts and to what extent they will rely on them to make decisions. Refineries often use forecasts both on a tactical level to schedule production and on strategic level to determine capacity. Once a refinery creates a forecast, the refinery needs a plan to act on this forecast. Strategic planning transforms forecasts into plans of activity to satisfy the projected demand. A key decision-maker faces the problem of how to use strategic planning both at the stage of manager's stage in the supply chain and throughout the entire supply chain.

In a refinery forecasting is mainly for product demand and crude oil availability and techniques used for forecasting is discussed in detail in Chapter 4. Information required for forecasting crude oil price and availability is available on services like Reuters net connection. Full details of crude oil and price are available in the published data. This information is available to subscribers only. On the basis of this information a refinery can decide up on purchase.

In the APM time demand was projected by GoI and was made available to marketing companies like IOC and refineries like KRL in the planning meeting as discussed in chapter 4. In post APM the demand projection can be the same but the market share of each company will not be the same. Marketing rights were restricted to a few companies in the APM time. But in the post APM marketing rights are not restricted. Companies like RIL will appear in the market with great power. So, each marketing company must do separate demand forecasting. Even stand alone refineries (refineries without marketing setup) will have to do their own demand forecast because their marketing companies demand fluctuation will affect the product holding of the company.

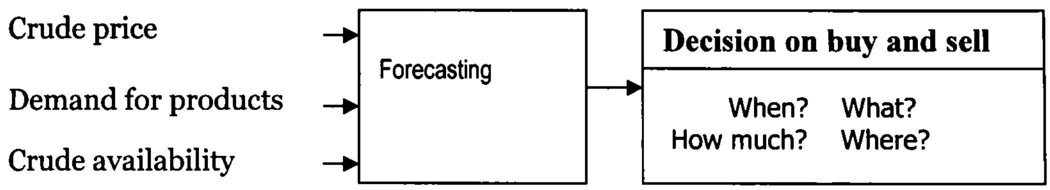


Figure 5.6 Information flow for forecasting

As given in the Figure 5.6 the major inputs are from crude oil markets and product market. Output of forecasting will be decision on when, where, what, and how much crude oil must be and products must be moved in the market.

Planning needs more input than forecasting. Planning based on the inputs from government policy, output of forecasting and availability of facility in the refinery. Planning in a refinery takes place at different stages. Annual planning in APM was national level (OEB). Each refinery target was given for the year depending on the capacity of refinery. Based on OEB suggestions, a monthly plan was drawn in SPM. Each refinery has to make there own production planning for each day. Everyday, a production meeting will be held to analyze the previous day's performance and make plan for the day. Information on condition of facility like distillation units, availability of tanks, maintenance schedule etc. must be available for planning the day's production. The demand for products also must be available for deciding on production. Government policy will be intimated in monthly plan and daily production must be tuned to government policies. Planning decision must directly reach the operations department for scheduling operations. Marketing effort must be there to minimize the value added inventory. This will necessitate transport planning. In short daily planning will trigger and direct the activities of operations department, marketing department, and stock oil department. In post APM scenario the planning will be more difficult because the demand for refined products may vary frequently. The market also need not be same and product quality demand also may change. So computerized integrated information flow may be needed to have better and accurate planning so that the efficiency of the refinery can be improved to compete with other refineries in the near by region.

5.3.2.2 Information flow for operations

Decision is taken in the planning meeting and second stage decision is taken in the department but to implement those decisions, it must be converted to information. Right information must reach the right place to have right course of action. In a refinery the specification of products are coming from laboratory and the operations are controlled accordingly. Product patterns are controlled by process department. Availability of tanks and pipelines are arranged by the stock and oil department. Products movement is controlled by marketing or sales department if the company is controlling marketing. If the refinery is stand-alone type, the product movement is controlled by marketing company. Integration of information is essential to have better combined performance of all departments. Data must be fed to the computer at the source of generation itself and it must be available at all the places where it is needed. For example, specification of sample taken from product line must be made available on computer and blending steps for making the product into required specification also must be available on the computer. So the implementation can be faster and data is generated for final specification. Information about the quality quantity in that tank is available to all concerned departments like sales, stock and oil ,and production.

5.3.2.3 Information flow for control

Controlling is a continuous process of measuring actual results and comparing with plant results and find out deviation to take corrective actions. Major elements of control are **(i)** Chart out standard of performance **(ii)** measuring the present performance **(iii)** comparing the performance with standard performance and **(iv)** taking corrective steps if deviation is noticed.

In refinery the performance is normally, measured in capacity utilization. In APM period government used to give incentive for production of more than 100 % of installed capacity. Every month the performance can be planned to match with annual planning or even weekly planning can be done. Weekly and monthly performance can be measured by calculating cumulative daily performance. At the end of every month the crude oil refined in MMT can be calculated. These values can be easily compared with the planned refining per month and if it is less than the planned, corrective action can be taken to compensate the lost production.

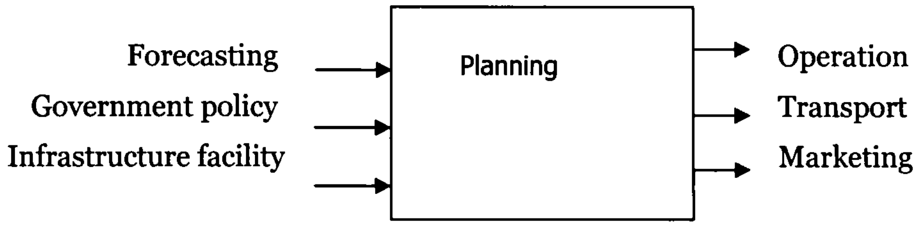


Figure 5.7 Information flow for planning

The controlling can be done well with a structured information flow. Daily production Figures must be entered in to the computer from the process department itself. This data can be used for remedial steps by OEC when they plan for the next month. Essential qualities of a control system are flexibility, prompt reporting, understandability, and economic feasibility. Control system must be flexible to have same performance level when plan changes. The reports must be available to the central information bank so that all concerned departments can retrieve the data fort checking with plan and suggestions for correction if deviation is there.

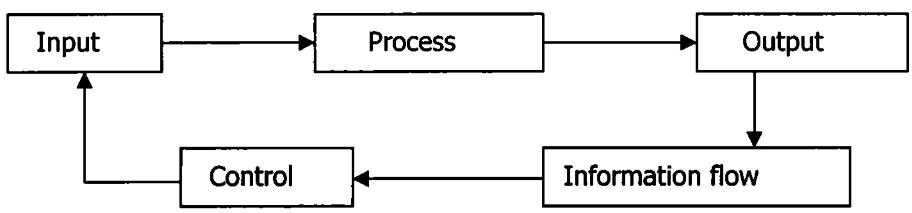


Figure 5.8 Control system

Figure 5.8 shows a flow diagram of information flow for control. A well designed control system will help for better performance in a refinery because small changes will affect he quality of out put of the product. Small changes in the distillation unit parameters will change the yield pattern and will affect the profit of the refinery. Controlling all the departments in tune with the strategic plan of the refinery need good quality information flow system.

5.3.3 Accounting Information System (AIS) for the Supply Chain

Important decisions in the AIS are (1) How to organize the accounting records in an organization to retrieve the data at appropriate place (2) How to design set proceedings to meet management and Government requirements (3) Value change management, gives stages of value addition taking place to the products while transforming from the raw material to finished product. Finding out correct answer to these questions is the prime objective of AIS. Dividing in to sub systems is essential for getting better solution to the problem.

5.3.3.1 Basic subsystems

- Expenditure cycle: involves activities of buying and paying for goods or services, payment by organization
- Production cycle: involves activities of converting raw material and labour in to finished goods.
- Human resource or payroll cycle: include activities of hiring and paying employees.
- Revenue cycle: involves activities of selling goods or services and collecting payment.
- Financing cycle: involves activities for obtaining necessary funds for running the organization; repay creditors and distribute profit to investors.

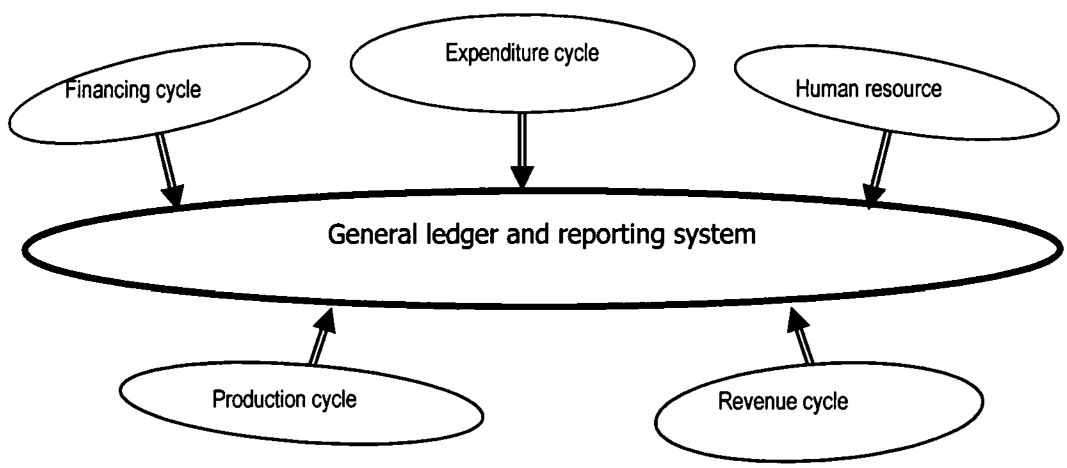


Figure 5.9 Ledger reporting system

Management of cash flow is very critical in profit making because the amount involved is very high. Logistics normally does not include the fund management in its prime activity. In supply chain management cash flow is also given equal importance for performance improvement. To improve the speed of movement of material, the payment of cash also must efficient. In Indian contest payment system has a lot of weaknesses. Even the banking system is not operating in the international standard, especially check dealings. So special case and attention is needed in the area of cash flow. Business objectives of good cash flow system are

- Efficient accounting system to support business processes
- Provide input for effective control of cost.
- Effective use of funds available.

Main functional requirement of a good information flow system is discussed in the next section.

5.3.3.1 General ledger accounting

It must provide a comprehensive picture of external accounting and accounts. It must automatically post all sub-ledger items in the appropriate general ledger accounts (reconciliation accounts) It must facilitate simultaneously updating of general ledger and cost accounting information (figure 5.9). It must also support real – time evaluation of reports on current accounting data, in the form of account displays financial statements with different balance sheet versions and additional analysis. The cash flow system must support integration with different taxes. Major stakes are sales taxes, excise duty, provident fund of employees, customs charges for import of crude oil and port charges for using the facilities at port.

5.3.3.2 Accounts payable

Accounts payable must record and administer accounting data from supplier. It must be integrated with purchasing. Purchasing not only includes crude oil and shipping but also chemical, spare parts maintenance and other utilities. All the deliveries and invoices must recorded based on each supplier. These data must give input for cash management and must support various kind of other payments like freight. Present procedure for data entries and checking are given in Figure 5.10.

Data are drawn from three different departments for matching. Goods receipt data is taken from the stores warehouse department, purchase order data is taken from materials department and invoice data is taken from accounts department. Based on the quantity accepted from warehouse and other factors from purchase order data the cash to be paid is worked out. This amount is matched with the bill amount in invoice. Three-way bill matching not required in an efficient cash flow system. Two ways – bill matching is enough for a computerized system. Efficiency of the system will improve by two way bill matching. Figure 5.10 shows it.

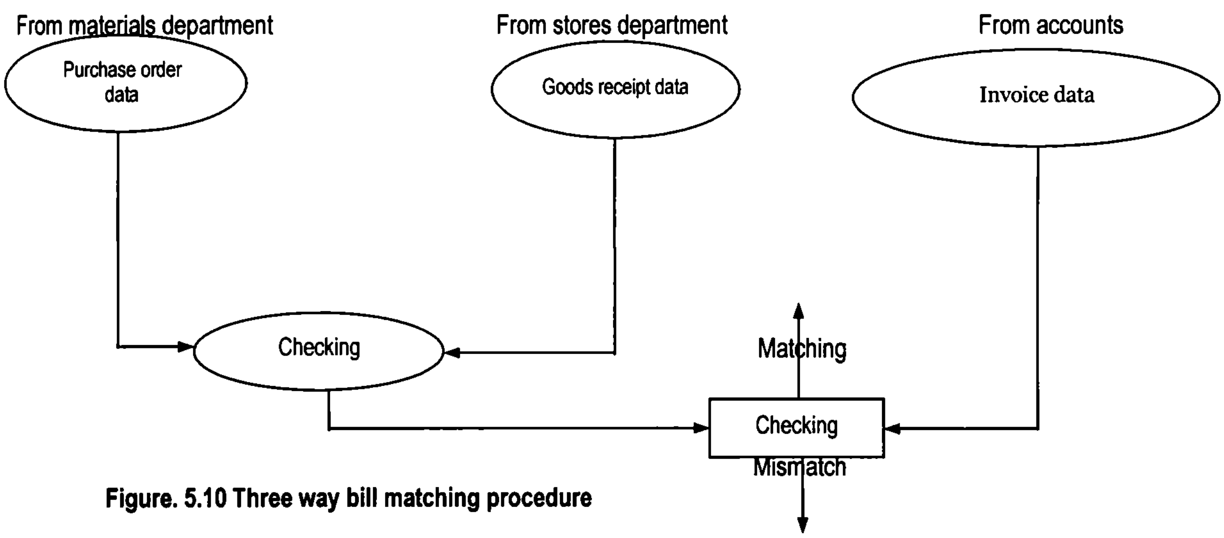


Figure. 5.10 Three way bill matching procedure

Two way bill matching works on the basic assumption of having high level of accuracy in warehouse data and purchase order data (figure 5.11). It avoids the non-value adding activity of invoice registration. The bills can be passed on the basis of inputs from purchase order and goods receipt

5.3.3.3 Accounts receivable

Accounts receivable must record and administer accounting data of all customers. It must be integrated with sales. All in account receivables must be recorded directly in the general ledger (GL). It must provide input directly for credit management. It must support alarm reports on defaulters of payment and due date list etc.

5.3.3.4 Costing

Overhead cost controlling enables to plan, control allocates, and monitor overhead costs. Planning in the overhead supports specify standards, which enables to control costs and evaluate internal activities. All overhead costs must be assigned to the cost centers where they are incurred. At the end of a posting period, when all allocations have been made, the plan costs must be compared with the corresponding actual costs on the basis of the operating rate. Analysis of the resulting target/actual variance can be used for further managerial accounting measures within controlling.

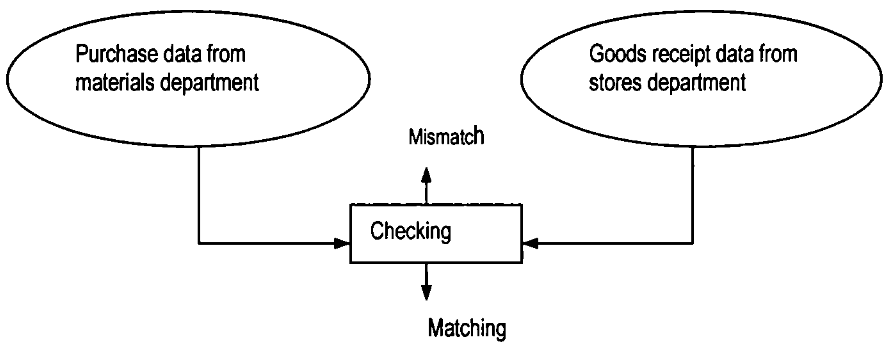


Figure 5.11 Two-way bill matching

Cost center accounting must be used to determine where costs incur in the organization. To achieve this, costs must be assigned to such organizational areas where the costs incur. The recording and assignment of costs not only enables to carry out cost controlling but also provides vital preparation for the subsequent areas of cost accounting.

5.3.3.5 Treasury

Treasury must support cash management, cash budget management and treasury management. Cash management must support:

- Maintaining optimum amount of liquidity to meet required payments as they become due.

- Monitoring cash inflows and outflows

It must support various types of inputs and cheques. This also must facilitate information on status of the cash and liquidity forecast. Cash management must take care of short term cash management where medium and long term liquidity management must be supported by cash budget management.

Treasury management must support

- Management of financial transactions and positions.
- To provide flexibility in reporting of financial transactions & positions.

All the transactions must be closely monitored for the efficient performance of a supply chain management.

5.4 Supply Chain Management Efficiency Improvement Using Information Technology

Information technology adds quality and speed to the decision making and it is true in the case of supply chain management also.

5.4.1 Introduction

Logistics and supply chain management (SCM) has been influenced by developments in information technology (IT) and computer systems. The allocation decision of products to various outlets can be carried out centrally. Capture of relevant data, their transmission to the central decision-maker and the ability to manipulate them and communicate the decisions to all different departments, in time for the decision to be effective, is now possible. It is now realistically possible to plan with shorter planning horizons. Refineries can plan their operation on daily basis using it (figure 5.12). The two major reasons for the use of IT in SCM are the spatial spread of production and service activities and the time element in planning, both of which require data intensive decision making. To make such decision making possible, there has to be efficient, reliable and timely data capture, data availability at various locations, and the ease with which it can be manipulated for the purpose decision-making.

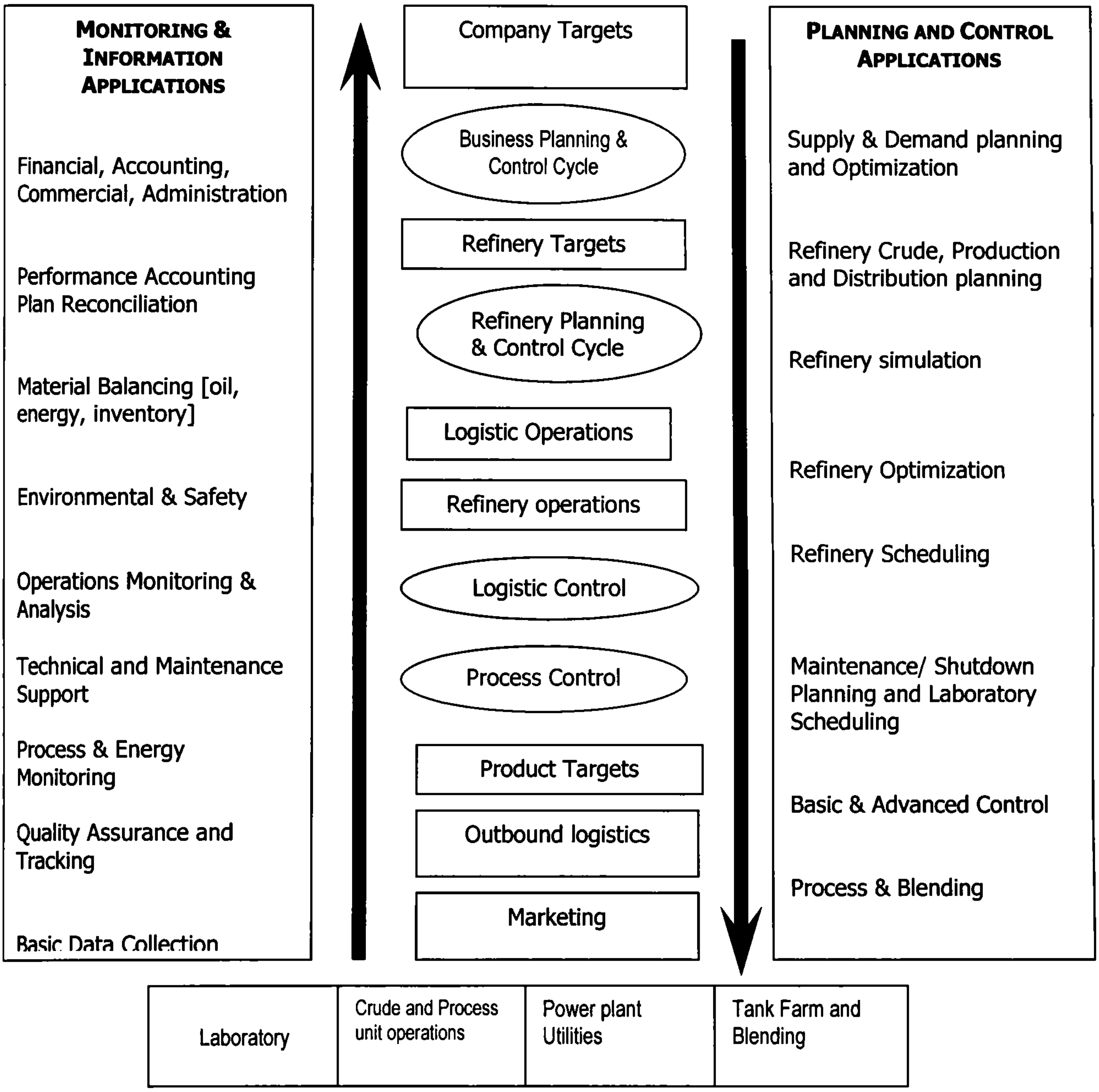


Figure 5.12 Priority of Applications

A further advantage of a computerized system is that reports and statistics, which allow the monitoring of supply chain performance, can be generated. Supply chain performance can be measured through an integrated information system. The IT segmentation speed of information ERP, software, e-supply chain and application of IT in a refinery are discussed in this section.

5.4.2 Segmentation of Information Technology

Information technology can be segmented in three dimensions. They are scope of application, functionality and stage of technological development. Each of these would further have the hardware and software aspects of technology.

5.4.2.1 Scope of Application

Based on the managerial scope of application, IT applications can be classified as Transaction Processing System (TPS), Management Information System (MIS), and Decision Support System (DSS)

- A TPS deals with individual transaction and interactions between different entities in a managerial system and is governed by simple logical rules of operations. The main role of a TPS is to ensure reliable information exchange and reduce the time of response, as compared to a manual system for the same purpose. For example the products moved from refinery by pipeline, ship, rail or road on a particular day could be traced easily in a computerized system whereas in manual system records must be examined. Data must be generated at the point of delivery for better and faster information at any time.

- A MIS goes one level further and provides information in various ways to managers at different levels. For example demand for each product in a particular month or area wise sales Figures of products like diesel, petrol, lubricating oil etc.

- A DSS has the provision for decision models in the relevant domains. A DSS will help to take decisions after considering the constraints. Options will be given by the system. For example number of ships for bringing crude oil to a port for a month can be decided with the help of a DSS. This problem has already been discussed in Chapter 4.

5.4.2.2 Functionality

The following major categories can be identified from the point of functionality

Data Capture, Display, and Organization. This is the basic function of collection and monitoring the data and information to do with logistics and SCM. Data Collection includes recording inventory, production, resource availability (eg. Tank availability), etc. using a variety manual and automated technologies. Data display is ideally in graphical form or formats that are close to what managers find convenient, such asTables. Data organization is achieved through a database management system and is briefly discussed in section 5.5.4.

In a refinery all the opening are done at different levels. Figure 5.11 desires the capture and transform and utilization of data. The most import and data generation points are process department, stock and oil, Delivery points and accounts sections. These generated data are used is by many other departments as shown in Figure 5.11.

Communication. An essential feature of SCM is that data is made available across spatially dispersed decision- making units. Communication of data across distances is now possible through a variety of technologies.

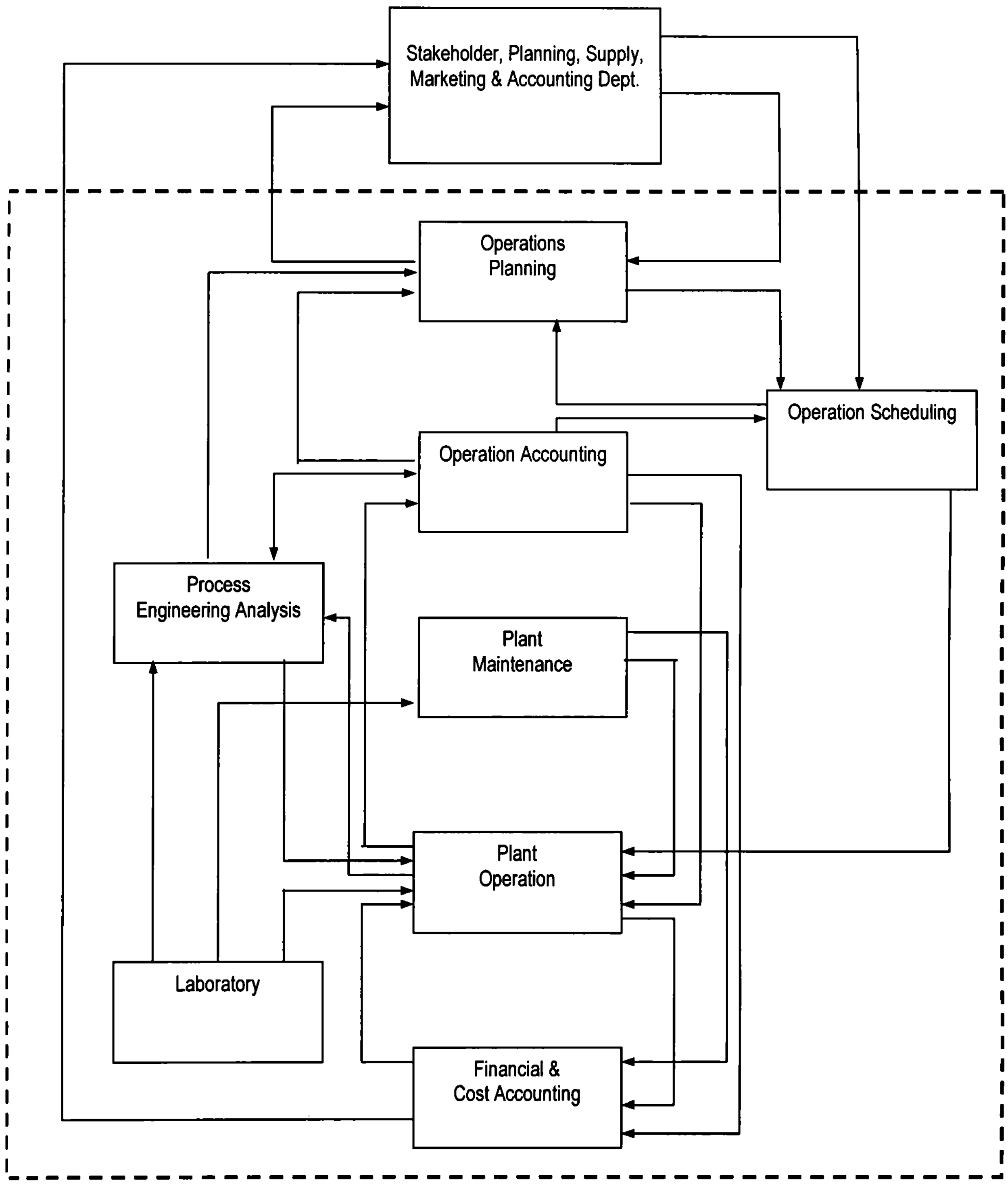


Figure 5.13 IT Functionality of a refinery

Competitive advantage in supply chain management is gained not simply through faster and cheaper communication of data. Ready access to transactional data does not automatically lead to better decision-making.

To effectively apply IT to manage its supply chain a refinery must distinguish between the form and function of transactional IT and Analytical IT. Transactional IT is concerned with acquiring, processing and communicating raw data about the company's past and current supply chain operations, and with the compilation and dissemination of reports summarizing these data, typical examples are general ledger systems, quarterly sales reports, and Enterprise Resource Planning (ERP) systems.

Processing. Analytical IT evaluates supply chain decisions based on models developed from supply chain decision databases, which are largely, but wholly derived from the company's transactional database, plus modeling systems and communication networks linking corporate databases to the decision databases. It is concerned with analyzing decisions short, medium, and long-term. Typical example is modeling for selection of crude oil form the world market or beating a new distribution center.

5.4.3 E-supply chain

The need for speed IT professionals place a high premium on speed when changing the value of Supply Chain Management solutions. How important is quicker access to supplies and buyers as a feature of web-based Supply Chain Management. 31% claims speed is extremely important. 26% says moderately important. 24% comments that speed is neither important nor not important. 11% of professionals feel speed is slightly important and 8% feels it is not at all important. To have the desired speed of information E-supply chain will help. Providing the right amount of relevant information to those who need to know it, when they need to know it is, in fact, effective SCM from information point of view. The e-supply chain will have customers and suppliers seamlessly linked together, throughout the world, exchanging information almost instantly. The velocity of relevant information flow will be so fast that responding to the inevitable changes in expected vs. actual customer demand–driven (pull type) production and supporting processes that provide for faster changes in the actual material flow to match demand.

Fast access to relevant supply chain information can pay off handsomely in lowering costs, less inventory, higher quality decision-making and better customer services. One of the biggest cost savings is in the overhead activity associated with lots of paperwork and its inherent redundancies. The non-value added time of manual transaction processing could instead be focused on higher revenue creation activities without proportional increase in expenses. The result in lower inventories, better decision-making quality, reduced overhead costs, among other benefits makes e-supply chain Management a highly desirable strategy.

5.4.3.1 Developing an e-supply strategy

E-supply chain Management significantly changes the way in which business does business. As a result, management needs to change and serve markets. Methods used so far are not sufficient, especially companies seeking to increase market share. As more and more companies evolve new supply chain models, management is compelled to take the right actions or risk being left behind.

Just applying more software at the problem is not the right answer to the core issues of SCM. Although software is needed, it is very necessary to define the process of information flow that will activate material flow at the right time. Lessons learned by early adopters of new technologies is that overzealous adoption of those technologies without a carefully planned strategy can prove very costly, especially when the strategy is missed or not defined in the first place.

5.4.4 Technology Development Stages

IT developments in companies have evolved overtime through the following stages. These reflect an increasing trend towards meeting the goal of supply chain management, despite several practical difficulties in implementing the changes smoothly.

- Sub optimization: This is optimizing the operations of each department. Typical example is selecting the purchase of crude considering all constraints using a mathematical model. Selection will be the best but it will not be considering the market demand predictions. So the selected crude oil need not give products, which are high in demand. This is commonly used in refineries.
- Organization level and inter organization-integrated systems.

This is the planning in organization level. The systems developed are Electronic data Interchange (EDI) manufacturing recourse Planning (MRP), distribution Recourse Planning (DRP) and ERP

- Integrated Systems.

Total integration of the organization is the feature. Customer to supplier is integrated through networking. Computational speed will be matching to operational decision – Making requirements.

5.4.5 Hardware Networking

The Hardware aspect of IT systems are described below. The main hardware systems which supports IT are Internet, Extranet, Intranet, and VSAT

Intranet: This is used to communicate within industry. Access to data collected is not open to all within industry also. It can be made available through networking of computers in each department. Authenticity of data is very high and sharing of information is good, decision-making becomes very fast. The main Advantage of intranet is less documentation and its storage. Paperless offices can be made using intranet. Privacy of data is very well maintained.

- **Extranet:** Connection between different offices in different locations can be attained through extranet. Privacy of data is maintained. Access is limited to permitted users.

Depots can be connected using and the product movement will be monitored.

- **Internet:** Information can be passed to anybody at any place in the world. Main disadvantage is privacy. Privacy is very limited in Internet but the reach is very good. Information, which does not require mush privacy can be, used the mode of communication. Sales Figures or balance sheet of the company can be communicated through Internet.
- **VSAT:** This is online communication. All the data generated will be communicated to the host system. Selling fuel at an outlet can be communicated to the refinery at the time of dispensing itself. It captures data at the source and transmitted through a satellite transmitter. The receiver at refinery will receive the communication instantaneously. At any point of time the total sale of any product like petrol can be seen directly. Production planning and products movement can be controlled in a better way.

5.4.6 Integrated systems.

The full force of supply chain thinking enabled by developments in IT emerges in the area of integrated systems. These are hardware and software elements. They permit analysis and decision- making across functions and narrowly defined entities. Some of the important developments in these are discussed below.

5.4.6.1 Geographical information Systems (GIS)

A technology that is suitable for use for management of logistics and SCM in spatially widespread operations is GIS. The technology captures the spatial characteristics of data and is typically map based. Data can be conveniently represented as attributes with pointers to specific geographical areas through an appropriate database. *Both location wise and area wise representation of data is possible. For logistics & SCM applications, the spatial information of the database is obtained by digitizing maps. This visual interface provided by such software is* very powerful and allows a good level of interface decision-making by the user directly. It also permits the use of decision models built upon the basic GIS. This enables decisions like market segmentation, location decisions, allocation decisions and routing decisions.

5.4.6.2 Electronic Data Interchange (EDI)

The spatial aspect of managing distribution and procurement systems can now be managed using EDI. This is a system highly structured message communication with tight pre decided formats of documents, which allows computers in different locations to communicate effectively with speed and reliability. There is a service provider through whom this transfer of data takes place, who provides translators between different formats and handles the EDI traffic between various sources and destinations. The uses of EDI requires adherence to certain standards. In addition to the hardware and software that a firm may have, EDI requires specific software that allows conversion from any application to an application free format.

5.4.6.3 MRP –II and DPR

High level of planning which includes capacity planning, some feedback in the planning based on individual process constraints and providing provision for some uncertainties, both internal and external is made possible under the framework of manufacturing resources planning (MRP-II)

On similar lines, Distribution Resources Planning(DRP) software attempts to synchronize the dispatch of multiple products to multiple locations based on orders placed.

5.4.6.4 Enterprise Resource Planning (ERP)

ERP systems are operational IT systems that gather information from across all of a company's functions, resulting in the entire enterprise having a broader scope. ERP systems monitor material, order schedules, finished products and other information through out the organization, ERP systems help to make better supply chain decisions.

ERP systems are good at monitoring transactions out generally lack the analytical capability to determine what transactions ought to happen. They reside more in the operational area in the IT map than in the planning or strategic areas. ERP system track orders through the entire company from procurement to delivery. Today's trend of using a product based instead of a function – based organizational structure has also helped make ERP systems more alternative because this structure increases the importance of the cross- functional scope that ERP systems provide.

ERP systems not only allow a company to track items through out the system, they also allow a company to automate processes. By automating processes, companies are often able to increase efficiency and reduce errors. It is also important that automating poor processes only guarantee that they will be executed poorly each time. So companies would review their processes before implementing ERP systems.

5.4.6.5 Supply Chain Management (SCM)

SCM systems are a combination of many of the preceding applications and are used to span the stages in the supply chain. SCM systems allow for a more global scope because they can span many supply chain stages with their different modules. SCM systems have the analytical capabilities to produce planning solutions and strategic level decisions. They do not usually span all of the supply chain stages, they rely on ERP systems to provide the information necessary to perform the analysis. SCM systems currently provide the highest level of functionality with respect to the vertical axis of the IT map.

Two features of SCM products are noteworthy. First the back end includes a number of analytical techniques based on the principles of optimization. The front end of SCM products provide more interfaces for model formulation and validation by users.

5.4.7 SCM Software

SCM software is described as "Effective supply chain management enables you to make informed decisions along the entire supply chain from acquiring raw materials to manufacturing products to distributing finished goods to the customer". ERP systems provide a great deal of planning capabilities the various materials, capacity and demand constraints are all considered separately in relative isolation of each other. The more leading edge SCM products are able to consider all the relevant information simultaneously and to perform real time simulations of adjustments within the constraints. Real time information through out the entire supply chain is needed to make correct decisions and SCM products are designed to gather that real time information. Traditional ERP systems generally do not gather real time information from everywhere in the supply chain on the contrary they often contain static, dated information only related to subsections of the supply chain.

Most SCM products are being designed with the Internet in mind, including web front ends for suppliers and customers, and transactions being sent over the Internet instead of via the more expensive and complicated EDI. This section will examine two of the leading SCM software vendors and four of the leading ERP vendors and their SCM products.

- **Manugistics**

They developed the very first SCM software in 1980. They have steadily been adding new functionality to their SCM products and now have one of the fullest product lines in the SCM market. Manugistics offers products in Demand Planning, Supply Planning, Manufacturing scheduling, Transportation management, supply chain navigator, NETWORKS.

The first four are SCM products, Supply Chain Navigator is a graphical SCM modeling tool that allows the user to simulate supply chain changes, including cost analysis and to view the current status of all elements in the supply chain. Networks are an Internet based supply chain collaboration frameworks.

- **i2**

i2 is formed to implement software from mathematical methods of supply chain optimisation. i2 has a product line similar to management. It includes: Demand planning, Distribution planning, Manufacturing planning, Transportation planning, Advanced scheduling, Order promising and data Integration

- **Baan**

Company started in 1978 in Netherland. The first version of Bann's next genaration. MRP software was released in 1987. In 1998, Baan created a separate business named baan supply chain solution (Baan SCS) to develop, implement and support their new suite of supply chain products. Their SCM products are tightly integrated with Baan ERP. Products include Baan SCS planner, Baan SCS Demand planner, Baan SCS Scheduler, Baan SCS execution.

- **SAP**

SAP was founded in Germany in 1972 by four former IBM employees. Unlike many of its competitors, SAP has adopted a build your own philosophy when adding functionality to its ERP product suite. This is true for its ERP product suite. This is true for its SCM products also. Product line include supply chain cockpit, Available to promise (ATP), Advanced planning & scheduling (APS) and forecasting.

- **People Soft**

People soft was founded in 1987, released their first Human Resource Management System (HRMS) software package in 1988. They started offering a manufacturing module in 1996. The SCM product line includes Enterprise planning, product planning and order promising.

- **Oracle**

Oracle corporation was formed in 1977. The SCM product line includes Materials management, Sales order management, Post sales customer service and Quality management.

The most important new feature of the new wave of SCM products must be the ability to give the end customer a " time to deliver" in real time. This is only possible to do accurately with a comprehensive SCM solutions being used through out an organization and its suppliers and customers. This ability will be the result of all the separate pieces of information being available, such as current manufacturing capacity, parts availability, inventory levels at all locations, distribution capabilities and current and forecast product demand. This ability has been described by many experienced manufacturing manager as truly revolutionary, processing a strong SCM system is quickly becoming a requirement for competitive success in an increasing number of industries.

5.5 Application of SCM Software in a Refinery

Real time information throughout the entire supply chain is need to make correct decisions and SCM products must be designed to gather that real time information. The procedure required by a refinery to develop an efficient SCM system is discussed in this section.

5.5.1 Factors influencing design of logistic information system

Logistic information system being very complex the design must consider a lot of parameters. Organization culture also influences the system because the changes must be acceptable to the organization.

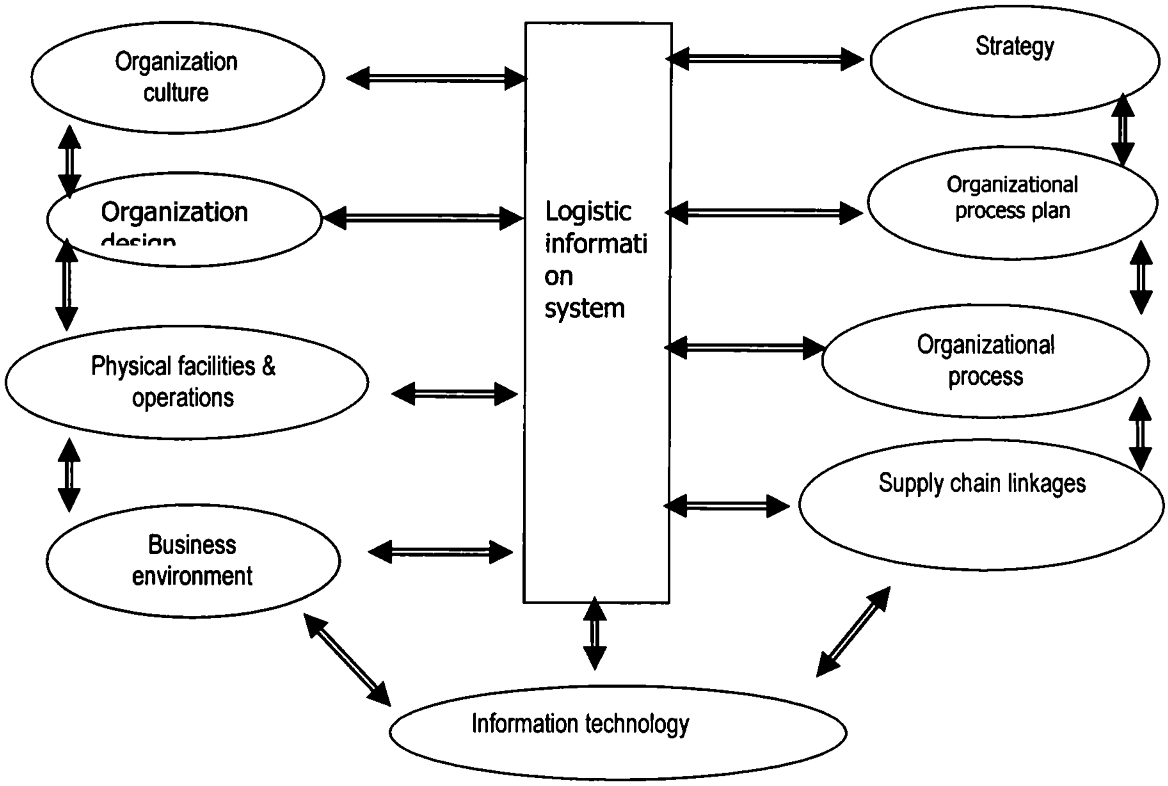


Figure 5.14 Factors influencing design of logistics information system

Figure 5.14 represent diagrammatically the relationship with each other factor with the information system.

5.5.2 Proposed Design of SCM information System for a Refinery

Total information flow can be divided in small modules for detailed analysis. Then these modules can be integrated to get the fully integrated model of information system.

5.5.2.1 Annual planning module

Annual planning module gives information on maintenance schedule, quantity of crude oil which is selected for purchase, and the expected net back from the processing of total crude oil. Crude price used for calculation is the landed price at refinery. Constraints like availabilty, distance,et. are used for the selection of crude oil.

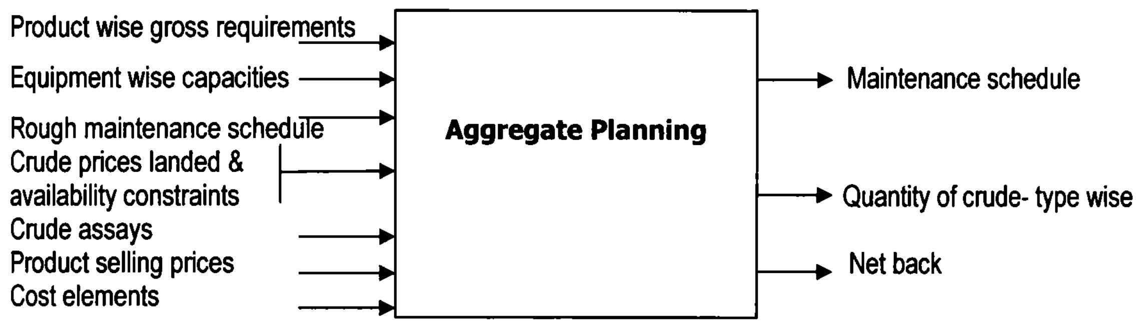


Figure 5.15 Aggregate Planning

5.5.2.2 Crude procurement module

Procurement of crude oil made on the basis of net back available from each crude, days available for production, production capacity, etc. Important decisions to be taken in this module are ship scheduling, determination of number of ships to be arranged for bringing the determined crude quantity. Failure in module will lead to payment of demurrage and shipping costs.

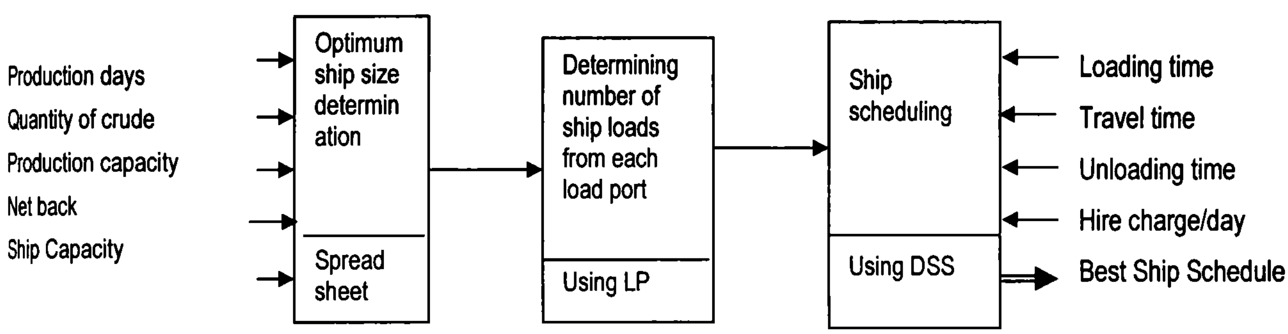


Figure 5.16 Ship scheduling procedure

5.5.2.3 Ship management module

Ship selected in the previous module must bring to the port in sequence, which is most favorable for the refinery in terms of production. Right sequence will avoid starving and blocking of crude oil.

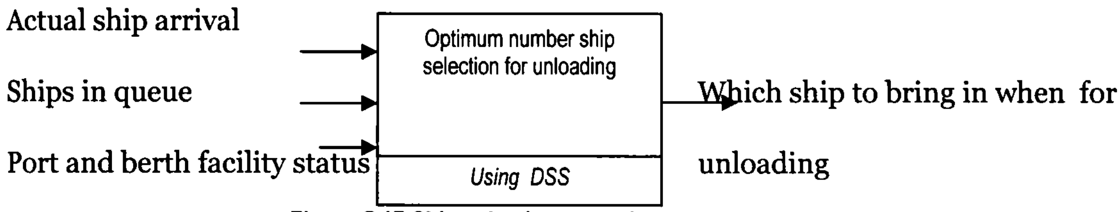
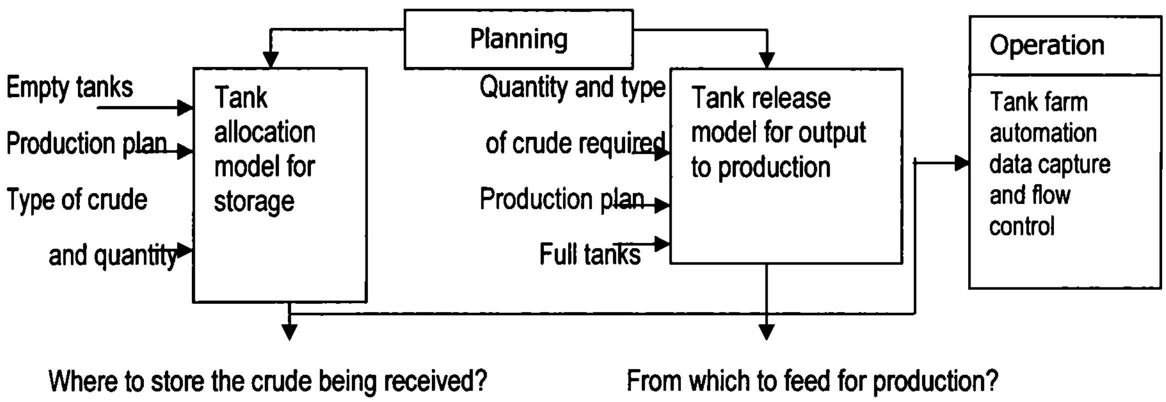


Figure 5.17 Ship selection procedure

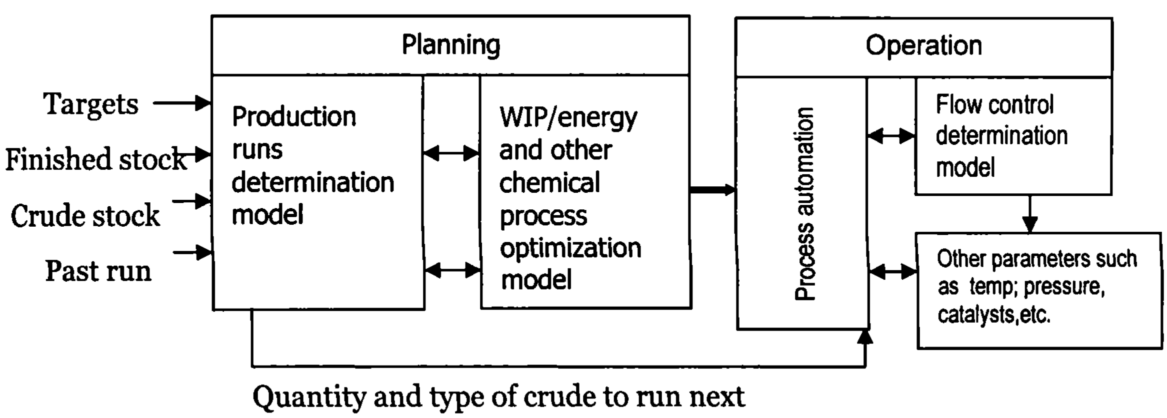
5.5.2.4 Crude tank yard planning module

Crude receiving tank yard planing and organizing is important because the number tanks available for storage is limited. Capacity increase is very expensive and time consuming.



5.5.2.5 Process Planning and Operation Module

Distillation process is automated but the planning must be done on the base of product targets to be met to meet the market demand.



Quantity and type of crude to be processed next is the output of the module. The operations to be performed for getting the desired results also can be achieved from the module.

5.5.2.6 Finished products tank yard plan and operation module

Product distribution is controlled by the decisions from this module. Type of transport, quantity, quality, etc. are decided in this module. Transaction Processing System (TPS) will compute the details of transaction.

Information flow must start from the retail outlet. Present practice in almost all refineries in India is on the basis of projected data by Govt. of India. Since the production was not enough to meet the demand and competition was not there, refineries could manage very well. Due to decontrol of petroleum industry anybody can import and sell in the market. So the information generation must be accurate as much as possible to minimize the inventory holding and maximizing flexibility of products. Figure 5.12 shows the overhaul information flow in a refinery.

In the years to come, all the outlets will not be demanding diesel with same centane number. Requirement for products will change from location to location. For example in Kerala demand for diesel with low flash point will be higher in the cities. This will reduce fire hazard at the event of accident. Demand for diesel with high flash point will be preferred in the high ranges of Kerala. Temperature on the hill top will be low so the starting will be difficult for vehicles with diesel of low cetane number. This indicates the necessity for an accurate projection of demand on the basis of the product demand in the outlets. Earlier this was almost impossible to get the real demand at retail outlet. Consumption at retail outlet can be now collected on daily basis or even hourly basis if a company desires so. Billing must be done using computers. So the sales data is generated in the computer. By an internet connection these data can be communicated to the company. All the outlets can communicate their sales through internet and the company will get exact demand for each product on desired time interval. This generated data must be compared with the projected data and the demand in the same time of previous year to make necessary corrections and reach the best and accurate demand projection. This projection must be the basis for all planning in a refinery. This will reduce the inventory holding and improve product movements.

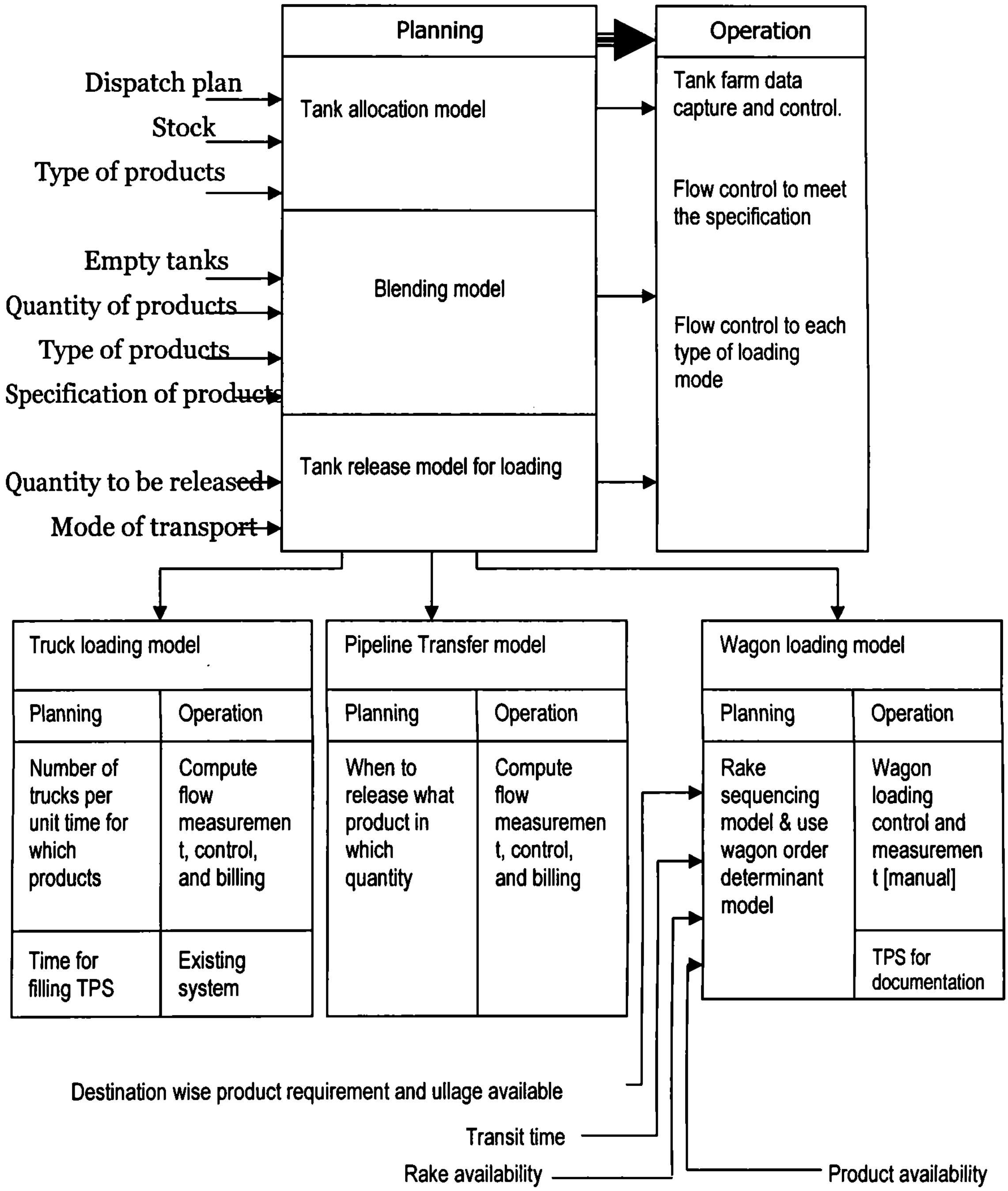


Figure 5.18 Planning and Operation Models

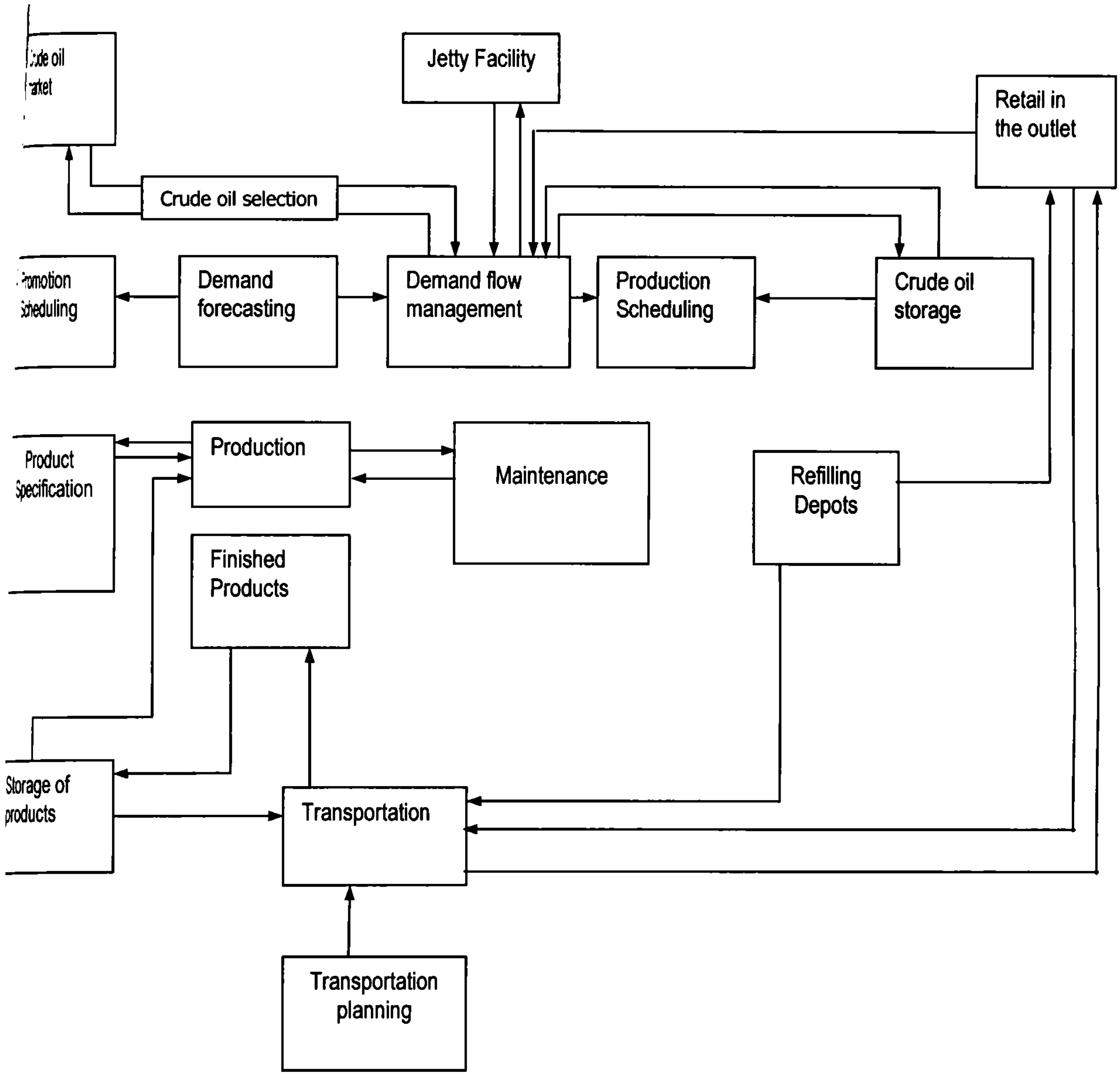


Figure 5.19 Information flow model for a refinery

Second data generation point is distillation column. A large number of products are made in the crude distillation unit and subsequent process. These products are fed to different tanks. Many industries are taking the manual or calculated measurement for records. These data need not be very accurate due to error in measurement and calculations. Real data generation is taking place when it is passing to the tank. So the measurement of quantity must be done from the pipeline itself using flow-measuring devices. This data will be the correct information, which is to be used for calculation of all products. Third data generation point is sales. Sold products are moving through pipeline, ship, railway wagons and trucks. Almost all refineries in India is having automatic filling stations. From filling stations consolidated statements are being send to the accounts department either on soft copy or hardcopy. In both the cases some re-entry is required in the computer. This leads delay, errors and unnecessary labour. Quantity difference is a common complaint and normally this difference will be adjusted in fuel and oil losses. In the case of railway wagon filling, the quantity is checked only using dipsticks. It cannot be cross-checked. By using a flow-measuring device in the main pipeline the sum of all the measurements can be checked. In all the outlets there must be automatic flow measuring devices and the readings must automatically go to the computer. These computers can be connected through network if filling stations are within a reasonable distance. Internet can be utilized if the distance is more. This data must be used for all purposes of accounting and production. For example sales tax calculation can be done in the accounts department with this data. All departments can know what is the present product stock in the company. Normal practice is stock and oil department will prepare a report and submit to all concerned departments on the basis of measurement from each tank.

Another important activity is the receipt of crude oil. This data is also generated by measuring from the storage tank. This can be measured by automatic measuring devices in filling line and delivery line. This filling line will give the quantity pumped from ship to refinery and delivery line will give the quantity of crude oil used for production. Difference between these two will be the actual storage. These type of actual data will help in real time optimization. Other data generation points are also there in a refinery. They are less in volume but critically may be the same for many of the data generated like maintenance. Maintenance department is generating the data related to maintenance of any equipment. This data can be used for planning the availability of each equipment. The availability is taken from the history of each equipment. Shut down maintenance is another data useful for planning and scheduling. This give details on equipment history, product produced by it, price of equipment, maintenance work carried out so far, and work orders. A number of equipment, which are down and its work order also will be initiated by the maintenance department. Inventory of chemicals and catalysts is another important information, which is to be trucked well to minimize inventory. Production details must be made available to the vendors through extranet. Extranet takes case of privacy of data. This data can be utilized by the vendor to calculate consumption of chemicals and catalysts. Inventory position also must be made available on the net. So the vendor can plan his transportation of these items to the company as when required. This will reduce the inventory holding. Responsibility of chemicals and catalysts inventory can be transferred to the vendors. Paper work and monitory of these items can be minimized.

Spares requirement is also generated at the planning stage of maintenance. It must give information on spares inventory, category wise inventory and short supply of critical spares. Plant monitoring is also requiring database to conduct inspection and classification of tanks. A refinery requires information on air pollution, ambient air quality, Effluent water quality, power demand in each bus steam venting, condense draining, statutory compliance reports on safety, accident free man hours, health level of employees against standards and govt. policies and regulations.

Table 5.1 Details of data generated at each department along with their main process.

Process	Department	Data Generation
Primary Processes		
Budget Planning	OEC	Crude cost
		Products Price
		Crude Throughout (OEB Target vs Actual)
		Production Today/MTD (OEB Target vs Actual)
		Production Today/MTD/YTD
Co-ordination with OCC	OEC	OCC directives
Crude slate meeting	OEC	Expected crude receipt as per OEB Plan
		Expected crude receipt as per crude slate plan
		Actual receipt dates and quantities

Process	Department	Data Generation
	S&OM	Ship wise Ocean loss
		Ship wise Ocean loss above norms
		Ship wise demurrage loss
Supply planning	OEC	Production Today /MTD (SPM Target Vs Actual)
	S&OM	
Manage sales		
Manage Institutional Sales	S&OM	Products movement today/ MTD (SPM Vs. Actual)
		Products movement – trucks and wagons
		Products movement – pipe line and tankers
	F&A (sales)	
Manage Direct Sales	Marketing	Discount to customers
		Outstanding payments
	S&OM	Products movement today/ MTD (SPM Vs. Actual)
	F&A (sales)	
Operate Plant		
Manage production	Manufacturing	Unit wise daily Net Back
		LPG Production
		Production units charge
		VGO yield (Today / MTD) (Potential Vs. Actual)
		CLO yield
		Benzene yield
		Toluene yield
		Naphtha consumption for DHDS
		Hydrogen Production for DHDS
		Fuel Consumption – DHDS
		HSD/ LSD Stock - DHDS
Manage Quality	Lab	Quality giveaway
		Off specs product tanks daily as of
Manage Inventory and movement	S & OM	Crude Inventory – No. of days and 7 days plan Horizon
		Pending payment for crude received
		Payment made and crude not received
		Crude Inventory – not within norm
		Product Inventory
		Intermediate Inventory
		Demurrage Loss
		Inventory Age Analysis
		Days stock of product Inventory

Process	Department	Data Generation
Maintain Plant		
Manage Maintenance	Manage Maintenance	Availability
		Unplanned shut Down loss in Rs.
		Shut down Monitoring (by unit and no. of hours)
		Aging of down equipment
Manage materials	Materials	Inventory of Chemicals and catalysts
		Monitoring of spares inventory against norms
		Category wise inventory
		Short supply of critical spares
Monitor Plant		
Manage process Engineering	Process Engineering	Fuel consumption
		Oil loss
		Daily net back
		Reactor temperature
		Conversion Percentage
		Hydrogen Mol Ratio
		VGO yield
		VR Viscosity
		Preheat Efficiency
		Cooling Tower Efficiency
		Cooling Water Outlet Temperature
		Heater Efficiency Design Vs. Actual
		Vis- breaker conversion
		Catalyst Loss
		Bottom Sediments and water (BS & W)
		Reactor Temperature/ Regenerator Temperature
	Design/ Inspection	
Manage Inspection	Inspection	Boiler certification
		Tank certification
Manage EHS	E&E	Power Consumption
		Water consumption
		Steam consumption
		Air Pollution – Process Heaters and Boilers

Process	Department	Data Generation
		Ambient Air Quality
		Effluent Water Quality at ETP and FE
		Power Demand in each BUS
		Steam venting
		Condensate draining
	Safety	Statutory Compliance Reports
		Accident Free Man hours
	Health	Health Level of Employees against Standards
Improve Plant		
Manage R&D	R&D	
Manage Projects	Projects	Progress %and pending Mile Stones
		Project variance
		Capital Expenditure (Planned/ Non- planned)
		Capital jobs – Monthly Status
		Revenue Projects – Status
		Exception on Projects
Support Processes		
Human Resources	Human Resources	Absenteeism %
		Over time Cost %
		Statutory Reports Compliance
		Over Time Cost
F & A/Cs	F & A/Cs	Net Outstanding
		Interest Cost on working capital
		Profitability
		Cash Flow
		Revenue expenditure – Administrative Heads
IT	C&A	System uptime
Legal & Compliance	Legal	
Governing Processes		
Govt. Policies and Regulation		
MoU	Corporate Planning	Monthly monitoring of MOU
		Refinery Capacity Utilization
		Crude Throughout w.r.t SPM
		Distillate yield w.r.t SPM
	OEC	
Vigilance		
Planning		

5.5.3 High Level Data Model

Based on the source usage and nature of various information integrated, the data model is divided in three high level layers of information to be integrated. The third layer of information will come from process control and monitor layer. Process control instruments are the sources of this layer of information. The information management at this layer aims at attaining and maiming the process stability.

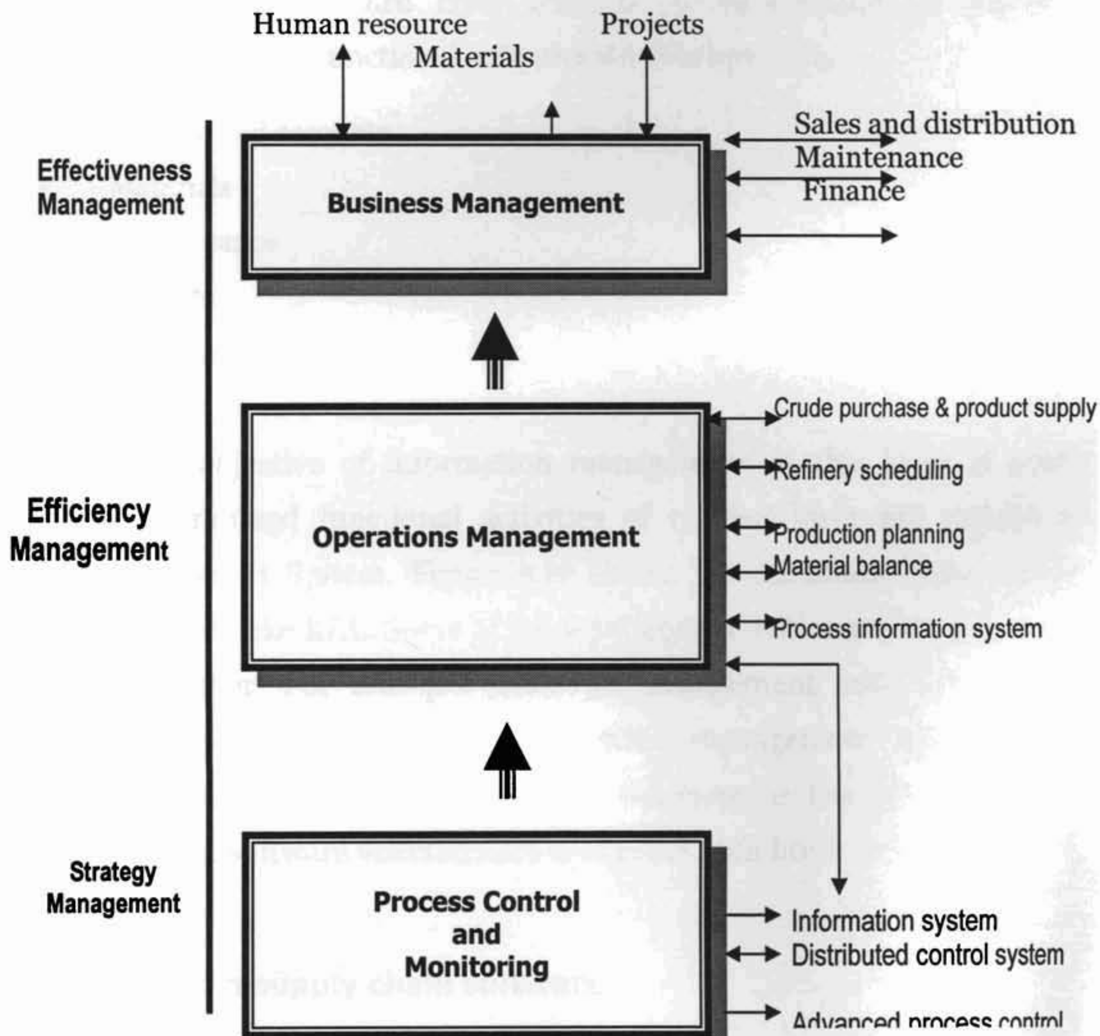


Figure 5.10 High level information model

The second layer of information is related to operations management activities. Functional activities that fall within the scope of this information layer are :

- Laboratory information
- Process information
- Production Planning
- Refinery scheduling
- Material balance

The objective of this layer of information management is to ascertain operation efficiency. The third layer consists of information on business management. Some of the functional activities for this layer are:

- Finance and accounts
- Materials
- Maintenance
- Projects
- Sales and distribution
- Human resource management

The main objective of information management at this layer is profit management. Combined functional activities of current layer are named as Business Management System. Figure 5.12 shows the schematic presentation system for a refinery like KRL. Some of the functional activities are interacting at more than one layer. For example materials management and maintenance activities are performing at both the operation management and business management level. Degree of integration of functions is the success of any information system software selected should support both horizontal and vertical integrate.

5.5.4 Features of a supply chain software

The main features required for supply chain management software are as given below :

- Planning
- Demand management
  - Forecasting

    - Operating monitoring
- Constraint planning.
    - Enterprise
    - Distribution planning
    - In plant
    - Safety Stock buffers
    - Advanced material management
    - Detailed scheduling
- Engineering constraints
- Vendor managed inventory.
- Transportation
- Real time product consumption
- Physical distribution interface
- Service requirements
- Optimizers
- Integration

These are the main requirements of supply chain management software. Integration is the key function in the system. There are many software systems that sub optimizes at different level but the integration part is weak.

5.6 Conclusion

In a supply chain management system there are three key components. They are information flow, material flow, and cash flow. Success of SCM lies in the systematic control of all these flows. Standard methods are there for improving material flow. Better technologies are there for faster information sharing and use. Effective banking systems are there for faster transactions. But better monitoring and control is required to reap the benefits of SCM systems. Planning and control functions performed by logistic managers rely on quick and accurate relevant data. Building an Information System for data capture, storage, and use is the pre requisite of a good modern Supply Chain Management System

The software system must have very good data collection facility from the source of data as much as possible. Single point data entry is the next stage if direct collection is not possible. Software system model must support all the functions in the refinery. The main functions in a refinery are process control and monitoring, operations management, and business management.

This chapter was devoted to discussion on an integrated (modular) information system model for managing supply chain activities in a refinery. The information system model presented focused on logistics planning and control. Such a model is necessary to integrate and implement the different planning models recommended in chapter four.

CHAPTER VI

Strategic and Operational SCM Problems and Some Solutions for a Refinery

6.1 Introduction

Tools such as simulation are used for improving performance of logistics systems in the previous chapters. Application of these tools in a refinery shows its appropriateness in refinery logistics also. For the purpose of study of the logistic system an important part of a refinery, Kochi Refinery Limited (KRL) was selected. Total supply chain was studied from two different perspectives namely strategic planning and operations. The discussion on strategic planning starts with history of KRL and its working environment. Strengths, weaknesses, opportunities and threads of KRL are analysed and difference in outlook needed for competitive advantage in post APM liberalized economy are suggested. Operations in supply chain are classified into conventional inbound, internal, and outbound logistics for the purpose of analysis. These are studied in detail to identify problems and some suggestions for improvement in system performance are also given at each stage.

6.2 Strategic planning for Management of Supply Chain in KRL

The present time is characterized from the following important changes in the petroleum refining sector in India. (a) After years of Government control, decontrol is nearly completely implemented. (b) The sector has been opened for private ventures (c) Crude oil prices are firm now after low prices in 1998 (d) Environmental standards are becoming stricter (e) Refining margins are on the decrease (f) Liberalized trade regimes allow both increased import and export of petroleum products. (g) New acquisitions, takeovers, and disinvestments are taking place in this important sector. The above changes create a need for refiners to reformulate their strategy more now than ever before. Planning at different levels is essential for the success of SCM application in a refinery. A through understanding of existing systems is required for the successful planning. In the sections below a brief history of KRL, its current status, and the present logistics planning practices are discussed. There after SWOT analyses is done and strategies for improvement are outlined.

6.2.1 Introduction to KRL

Kochi Refineries Limited (KRL) was incorporated as a Public Limited Company in September 1963 with technical collaboration and financial participation from Phillips Petroleum Company of USA. The Refinery was commissioned in 1966. Under APM increasing capacities and throughput was the best strategy. From the date of commissioning to-date, the Refinery undertook three expansions in refining capacity and installation of Secondary Processing Facilities. The capacity was first expanded from 2.5 million tons per annum (MMTPA) to 3.3 MMTPA in September 1976. The production of Liquefied Petroleum Gas (LPG) and Aviation Turbine Fuel (ATF) commenced after this expansion. This was done as a strategy to diversify portfolio of products. Capacity was further increased to 4.5 MMTPA in November 1984 along with the addition of 1 MMTPA capacity Fluid Catalytic Cracking Unit. Crude processing capacity was further expanded from 4.5 MMTPA to 7.5 MMTPA in December 1994. Along with this expansion the capacity of the secondary processing facilities was enhanced to 1.4 MMTPA. This formed part of strategy to anticipate and meet strict fuel specifications to control pollution. A Fuel Gas De-sulphurisation Unit was also installed as part of the expansion project, as an environmental protection measure to minimize sulfur dioxide emission from the Refinery. During the year 1989, the Company commissioned Aromatics production facilities with a design capacity of 87,200 tons per annum (TPA) of Benzene and 12,000 TPA of Toluene, marking KRL's entry into petrochemicals. This was the time when petrochemical Industry in the country was expanding and KRL strategy to enter this field was a part of forward integration A Captive Power Plant of 26.3 MW was commissioned in March 1991 to meet the power requirements of KRL and to safeguard the operations against power supply fluctuations in the State grid. During the year 1998, an additional Captive Power

Plant of 17.8 MW capacity was commissioned making KRL self-sufficient in power. The above strategies to become self sufficient in power requirement at the right time and was a very good strategy since power shortage became regular in Kerala soon after this. A Light Ends Feed Preparation Unit (LEFPU) to supply Polybutenes feedstock to Kochi Refineries Balmer Lawrie Ltd. (CRBL), a joint venture company, was commissioned in March 1996. KRL also commissioned a Raffinate Purification Unit (RPU) for the manufacture of 10,000 TPA of Petroleum Hydrocarbon Solvent in January 1994, with the technology developed by the in-house R&D Center. KRL started commercial production of Mineral Turpentine Oil (MTO) in March 1995, utilizing the existing facilities of the Refinery. KRL started production and marketing of Mixed Aromatic Solvent in March 1996.

KRL has demonstrated the capability to implement projects within approved cost and time. During the last decade, KRL had undertaken implementation of the following major projects:

A. Aromatics Project (Aromatics)
B. Captive Power Plant (CPP)
C. Capacity Expansion Project (CEP)

All the above Projects were completed within approved cost and ahead of the targeted completion date. Details of which are given in Table 6.1

Table 6.1 Project implementation in KRL

	Aromatics	CPP	CEP
Approved Project Cost, Rs. Crores	75.80	67.89	481.24
Actual Project Cost, Rs. Crores	70.71	64.63	472.98
Scheduled Completion	February 1989	April 1991	June 1995
Actual Completion	February 1989	March 1991	December 1994

6.2.2 Current scenario for KRL

The deregulation programme of the refining sector commenced in April 1998, and the most visible impact on operations of the refineries due to deregulation has been vastly improved bottom lines. In the Administered Price

Mechanism (APM) regime, the margins of the oil companies were artificially suppressed and the introduction of Market Determined Pricing Mechanism (MDPM) witnessed quantum jump in the profitability of these companies.

The projection of gross refining margins in dollars per barrel made by "Credit Lyonnais Securities Asia (CLSA)" in its report on "Oil & Gas Sector - India Research" dated July 1998 for Indian oil companies is given in Table 6.2.

Table 6.2 Refining Margins

Company	APM	1998-99 MDPM	1999-00 MDPM	2000-01 MDPM	2001-02 MDPM	2002-03 MDPM
IOCL	1.63	2.02	2.94	3.60	4.33	4.63
HPCL	1.61	2.49	3.38	3.97	4.72	4.96
BPCL	1.51	2.59	3.55	4.37	5.02	5.43
KRL	**1.66**	**2.53**	**3.49**	**4.27**	**4.96**	**5.35**
MRL	1.75	2.15	3.04	3.62	4.43	4.64

While all the PSU refineries improve their margins substantially, BPCL and KRL show the biggest improvement due to their superior distillate yield. This projection has proved to be correct to a great extend by results from the industry. Any depreciation in the value of the rupee will result in further improved margins due to import parity pricing for products. The de-licensing of investments in refining has resulted in setting up of private sector refineries and joint venture refineries with PSU participation. Pure refining companies such as KRL, MRL and BRPL will have to ensure firm tie-up for marketing of products to ensure 100% capacity utilization during this period. The petroleum products market in the country promises to be more dynamic and turbulent in the short-to-medium term.

6.2.3 SWOT analysis of KRL

Table 6.5 SWOT analysis of KRL

Strength	Weakness
Capacity	Dependence on IOCL for crude
Capacity utilization	Lack of experience in sourcing and procurement
Crude use flexibility	Low priority to SCM
Trained and motivated work force	Low priority to Logistics
Captive power generation	Limited crude oil unloading facility
High netbacks	Lack of own marketing facility
Nearness of industrial customers	Dependence on public sector oil marketing Cos.
Project management	Demurrages
Opportunity	**Threat**
MDPM and opportunities to increase profit	New Start up refineries
Freedom for alliances and tie ups	Competition among public sectors
Financial freedom	Small size stand alone refineries
Free to expand	Stricter environmental rules
Nearness to international sea trade line and port	No common account for logistics costs
Cost reduction exercises	Location away from major domestic consumer centers
Stable cost for crude oil	Over capacity in short and medium term
Product export	Scarcity of water in Kerala

SWOT analysis of KRL is done in order to understand the present position of KRL with respect to other refineries in the country.

6.2.3.1 Strengths of KRL

KRL is above national average in capacity utilisation. It is an advantage in getting better netbacks and more profit. KRL is consistently utilizing its capacity above 100% for the last five years. So capacity expansion also will give better utilization of resources and can be justified. A variety of crude oil can be processed in crude KRL. Both low sulphur and high sulphur can be processed. This increases the flexibility in selecting the crude oil. This can also lead to better price gain in purchase of crude oil. Work force is highly trained and motivated. The compensation package is also very good when compared to other industries in the state of Kerala. So the level of satisfaction is better. Concern for environment of KRL is also very good. They are promoting environment preservation programmes. KRL has its own captive power generation unit. It eliminates the over- dependence on state electricity board. Netback from refining in KRL is high when compared with similar refineries in India. Nearness to industrial customers like FACT is an advantage for KRL. Large volumes of products like naphtha will be consumed by the large industrial customers. It gives an assured market for value added products. Project management is strength for KRL. All the projects taken up were completed before schedule at less than the estimated cost. So any expansion project can be taken up by KRL for its own benefit.

6.2.3.2 Weaknesses

At present IOCL(IT) is making purchase of crude oil for all the refineries in India. So the freedom for selection of crude oil is limited. Since IOCL is doing the purchases, refineries like KRL could not develop the expertise in sourcing and procurement of crude oil from the international market. Priority for practices like SCM is less because integration is almost impossible. Purchasing of crude oil is done by one company and marketing is done by another company. Logistics performance improvement is not required because the cost of logistics is shared by other refineries also. So the improvements are not attempted. Crude oil unloading facilities is not sufficient to handle big ships at all times of the seasons. This is making the unloading as one of the major bottle necks for KRL. KRL does not do any direct marketing for the controlled products such as LPG, MS, HSD, SKO and ATF, which forms about 70 percent of the total products produced by weight. There are the four Public sector petroleum marketing companies that market controlled products of KRL. Different companies take different shares of the petroleum products produced. The graphs in Figure 6.2 show the product portfolio of each company.

From figure 6.2 it can be seen that Motor Spirit (MS) forms nearly 12 to 18 percent of the total products taken by the marketing companies. For BPC and IBP, MS forms a greater part of their total product marketed. HSD no doubt is the largest sold product for all companies. Its share varies from 62 to 82 percent. All the four companies take SKO, but its share for IOC and HPC is much higher. ATF is given to both IOC and BPC. LPG is not sold through IBP.

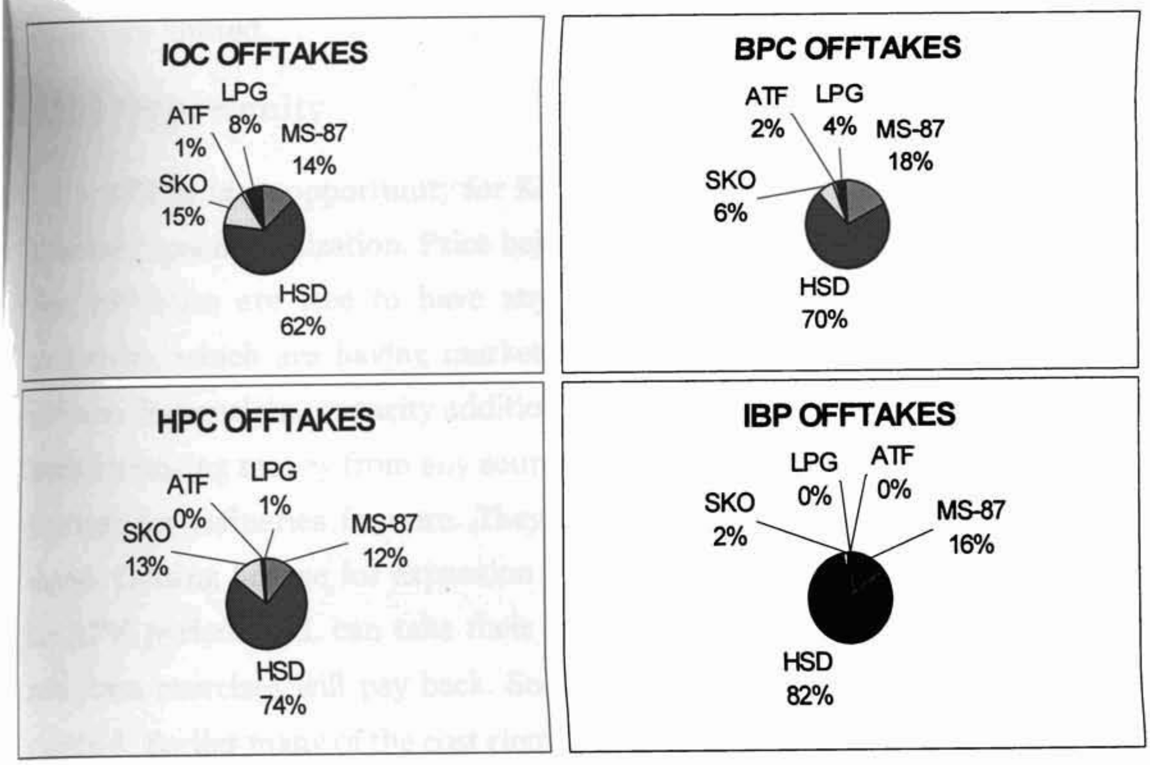


Figure 6.2 Product portfolio of the marketing companies

Figure 6.2 shows the relative share of different products in the marketing portfolio of each company. In order to understand the marketing mix correctly it is also necessary to look at a comparison of quantities of each product handled by different companies, for this graphs in Figure 6.3 is presented.

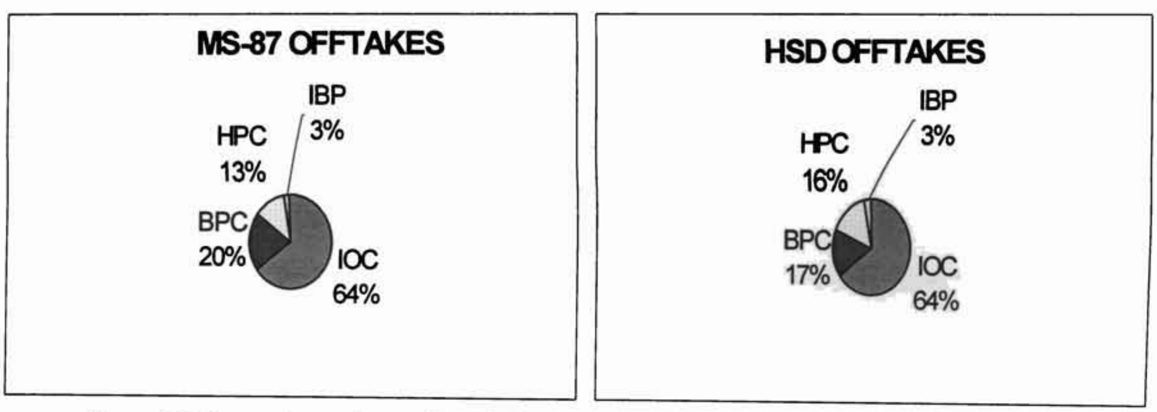


Figure 6.3. Comparison of quantities of different products sold the OMC

Huge demurrages are paid by KRL due to insufficient port facilities. The performance of ships coming to Kochi port also not very good. The selection of ships is done by IOC and Shipping Corporation of India. KRL 's involvement in this is very limited.

6.2.3.3 Opportunity

MDPM is an opportunity for KRL because they can make more profit due to better capacity utilization. Price being market driven, profit is always assured. Now refineries are free to have any sort of alliances. KRL can tie-up with companies, which are having marketing strength. It will lead to easy capacity addition. Expansions, capacity addition, or developing marketing network can be made by raising money from any source. Government control is minimum so the freedom for refineries is more. They can collect even through public issue of shares. Getting license for expansion or capacity addition is much simpler than the APM period. KRL can take their own decision in this regard. Now the cost reduction exercises will pay back. So implementation of methods like SCM are justified. Earlier many of the cost elements were shared by all the refineries in the country. In the post APM scenario each refinery can make saving by proper selection of crude oil and ship for transporting crude oil. Kochi is connected by all modes of transport to the other parts of the world. It is also near to the international sea trade line. So the cost of transporting can be less and availability of ships will be more. Crude oil price is almost stable for the last few years. It makes the crude oil purchase planning easier and better. Small variation can be adjusted in the selling price. It is possible in the MDPM. In a liberalized economy export is promoted. KRL also has chances to export to neibouring countries where there are not much refineries.

6.2.3.4 Threat

Many new refineries are setting up in India. These refineries have high capacity and more flexibility. These qualities will enable them to process cheaper crude oil, which will lead to more profit. Due to opening up of economy in India even public sector refineries are started to compete in the marketing. This will affect the marketing of stand-alone refineries. Capacity of the refinery is not enough to develop a marketing network. It is also difficult to buy and transport large quantities of crude oil in order to gain cost advantages. environmental regulations are getting stricter these days. So the product specifications will be rigid. Present setup of the refinery may not be enough to meet those specifications. By complete decontrol, the cost sharing of logistics will disappear. KRL will be forced to meet all the logistic costs by themselves. Smaller parcel sizes of crude oil will be a disadvantage for KRL. Location of KRL is at south most end of India. Both crude oil and refined products must be transported more. Capacity expansion may increase the problem. KRL products are marketed only in India. Products demand for the near future is not expected to surpass the production. Capacity addition may increase this problem also. KRL is depending on water from a river for all requirements. Ground water level in Kerala is reducing gradually. Scarcity of water can be problem in the future.

6.2.3.5 Recommendations of SWOT analysis

The area of international trade of crude presents opportunities to explore the international crude markets and select and buy suitable crude in right size parcels at the right time from the right supplier so as to maximize refinery profits. This is a special area of international trade where KRL has no expertise at present but must soon build some, if not presently to get into buying directly, but to monitor purchases for KRL by IOCL to see if its interests are being protected properly. This is an area where expertise cannot be built overnight and therefore starting early is important. With reference to shipping also the expertise and involvement of KRL is minimal. It is the OCC that through the Shipping Corporation of India (SCI) arranges for all petroleum product related shipping. Therefore one is not sure whether the optimal size vessels are being used to transport crude at the most appropriate dates. There are chances that crude movement is constrained by SCI ship availability. If this is true, they will shift the burden of this inefficiency in shipping onto the refinery. Single point mooring is good option in overcoming the problems in jetty operations. KRL must consider capacity addition with new technology because it will lead to increased flexibility in crude oil selection. This will give the refinery more value-added products. It will also help in meeting the international product specifications. KRL must develop its own marketing network for marketing refined products. This will increase the profit of the company and freedom in marketing and selection of crude oil also will be more. Implementation of SCM will further improve the profitability of KRL.

6.3 Logistics Operations in Supply Chain Management of KRL

Practices in the inbound, internal, and outbound logistics are analysed in this session. Inbound logistics being complexed, It is analysed separately and internal and outbound logistics combined together for the purpose of study. The objective of this part of the work was to study the processes involved in inbound logistics, and to analyse them for weaknesses and problems. Important tools used for the above were work study techniques study of documents and manuals, and discussion with managers and workers.

6.3.1 Issues in logistics planning

In a refinery, supply chain is very important since, this is a material movement intensive industry. A block diagram showing the supply chain in the Oil and petroleum industry is shown in figure 6.1. The upstream sector faces the problem of deciding which wells to tap for how much crude, so that over production does not have adverse impact on world oil prices. It also has to manage the logistics of storage of crude produced and arrange for sale and shipment of the same. Therefore crude tanker loading operations form a critical operation for them. For a downstream operator, the refinery, key supply chain issues are as given under:

Crude oil Procurement: The major issues here being decisions regarding when to purchase? How much of what crude to purchase? And From whom to purchase?

Crude oil shipping: This decision has to be examined along with the Crude procurement decision. Here one has to decide when to ship from which load port in what capacity of ship. That is deciding on the carriers for moving the crude from the load port to the unloading port.

Unloading port operations: When the crude carriers and ships for taking products come, they have to be received, berthed and crude unloaded or product loaded as required. The main problem that occurs here is restrictions put on vessel size due to draft limitations due to which more economical and larger vessels cannot be used for bring in crude. Delay in berthing of vessels or in their sailing out also occur at times due to lack of night navigation facilities (night pilotage). The main problem in relation to operation planning occurs due to the bunching of vessel arrivals creating a situation when there are many vessels waiting for berthing, resulting in demurrage payment. There are also times when the berth is unoccupied and the crude handling facilities are idling.

Crude Oil Storage: This area of refinery logistics has its special problems. The allocation of storage tanks to different types of crude is one such problem. This should be done in such a way that required ullage is available for the required crude at the time required. Also, enough storage capacity to act as an effective buffer between supply fluctuations on one hand and production demand variations on the other is essential. Since crude is an expensive commodity excess storage of the same should as far as possible avoided.

Refinery operations: The configuration of the refinery i.e. the different units in it and their capacities and its range of operability should have be balanced. By this, it means that as far as possible there should be no need to build up interstage buffers in the refinery. The refinery should also be flexible in terms of its ability to refine a wide variety of crude. Its operating characteristics should be such that more of distillates having higher demand and giving more returns should be produced. The products produced should be requiring minimum blending.

Finished product storage and blending: As in the case of crude oil tankage, a crucial decision here also is which tanks to allot to which products. Both offline and on line blending options are available. The former is the traditional method, and requires less investment in machinery, but requires more product storage tankage. On-line blending is a more recent addition to refinery operations; it is instrumentation and automation intensive option that significantly reduces the product tankage requirement and product inventory carried by the refinery.

Finished product dispatch: There are four major means of movement of products to the consumers or distribution storage points. Naturally, when the parcel size is around a few thousand tons, the transportation is done by road in Tanker lorries. This offers the greatest flexibility in route and parcel size and mix and is the only means of delivering products to retail outlets directly.

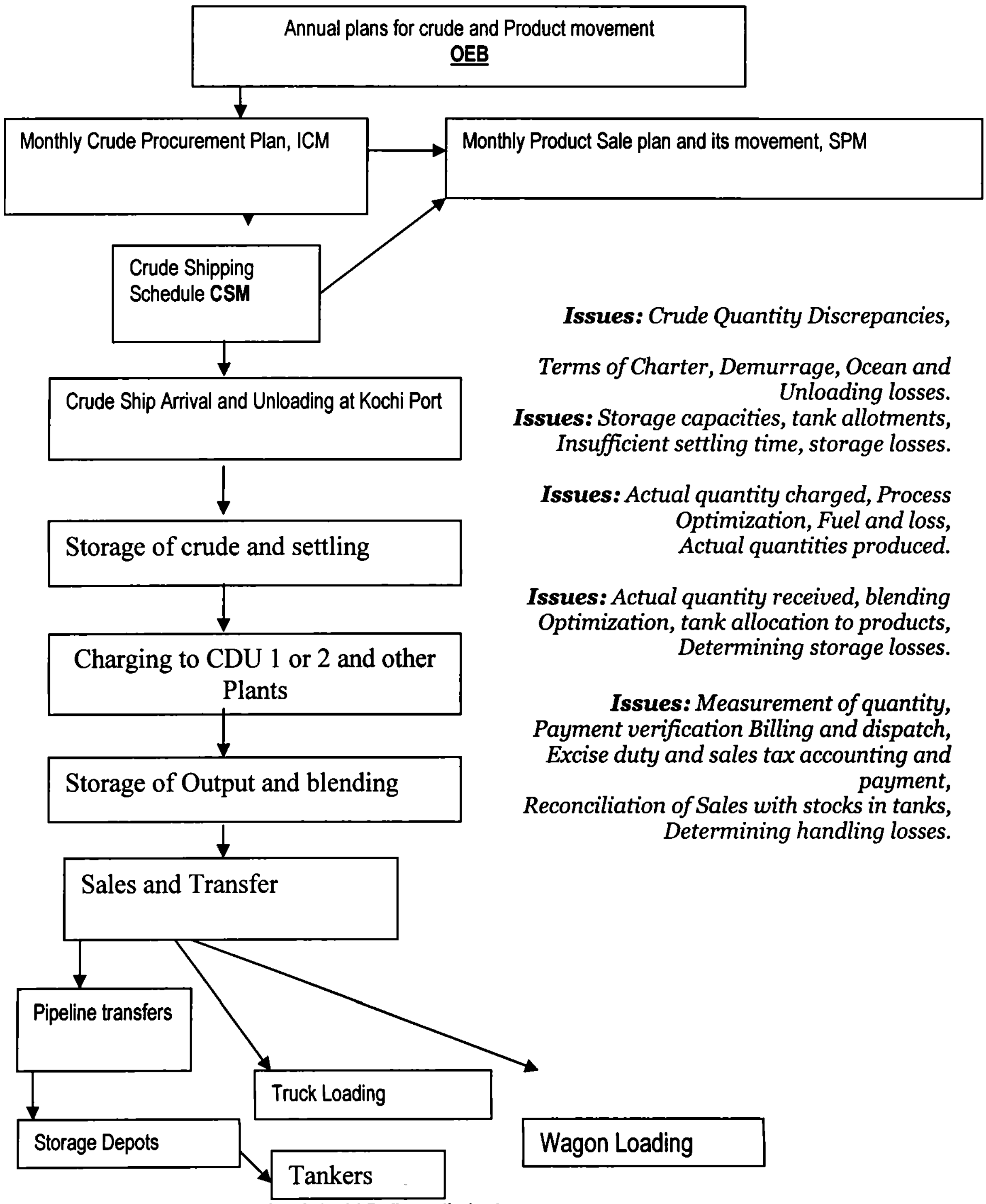


Figure 6.1 Supply chain of Kochi Refinery limited

The railway wagon rake is used to transport products to big storage depots of marketing companies located at railway sidings. The third means of transport is the pipeline; this is only economical if bulk movement is required. The only problem with this is its very high initial cost, but the operation cost of this is very low. The rigidity of route and fixed source and destination is another problem with this means of transport. This is used for short distance transport of bulk products to marketing company depots and large users nearby. The next mode of movement is by ships. This becomes economical only with large parcels and to greater distances. This is used for movement of products from one port location to another. It is also the only means many a time, for exports.

The value addition that takes place in a refinery is due to the separation of crude oil into distillates and heavy ends that each have separate demands and uses. It is the total amount of crude that is processed that will ultimately increase the bottom line. The supply chain of Kochi Refineries Ltd. can be divided into the conventional three parts of Inbound, Internal and outbound logistics. Inbound logistics is discussed in the sections below.

The Inbound logistics consists of all activities done to plan and implement procurement and delivery of crude necessary for the refinery. The movement of crude oil in the case of KRL is in discrete parcel form, unlike some refineries that have pipelines from the oil fields. The only means of bringing crude to the refinery is by sea route. The main decision problems that are encountered in the planning stage are discussed below.

6.3.2 Monthly plans

The monthly planning for crude supply and product movement is done through three important meeting called the Industry Co-ordination Meeting, the Crude Slate Meeting and the Supply Plan Meeting.

6.3.2.1 Industry Co-ordination Meeting (ICM)

This is the monthly meeting held to achieve the following objectives:

- To create a platform to bring together all members of the industry for sharing of the industry news and to plan for the future

- To discuss and review status of the short and medium term projects undertaken by the industry
- To take stock of the previous month performance for the industry
- To discuss the current month's performance till date and plan changes required
- To present the problems envisaged in the next month and discuss possible solutions
- Discuss and finalize crude requirements for the month after next
- To finalize next month's crude requirements for the industry
- To finalize and match next month's production and requirements for the industry
- To review inventory status of crude and products

This is the industry meeting to make a rolling plan for the three moths ahead

6.3.2.2 Crude Slate Meeting (CSM)

This meeting is held after the ICM every month with OCC, IOC(Shipping), Shipping Corporation of India and the representatives from each refinery attending it. The aim of this meeting is to finalize the crude allocation to each refinery by deciding the crude type and parcel size for different tankers, allotting them to different refineries and scheduling their arrivals at discharge ports. The crude requirement for next month of each refinery projected in the ICM is after consolidation by OCC(Technical) given to IOC(IT). They obtain quotes for crude. The initial crude shipping schedule is then made in consultation with IOC (Shipping). Here, a model that takes as input, data regarding crude and crude tanker availability from load ports, crude requirement of each refinery and laydays available at load and discharge ports and gives as output and optimum crude allotment schedule is used. This schedule gives the type and quantity of crude allotted the tanker schedule to reach the discharge port for the refinery. This crude allocation, and tanker schedule forms the basis for the CSM. The purpose of the CSM is to provide opportunities for the following:

- Exchange two crude between two refineries
- Move one tanker scheduled for one refinery to another to take care of emergencies
- To cancel or postpone certain tanker schedules
- To allot certain unallotted crude available to the refineries that can process them
- The result is the allotment and tanker schedule of crude
- The Bill of Lading holder for all parcels for the month is also finalized

6.3.2.3 Supply Plan Meeting (SPM)

This meeting is usually held on the day after the Crude Slate Meeting. This meeting is held to plan for the movement of petroleum products from the refineries to the depots and from there to the sales outlets. This has to be done at least cost to meet the demand subject to constraints such as loading capacity, rake availability, and ullage availability. As far as possible no refinery should have problem of excess products in store and therefore no ullage to keep newly produced product forcing it to slow down throughput. The Production figures, and demand projections by the oil marketing companies during the ICM are used by OCC to prepare the initial product allocation plan for different oil marketing companies. This serves as the beginning point for discussions during the SPM.

The Supply Plan Meeting is held in two parts the first part held in the morning has participants from OCC(Operations), OCC(Technical), Oil marketing companies and the representatives of each refinery. The objective of this meeting is to finalize the production numbers and off-takes from each refinery. This is then used by OCC (Logistics) to do an LP run to get the plan for product evacuation from all refineries during the next month. General issues regarding marketing and distribution and the problems faced there are also discussed here.

Indian Railways will join in the second half of the meeting. This meeting deliberates on and finalizes the rake allotment and wagon movement plan for the coming month. This is a meeting in which the oil marketing companies and the Indian railways play the major role in decision making. KRL's role is limited in safe guarding its interest of seeing that the finished product inventory in its stock remain as low as possible, and on no occasion choking of the refinery occurs because of non-movement of products.

The process units in KRL have flexibility to process different types of crude oil. However, in order to facilitate production of Benzene and Toluene, the company has to process approximately 3.5 MMTPA of Bombay High or equivalent high aromatic type of crude oil. Presently, the crude mix to be processed in a particular year is broadly decided during negotiations with the Government for finalization of the MoU document for the Year. The monthly allocation is generally in line with the agreed crude oil mix in the MoU and is decided during the monthly crude slate meetings.

Government has now permitted the private sector refineries and joint venture refineries to source their own crude oil directly. However, pure refining companies in the public sector viz. KRL, MRL and BRPL and the Oil Refining and Marketing companies viz. HPCL and BPCL cannot directly import crude oil. The crude oil requirement for these companies is still being canalised by IOCL. However, after complete deregulation of the petroleum sector slated after 2002, procurement of crude oil would be decanalised and hence KRL has to make its own arrangements for sourcing and procurement of crude oil.

It is imperative that KRL acquire adequate expertise in sourcing and procurement of crude oil in advance to maximize the profits of the company under deregulated scenario. About 95% of the total operating cost of a refinery usually are represented by cost of crude oil. The decision on crude selection should be based on net back analysis and product supply commitments.

6.3.3 Inbound Logistics Operations

Inbound logistics starts with the selection of crude and its procurement function for a refinery. The current practice is to evaluate the crude proposed by OCC and if found suitable to ask for the same in the OEB and the ICM submissions. Firm figures of when and how much of what crude KRL will get comes only after the crude slate meeting. These are only plan figures and actual figures, specially the date of tanker arrival at Kochi varies much from slated dates. The type of crude rarely varies but the quantity varies by about plus or minus 5 percentage and the date of discharge varies by about 2 to 3 days.

With reference to shipping also the expertise and involvement of KRL is minimal. It is the OCC that through the Shipping Corporation of India (SCI) arranges for all petroleum product related shipping. Therefore one is not sure whether the optimal size vessels are being used to transport crude at the most appropriate dates. There are chances that crude movement is constrained by SCI ship availability. This if true, will shift the burden of this inefficiency in shipping onto the refinery. Thus KRL should build expertise in these two important areas on a priority basis.

The inbound logistics operations consists of three important parts (i) the receiving, berthing and unloading of the tankers (ii) the storage of crude oil in Tank farm (iii) the accounting of crude receipts, shipping and related charges and their payment and settlement of disputes. All these functions are discussed in separate sections below.

6.3.3.1 Shipping and Jetty Operations for Crude

Kochi Refineries uses Kochi port for getting all its crude. The refinery which has a processing capacity of 7.5 million metric tons of crude per annum, refines 4.26 MT of Bombay high crude, 2.08 MT of imported Low sulfur crude and 1 MT of imported high sulfur Persian Gulf crude during 1999-2000. This results in the requirement to handle on an average of about 17 crude tankers per month (minimum of 4 tankers in May to maximum of 24 tankers in December). The parcel size of these tankers varied from 24,918 MT to 59,932 MT with the mean at 38,927 MT (April 98 to March 99 data).

The Kochi Port has three jetties for oil handling called South Tanker berth (STB), North tanker berth (NTB) and the Cochin Oil terminal (COT). Some more details regarding these are given in table 6.1. It may be noted that though the maximum pumping rate is shown at 2500 MT per hour this is not achieved in practice. From the data for 1998-99 it can be seen that the actual pumping rates for the ships range from about 1000 to 2000 with the average being 1500MT per Hour. This being the case, a simple calculation shown below reveals that about 57% of the year crude pumping should be working to meet the refinery's requirement. Considering the fact that monsoon limits operations to 50% of normal levels during four months of the year the pumping requirement for the rest of the year becomes 68 %. Considering the fact that about 204 crude tankers have to be handled per year, and that pumping of crude cannot take place during the 12 hours gap that comes between pumping from successive tankers the crude pipeline utilization goes up to 103 percentage. This creates an impossible situation. Thus there is urgent need to increase the average pumping capacity of the crude from the ships.

Hours of pumping required per year = i.e. Refinery capacity/pumping rate = 7500000/1500 =5000 hrs.

A. Pumping time required = (Hours of pumping/ Hours in a year)*100=(5000/8760)*100=**57 %**
B. Pumping time with monsoon = (5000/(24*30.4*8+12*30.4*4))*100
=**68 %**
C. Percentage of pumping time with monsoon and berthing time allowance of 12 hours between a ship departure and a berthing =(5000/{(24*30.4*8+12*30.4*4)-204*12})*100
=**103 %**
D. The same calculation as **C.** but with inter ship time 18 hours instead of 12
=(5000/{(24*30.4*8+12*30.4*4)-204*18})*100=**137 %**
E. The same calculation as **C.** but with inter ship time 24 hours instead of 12
=(5000/{(24*30.4*8+12*30.4*4)-204*24})*100= **208 %**

Based on the above calculations results are presented in table 6.4. It shows the effect of change in average pumping rate, and inter ship gap in berthing on the need for utilization of crude lines from jetty to KRL.

Table 6.3 Details of Berths available at Kochi fort for oil handling

Name of Jetty	Draft in Feet below Chart datum	Pumping rate in MT per Hr.	Oil handled
Kochi Oil Terminal (COT)	38	2500	Crude
North Tanker berth (NTB)	30	2500	Crude and Products
South Tanker berth (STB)	29	2500	Products

Table 6.4 Analysis showing the crude handling bottleneck at Kochi port

Average pumping Rate **MTper Hr.**	1250	1500	1750	2000	2250	2500
A. Normal Crude pumping in %	68.49	57.08	48.92	42.80	38.05	34.25
B. with monsoon allowance in %	82.24	68.53	58.74	51.40	45.69	41.12
C. with monsoon allowance+12hrs%	123.76	103.14	88.40	77.35	68.76	61.88
D.with monsoon allowance+18hrs%	165.56	137.97	118.26	103.48	91.98	82.78
E. with monsoon allowance+24hrs%	250	208.33	178.57	156.25	138.89	125

6.3.3.2 Analysis of Crude handling operations

Data was collected and analyzed of all crude tanker berthing from April 1998 to March 1999. The findings from this study are discussed below.

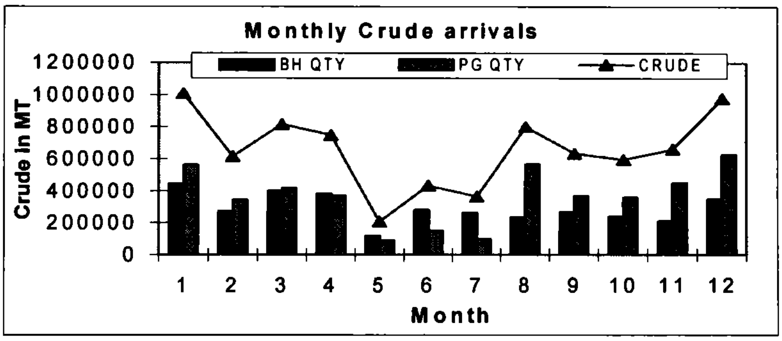


Figure 6.4 Monthly crude arrivals

- The figure 6.4 shows monthly crude arrivals both BH, PG crude and total crude is shown above. This shows that the crude arrivals in monsoon reduce to less than half of the highest month, which is usually January. This wide fluctuation in arrivals makes it necessary to build up crude oil stocks before monsoon. The maximum crude tankage requirement is thus determined by this peak requirement. This peak requirement can be reduced if movement of crude to top up the stocks is done during the lulls in between the monsoon.

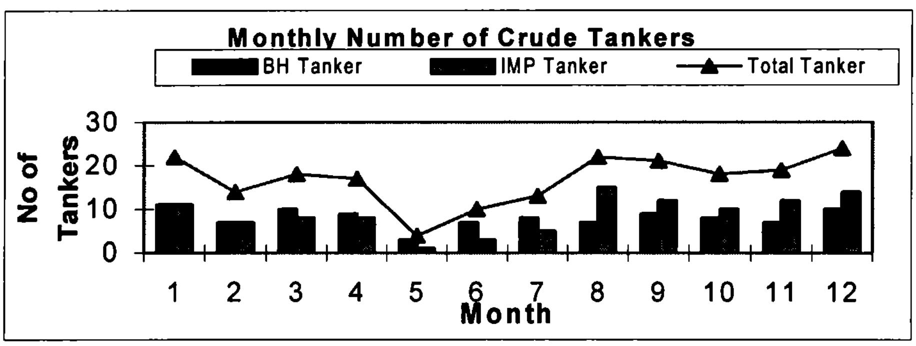


Figure 6.5 Number of tankers received

- As is expected from the data of crude arrivals the number of ship arrivals during each month also follows a similar pattern. It is however worth noting that the average parcel size during monsoon drops to about 33,000 tons from the otherwise normal of 43,000 tons. This is due to loss of draft in the navigation channel due to monsoon siltation, this results in about 25% loss of cargo carrying space for each tanker trip which further aggravates the monsoon crude build up requirement. The graph of tanker arrivals is shown in figure 6.5.

- The next interesting data is related to the time elapsed from NOR to berthing. Figure 6.6 shows the minimum, mean and maximum values for these for the same period as shown in graphs above but here the months are numbered 1 to 12. It is worth noting here that the minimum does not vary much from month to month, however the mean and maximum times are higher in months when more ships come. The period of July to October 1998 is worth looking at in detail because though during some of these months the number of that came were high enough. The Mean and Maximum delay between NOR to berthing was low.

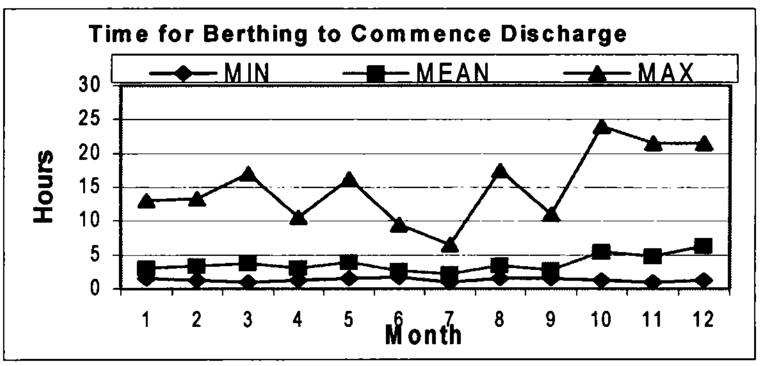


Figure 6.6 Time for berthing to commence discharge

- The next important time is that from berthing to commencement of discharge. The graph showing the minimum, mean and maximum of these times is given in figure 6.6. From that it can be seen that the minimum and mean of this are close together at below five-hour levels. However it can be seen that in most months there are also cases of maximum that have gone up to 25 hours. This maximum can occur is a previous tanker after part discharge has been moved to NTB and is discharging from there. If this is not the case this unduly high wait before discharge should be reduced.

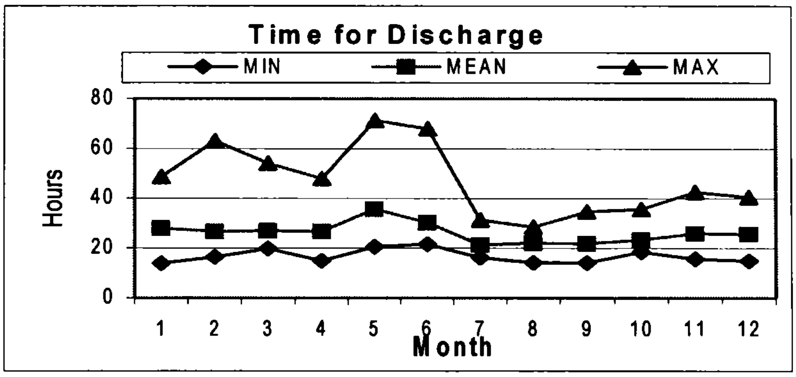


Figure 6.7 Time for discharge

- From the figure 6.7 it can be seen that the maximum time for discharge is high in the months of January through June. This should be reduced. The curves of minimum, mean and maximum should be close to each other, especially since berth is a bottleneck. The discharge should be maintained at highest levels so that discharge time is reduced. The maximum discharge time could have been higher due to larger tankers coming in fair-weather months.

- The figure 6.8 shows the time between completion of discharge to ready to sail. Here it is worth noting that during the months of April to August the tankers have been detained longer after completion of discharge. This is undesirable. This could have been due to the following reasons, no out-pilot, no tankers waiting to berth, rains delaying final pumping from the arms and disconnection of chiksuns and removal of moorings.

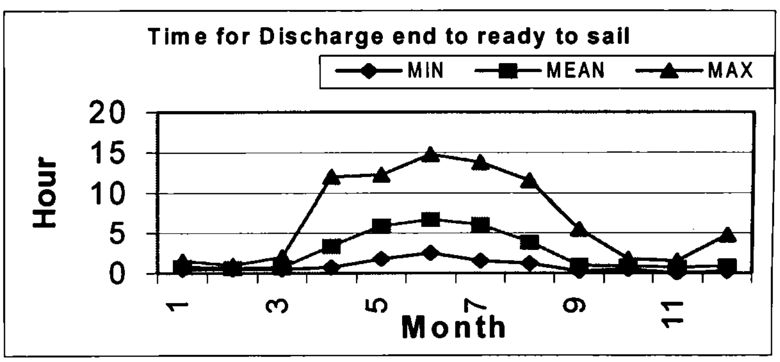


Figure 6.8 Time for discharge end to ready to sail

- The figure 6.9 shows the variation of pumping rate over the 12 months. From this it can be seen that over the months there is not much variation in the mean pumping rate but the minimum pumping rate varies very much so

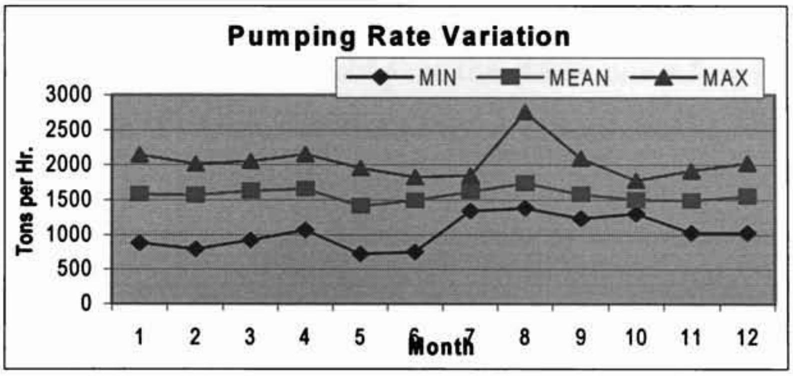


FIGURE 6.9 Variation in pumping rate

does the maximum pumping rate to some extent. This variation should be controlled and all the three curves should be very close to the maximum curve for best performance. Closer monitoring, and more pressure on SCI to send ships that have good working pumps on board to Kochi port can achieve this.

- The figure 6.10 the hours of overstay of tankers at Kochi Port over 36 hours of normal time. This time takes into account of all times from NOR tender to ready to sail. This is the time that has direct impact on the demurrage the company has to pay. It can be seen that there is wide variation between minimum, mean and maximum in most months. This is higher during the monsoon months as well as in months when more tankers are brought in typically above 19 tankers. The

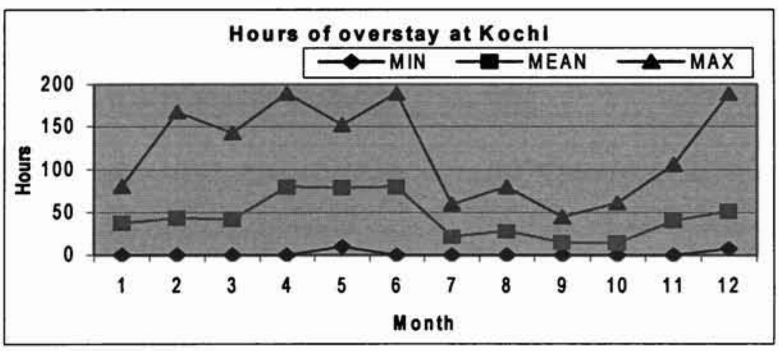


Figure 6.10 Hours of overstay at Kochi Port

height of the curves in this graph has to be minimized for better performance. A measure for good ship scheduling is that in this graph the minimum, mean and maximum will tend to be near each other.

Recommendations

It has been proved beyond doubt that the crude unloading operations at Kochi Port is a major bottleneck. Therefore means of augmenting this facility has to be planned and implemented at the earliest. As a very temporary measure one has to ensure that pumping of crude from tankers is at near maximum allowable pressures. Ships that are not capable of meeting this pumping requirement should be avoided, especially in months when above 16 ships have to be received. It is seen that soon after monsoon there is a crude inventory build-up. If this is not for strategic and defense related reasons (KRL crude stock being a part of India's strategic oil reserves) then the crude inventory need not be built up in the months of October to December. It can be built to sufficiently high levels during the period from January to mid-May, just before the onset of the monsoon; this strategy will result in reduced inventory carrying charges for crude. It may however be noted that, the crude pipeline discharge constraint will come in the way of implementing the above suggestion fully. It was also be noted that one of the four chicksuns at COT is not being used for some time now, this disuse of a very expensive piece of equipment will render it useless after some time. Therefore the recommendation is that arrangements to use three of the four chicksuns by rotation should be done.

6.3.3.3 Short Term Solutions Recommended

A. As a short-term measure, the use of drag reducers to improve discharge rates of crude from the tankers may be considered. However the main problems with its use are the following:

There will be some capital investment initially to have the necessary equipment for the injection of GEL Flow improvers into the crude lines. The operating cost with this type of solution is comparatively high because of high cost of the GEL used. There are fears that its use might affect the quality of distillates especially the ATF and JP-5. KRL pipeline is old and if corroded, the greater pipe roughness will adversely affect the performance of the drag reducer. As compared to smooth flat terrain in most parts where pipelines are laid, KRL crude pipelines have sharper bends, which have adverse affect on drag reducer performance. The use of these has proven economical for long distance pipelines. It is not much in use in short distance pipelines, such as KRL's crude pipeline. At best also it can only be a short-term solution because of the above limitations, and not a permanent one.

B. Another short-term solution is to make arrangements for bringing Suez-max tankers to COT. These tankers could be used just before monsoons to build up the crude inventory. These tankers may bring crude parcels of about 80,000 MT. The major issues that have to be catered to make this possible are the following:

A draft survey of the channel and COT area has to be undertaken to find the patches where maintenance dredging will have to be done to meet the draft requirement of Suez-max vessels. The capacity of the fenders at COT has to be checked to find if it is capable of taking the shock of impact by the Suez-max vessel with the crude parcel. If not sufficient augmentation of fender capacity has to be made. Another way of handling this problem is with the installation of a velocity meter at COT that will call out the velocity of the tanker as it approaches the berth. This will be known to the pilot, and the tugs helping in berthing, resulting in better control of the approaching velocity, so that the impact on the fenders is reduced. Arrangement for mooring of the longer Suez-max vessel. The fore and aft moorings of the tanker will require, installing more bollards. A cost-effective solution in this matter could be using floating dolphin buoys with pelican hooks to moor the Suez-max tankers. The breast lines from the Suez-max tankers could be tied to the existing bollards. The next problem that could be encountered is when the vessel has to be turned before sailing off. From the discussions with some CPT personnel including a pilot, it was noticed that the present turning circle is large enough for a Suez-max vessel to turn. This was also demonstrated when one suez-max tanker was brought to CPT

C. The best short term solution appears to be to make arrangements for using the pipeline now being used for Black oil movement from plant to jetty for the purpose of crude pumping when it is free and not being used for product movement. This is made possible will considerably decrease the ship unloading times associated demurrage and will help remove the crude pipeline capacity bottleneck to a very great extent.

6.3.3.4 Permanent Solution-Single Point Mooring (SPM)

The Proposal for the Single Point Mooring system being examined by KRL appears to be the only stable and permanent solution to this problem. It is the type of solution that is required for this pressing need for more crude unloading facility. It was noticed that KRL is examining two alternative proposals, one in which the SPM will be located nearer to the shore at a site where only vessels of up to LR-2 make or Suez-max can be accommodated. The second proposal is to locate the SPM at a site further off the coast at a site where the draft is enough for handling VLCC vessels also.

At this point it is important to make two observations regarding project planning and implementation that were observed during the course of this study. The first relates to the time horizon of strategic plans of KRL. Most plans implemented by KRL were with the present and medium time in view. A long-term perspective to project selection and implementation, when dealing with facility creation, will be more desirable now with the opening up of the oil sector. At this point it is worth noting that the initial crude pipeline laid for the 2.75 MT refinery laid at the time of initial commissioning of the refinery, has enough surplus capacity to more or less cater to the current requirement of the expanded refinery with 7.5 MMTPA capacity. This foresight has to be maintained especially when creating key facilities, where incremental addition of facility later make it difficult and prohibitively expensive once the project is over.

The second observation is regarding project implementation. KRL's strengths are in selection equipment and of partners for project implementation. However, one important thing that is often overlooked is the way the facility will be operated after commissioning (that is the operability point of view). It is worth noting here that small changes and facilities if incorporated to facilitate operations will go a long way is improving system performance. The maintainability aspects are also underplayed at design and commissioning stage, resulting in permanent problems for the maintenance staff. This problem is not unique of KRL; it is also the problem of most other project organizations. When evaluating the benefits of SPM proposal it is important to consider at least the following benefits that KRL will get from it:

- Inventory carrying cost released from reduced need for inventory carrying
- Netback from utilization of refining capacity that was unutilized due to lack of crude supplies
- Savings from reduced demurrage paid to crude tankers
- Savings from crude transportation charges occurring due to use of larger tankers for crude transport
- Crude handling charges that can be apportioned from refining charges of future expansion
- Money released from cancellation of the need of some new crude storage tanks that are planned for the capacity addition project, because of release of some crude storage tanks from the current set as a result of reduced crude storage requirement with SPM.
- Savings from reduction in charges to be paid to Kochi port trust for crude handling.

6.3.3.5 Tankers coming to Kochi and their performance

In the days of APM costs were not much of a concern especially since, the shipping costs that were paid from a common pool account. The post APM conditions make it necessary to monitor this important cost closely. It is but natural that different ships have different features that make some more cost effective in certain routes compared to others. The important features of a crude tanker from KRL point of view are the following.

- The flag of the ship, this is important since port charges are less for Indian ships.
- The hire charges per day and other charges such as fuel etc. for the tanker.
- Familiarity of the master and crew with CPT and KRL.
- The carrying capacity of the vessel. The nearer the carrying capacity of the vessel to the parcel size planned the more economical would it be.
- The loaded draft requirement of the vessel. This should be within what is available at COT.
- The number of pumps on board and their discharge capacity. This should be at least the maximum KRL can allow.

In order to understand which tankers have comparatively lower freights, it was collected and analyzed the freight data for some ships that have come to CPT with crude for KRL in the past, this data was collected from the crude cell. The tankers have been classified into those that came with imported crude, and those that come with BH crude. The classifications of tankers that come with crude for KRL are given in the table 6.5.

Table 6.5 Ships and their details

TYPE	DWT Capacity	Max pumping rate	DWT Load for KRL	Draft Reqmt (full)
MR	40,000	2040 t/hr	37,000	10 M
LR 1	63,000	2720t/hr	49,000	12 M
LR 2	87,000	4080t/hr	58,000	14 M
Suez max	1,47,000	6125t/hr	80,000	16 M

The study of ship-wise performance has not been a practice at KRL because the crude shipping costs were met from a common pool account during APM. This situation is slowly changing; therefore ship-wise performance tracking has become important now. As a beginning to this exercise the data was collected for all crude tanker arrivals during 1998-1999 and analyzed for ship wise performance. The summary of the findings is presented in Table 6.5. The important parameters shown in the table and their significance will now be discussed. The tanker names are used to identify them. The total crude brought by each tanker during the period of 1998-99 and the number of trips made by each are used to calculate the average parcel size brought by the tanker to CPT. This data gives information about how regular a tanker is in the KRL circuit and the amount of part loading that is done for it. The next column gives the mean NOR to berthing time this is the measure of the average time the tanker spends outside CPT waiting to be berthed and this is mainly due to bunching of ship arrivals or due to longer berth occupancy by the previous tanker due to slow discharge.

The data in the next column is regarding the mean time from berthing to start of discharge. This time should be around two hours and is something that has to be controlled if it is consistently high for some vessel the reasons for the same have to be looked into.

Table 6.6 Performance of tankers that brought KRL crude in 1998-99

Tanker Name (1)	Total Crude **(2)**	No of Trips **(3)**	Average Parcel size **(4)**	Mean NOR to Berth Hrs. **(5)**	Mean Berth to pump Hrs. **(6)**	Mean pumping time Hrs **(7).**	Mean End pump to sail Hrs. **(8)**	Mean Hrs of over stay excess of 36 hrs **(9)**	Mean Demurrage at Rs. 20,000 Per Hr **(10)**	Mean Discharge rate in T/ Hr. **(11)**
A B Tarapore	315708	8	39463	42.66	5.59	24.84	3.31	40.91	818125	1598
A Friendshi	50084	1	50084	7.25	2.25	36.00	0.50	10.00	200000	1391
Abdul Hamid	88430	2	44215	51.00	2.13	26.88	1.25	45.25	905000	1640
Addai	43274	1	43274	3.50	4.50	42.00	0.75	14.75	295000	1030
Alex	24918	1	24918	107.3	7.50	17.75	0.50	97.00	1940000	1404
Alina	55566	1	55566	60.25	3.25	40.50	1.00	69.00	1380000	1372
B C Chattergi	377251	12	31438	28.90	7.17	21.77	1.46	25.46	509167	1453
B R Ambedkar	444657	9	49406	82.33	6.42	31.72	2.33	86.80	1736000	1574
C P Shivaji	571567	12	47631	35.81	4.81	36.05	2.92	43.60	871917	1399
C V Raman	680654	23	29594	36.39	4.45	18.80	3.02	27.83	556522	1616
G B S Salaria	260881	6	43480	56.08	2.04	26.75	2.88	52.13	1042500	1631
Homi Bhaba	550963	19	28998	36.78	3.45	19.87	1.96	27.66	553105	1484
J N Singh	79152	2	39576	28.63	2.00	18.50	6.00	19.13	382500	2260
J Nehru	142954	3	47651	17.50	4.75	25.25	0.67	16.25	325000	1899
Jadu Singh	46333	1	46333	2.25	2.00	23.00	0.75	0.00	0	2014
Jadunath Singh	40681	1	40681	6.50	2.00	22.25	4.75	0.00	0	·1828
Joginder Singh	40406	1	40406	114.0	4.00	24.00	8.75	114.75	2295000	1684
L M Tilak	205236	4	51309	61.31	1.94	57.94	8.44	93.63	1872500	943
M D S Thapa	429279	11	39025	57.18	2.23	24.75	1.36	49.89	997727	1591
M J N Singh	152248	4	38062	53.50	2.06	21.25	2.56	43.38	867500	1791
M karve	44553	1	44553	20.50	5.25	39.75	0.50	30.00	600000	1121
Motilal Nehru	235226	5	47045	43.75	4.10	27.25	3.15	43.15	862920	1719
N S Bose	265514	6	44252	24.67	3.33	30.42	2.54	25.13	502500	1501
N Shiv Chand	94524	2	47262	101.0	1.75	23.00	3.00	92.75	1855000	2059
Piru Singh	317921	8	39740	54.34	3.63	24.25	2.31	49.56	991250	1641
R N Tagore	245309	8	30664	56.84	1.94	20.43	2.63	47.49	949875	1497
R R Rane	315597	8	39450	49.09	2.63	24.28	3.41	43.41	868125	1642
Ratna Abha	243489	6	40582	82.13	3.38	21.77	0.71	72.18	1443667	1881
S Sarma	342843	9	38094	45.53	5.03	22.60	0.83	39.43	788667	1684
Saitan Singh	269795	7	38542	33.32	2.21	25.93	1.32	28.39	567857	1485
Satya Moorty	153235	3	51078	59.25	2.58	38.33	1.92	66.08	1321667	1346
Vivekananda	239897	5	47979	48.20	3.30	39.25	0.81	55.56	1111200	1231

The next column (7) shows the average time taken for discharge. This information along with the data in the last column (11) regarding average discharge rate, are the most crucial information as far as KRL crude unloading is concerned. Tankers such as L M Tilak, B C Chatterjee, Homi Bhaba, Vivekananda, Satya Mooty, Saitan Singh, R N Tagore have poor average discharge rate performance and they unnecessarily choke up the crude unloading system, therefore they should be avoided as much as possible. At this point it is worth noting that all the foreign tankers that came with crude to KRL i.e. A. Friendshi, Addai, Alex and Alina have an average discharge rates below 1500 T per hour. This is rather unusual, therefore the performance of foreign ships that bring crude for KRL is worth examining. The average waiting time after the end of pumping to ready to sail off is given in column eight. This has also to be closely monitored and controlled, since this increases berth occupancy which is undesirable. In the next column (9), it is shown the time in excess of 36 hours that the tanker spent at CPT for unloading crude. The average Demurrage incurred by on the tanker is given in column ten. This has been calculated as the charges payable for time in excess of 36 hrs spent by the tanker for unloading crude at the rate of Rs.20,000 per hour.

The figure 6.7 shows the variation of average crude parcel size over different months. From this it is clear that the monsoon parcels are smaller. It is also worth noting that the average parcel size does not improve quickly just after the monsoon.

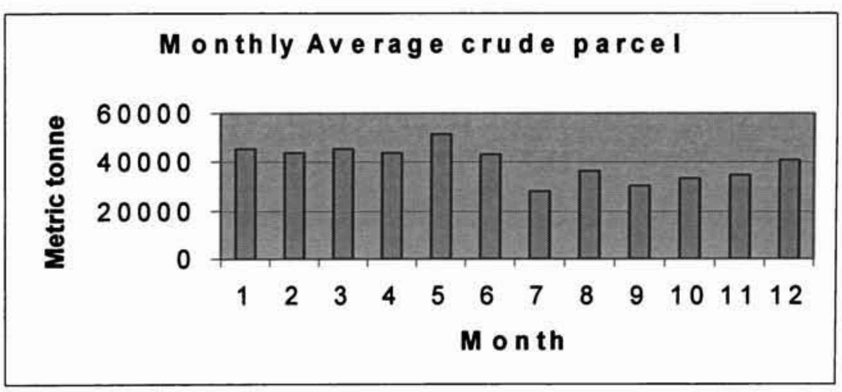


Figure 6.7 Average Crude Parcel

6.3.3.6 The Simulation Model Experiments

The computer simulation based model for modeling the crude tanker unloading operations at Kochi Port discussed in chapter 4 section 4.6.4 . This model forms the base of the Decision Support System (DSS) that provides for the "What if Analysis' for crude slate meeting.

This model has been modified and used to study the effect of increasing the number of tankers that are brought to Kochi Port on the cost per ton for crude unloading operations. The performance measure called 'Cost per Ton for crude unloading operations', was calculated using the formula given below:

Cost per tone for crude unloading = (Total Days spent by all ships that came to unload crude at Kochi port) x (24) x (Rs20000) / Total tonnage of crude unloaded

Table 4.5 Relationship between ship hire cost per ton and number of ships per month

Number of ships per month	Total ship hire cost for unloading days	Total of Crude tonnage unloaded	Cost per ton for crude unloading
8	7200000	360000	20
9	8160000	405001	20.15
10	8160000	450001	18.13
11	9120000	495000	18.42
12	11040000	540000	20.44
13	12000000	540000	22.22
14	16320000	585001	27.9
15	24480000	585000	41.85
16	32160000	585000	54.97
17	39840000	585000	68.1
18	47520000	585000	81.23
19	55200000	585000	94.36
20	62880000	585000	107.49
21	69120000	585001	118.15
22	75840000	585001	129.64
23	85920000	585000	146.87
24	93600000	585000	160
25	99840000	585000	170.67
26	108480000	585000	185.44
27	109440000	630000	190.71
28	118080000	585001	201.85
29	125760000	585000	214.97
30	137280000	585000	234.67

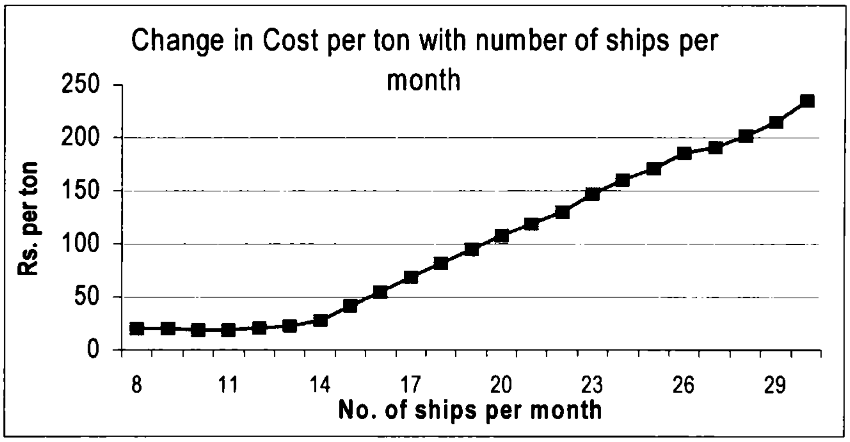


Figure 6.8 Change in cost with number of ships

From figure 6.8 and table 6.7 it is clear that with increase in number of ships per month the total number of ship days at Kochi port increases resulting in increased cost per ton for ship hire for just the unloading days of the tanker trip. *It can be seen that up to a 16 or seventeen ships per month, the cost is Rs. 60 per ton or below can be received at minimum cost. This is within the tolerable limit.* In the above model *scheduled ship arrivals in equidistant intervals of time; this is* not true in real case where clubbed ship arrivals do take place making the situation worse.

Another major issue related to shipping is related to the quantity loaded when BH crude is shipped from Mumbai. This issue comes up because the crude quantity shipped is determined by measurement of discharge figures from ONGC tanks. The conventional method of surveying the ship's tanks for determination of crude loaded is not followed here. A switchover to this system will be the best solution to this problem.

Another problem related to quantity comes in the case where part unloading of crude takes place at Mangalore port for MRPL. In this case also the quantity unloaded is measured by MRPL by taking its crude tank receipts figures. The KRL receipts are then arrived by taking the deemed bill of lading figure of original B/L figure less MRPL receipts. There is the problem of verifiability of MRPL receipt figures by KRL. The second problem is that unloading loss if any at Mangalore Port become part of KRL losses not MRPL losses as it should have been. The next issue is that MRPL being the first receiver of crude pumps off the clear top portion of it leaving the bottom muddy part in the share of KRL. This problem has however now decreased very much since April 1999 when MRPL has started buying crude from the international market directly.

The next issue that is pointed out is related to the ocean loss incurred by KRL. The figures for the ships that brought crude in January 1999 were analysed. From the analysis it is seen that ocean loss is lower raging from 0.01 to 0.7 % with mean at 0.2 % in the case of imported crude. The monetary loss in the same period works to Rs. 82.1 Lakhs. The figures for BH crude are in the range of 0.16 to 1.28 % with mean at 0.6%. The monetary loss on this account in January 1999 for KRL is Rs.125 Lakhs. The ocean loss might be higher in the case of BH crude due to the Custody transfer measurement issue mentioned earlier. To take care of this KRL has to develop greater understanding of shipping and its rules, the terms of charter have to be drafted properly and losses beyond standards must be recovered from the shipping company or the insurance company.

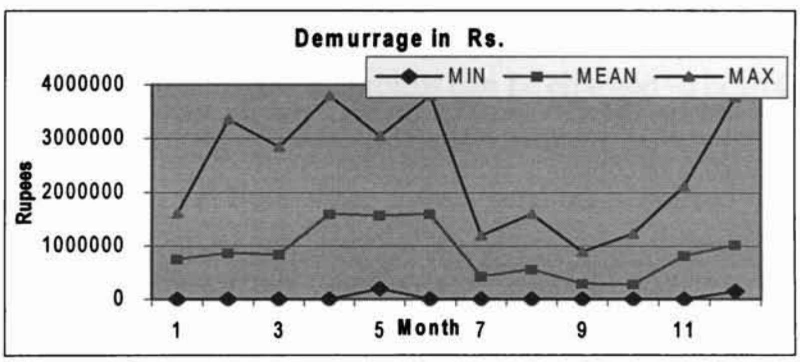


Figure 6.9 Demurrage paid by KRL

The figure 6.9 shows the demurrage payable by KRL for tankers overstay beyond 36 hours for unloading crude. An hourly charge of Rs. 20,000 has been taken for the calculation. This chart is for the financial year 1998-99. It can be clearly seen that there is wide variation between the minimum, mean and maximum figures in most months. This indicates the problem due to clubbed arrival of ships, which is more in January to May, leading to higher demurrage during these months. It is worth examining at this point if the black oil line that is available from the jetty to KRL can be used for crude pumping at times when it is not in use for black oil pumping.

6.3.3.7 Storage of Crude

KRL has two tank farms for the storage of crude. The first is the old tank farm, which has 7 tanks for crude storage. The second and later addition is the Additional Crude Tankage Project (ACTP) that has 6 crude tanks. There is a 30 inches (internal dia 29.5 inches) pipeline from the Jetty to the Old tank farm. This crude line now extends to the ACTP. Therefore there is facility to receive crude from one tanker each berthed at either COT or NTB at a time. The other could meanwhile prepare for discharging

Crude from a vessel is usually received into one tank and when it is full the connection is slowly switched over to another tank. The pipeline connections in the crude tank farms is in such a way that at any given time crude from two tanks with different crude can be separately charged to different units i.e., CDU 1 or CDU 2. But LSPG and BH from Group 2 cannot be separately charged to CDU 1 and CDU 2 at the same time since there is only one line for charging from Group 2. One tank from each group can be independently charged to CDU 1 and CDU 2. Similarly one tank form both the groups can be charged to both CDU 1 and CDU 2 simultaneously. At KRL, CDU 1 is usually run on Imported High Sulfur crude almost 40 % of the time. Rest of the time it runs on Imported Low Sulfur crude or on Bombay High crude depending on the requirements of heavy ends. Whereas, CDU 2 always runs on imported low sulfur crude or on Bombay High crude.

6.3.3.8 Crude Arrival and Consumption

The current pattern of crude arrival and consumption at KRL is discussed here. The data used is of 1998-99. A look at the figure 6.10 shows the monthly crude arrival pattern. It can be seen that crude arrivals were low in April, May and June. The low arrival from April to mid-May should not be allowed, that is the month when maximum pre-monsoon build up of stock should be done. The inventory holding cost can be reduced by postponing the crude stock build up to the last month, rather that building it up in February and March itself. It can also be seen that it is BH crude arrivals that undergo greater fluctuations.

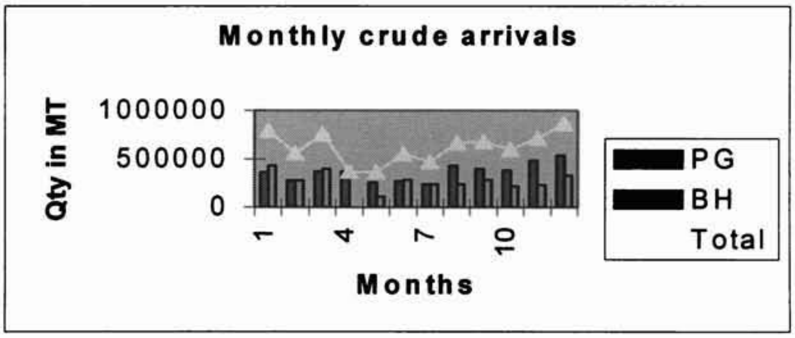


Figure 6.10 Monthly crude arrival

The figure 6.11 showing monthly crude consumption reveals that PG crude consumption is generally higher than BH crude consumption. And that the variation in crude consumption is lesser than variation in its arrival (except for shutdown month).

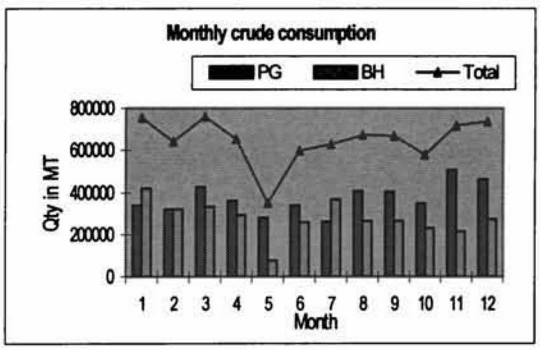


Figure 6.11 Crude consumption

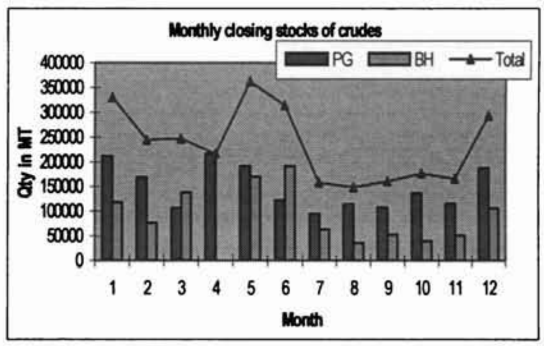


Figure 6.12 Crude stock in each month

In order to understand the crude stock depletion and buildup a graph showing the difference between crude supply and consumption for different months. The ideal requirement of KRL is that the total line in the graph should have a bulge to the positive side in the months was drawn (figure 6.12) The ideal requirement of KRL is that the total line in the graph should have a bulge to the positive side in the months of February, March and April indicating stock build up during this period. A corresponding bulge towards the negative side should be seen in June, July, and August indicating depletion of stock during these months. But, in the case of the figure 6.13, the negative bulge exists showing stock depletion in monsoon. However, another negative bulge can also be seen in April that is very undesirable.

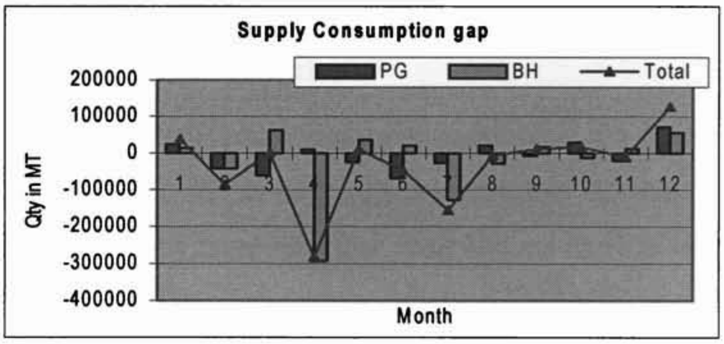


Figure 6.13 Supply consumption gap

6.3.4 Internal and Outbound Logistics Operations

In this section internal logistics as well as outbound logistics are discussed. The refining logistics is much simpler since the crude and intermediate products are all handled through pipelines with flow control valves, the control of most of which is automatically controlled from the control room. The major logistic related decision relating to refining that has to be taken is the determination of how much of what crude to process on a given day. This leads to the decision of which crude tanks to put on line for feeding the production unit.

Once production is over, the products produced will also have to be received in product tanks in such a way that subsequent blending if necessary is possible. The final products in the tanks will then have to be transferred to the marketing companies by pipelines, loaded on to product tankers at the jetty, loaded into railway wagons or trucks for dispatch and sale.

6.3.4.1 Refining Operations

This is the area where KRL has the maximum strength. The production plan for the next 24 hours is made in the daily production meeting every morning, during this exercise attention is paid to the following:

- The last day's performances, performance till date, and required production
- The crude availability i.e. the type and quantity of crude available and expected
- The product off takes planned and the ullages available for product storage
- The level of VGO buildup and ullage available for it's storage

- Plant maintenance or shutdowns
- Net back for different options

Automation in the plant has been achieved to a great extent at KRL. The problem however is that these plant automation systems operate as separate islands and they do not have any link with the management information system. The management information system has to still rely on the figures reported from each unit on paper or by phone. This results in different versions of the same fact being reported, the authentication of which is a major trouble. It also gives opportunities for temporarily hiding inefficiencies. An Information system based on data collected from the instruments directly would serve the purpose of management better.

Having verified the sales to the marketing companies now the production and sales of different products in different months of a year can be studied and understand the seasonality in demand. The difference between production and sale are also noted to determine periods in which there are stock buildups and stock erosions. The figures 6.13 to 6.23 shows the variation of stock and sales

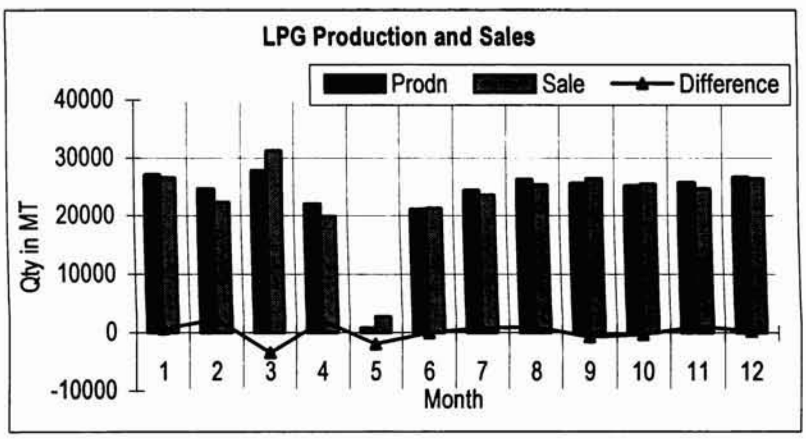


Figure 6.13 LPG Production and sales

during the period 1998-99. The line is used to show the difference between production and sales to represent stock build-up or erosion. The figure 6.13 shows the Production and Sales of LPG during the period 1998-99. It shows that the production and sale of LPG remains nearly equal in most months. Only in March the sale was significantly more that production. The months of May and June had low overall production that reflects in the production of LPG too. The production and sale of MS is shown in figure 6.14. The production in the month of May was comparatively low. A more stable production will go well towards making the logistics stable.

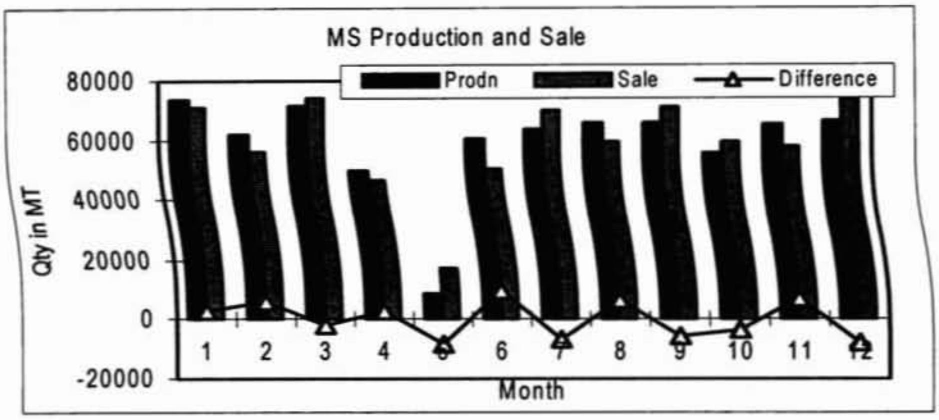


Figure 6.14 MS Production and sales

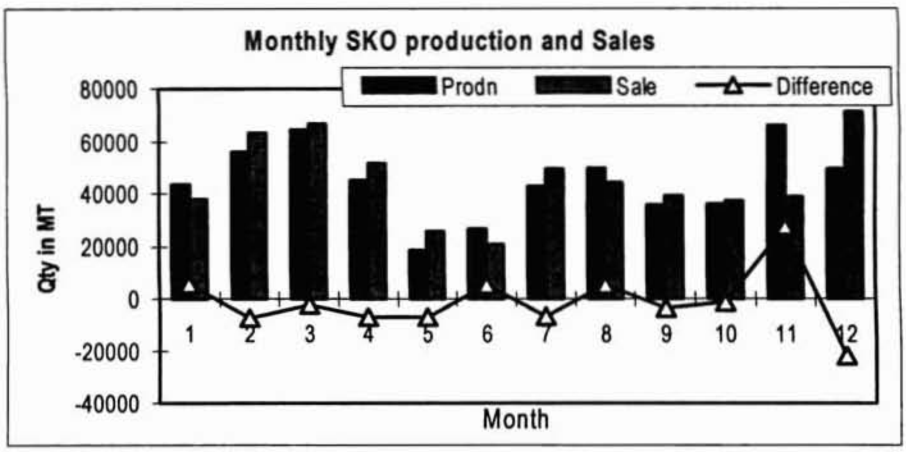


Figure 6.15 Monthly SKO production and sales

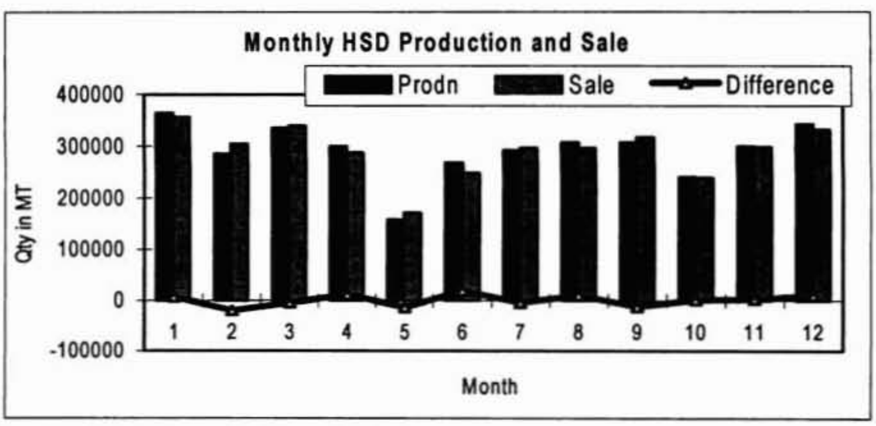


Figure 6.16 Monthly production and Sales

The production and sale of SKO varies very much from month to month. There is a significant demand increase in winter and during the pre-budget season. Therefore there is significant build up and depletion of stocks associated with these periods (Figure 6.15).

The production and sale of HSD over the months is not uniform there are dips during May and October (Figure 6.16). But there is no significant build up during any period, partly because KRL storage is limited.

The graph for Naphtha production and sale is given in figure 6.17. A study of it shows that there is significant variation between its production and sale. This could be because in certain months when stocks are high, transfer is done by coastal tankers. Major stock variations take place during February and March.

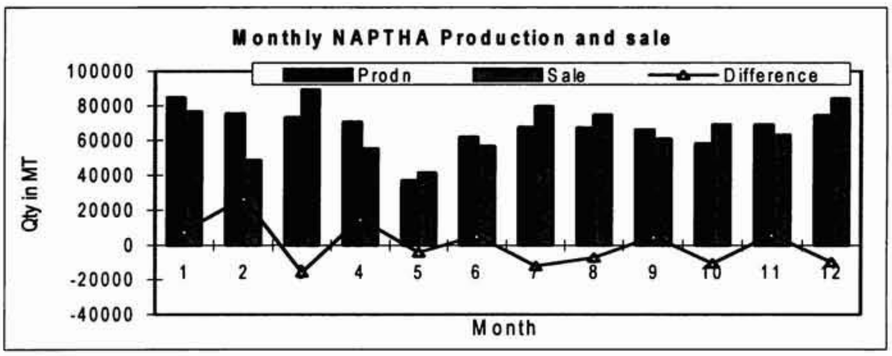


Figure 6.17 Naphtha production and sales

The figure 6.18 shows the production and Sale of ATF. This varies from month to month significantly. The sale is higher during the Months of January to March. Stock of this fuel is maintained at most times. Whenever stock becomes low production is increased to build it up again; this can be clearly seen from the difference in Production and Sale tending to be positive always.

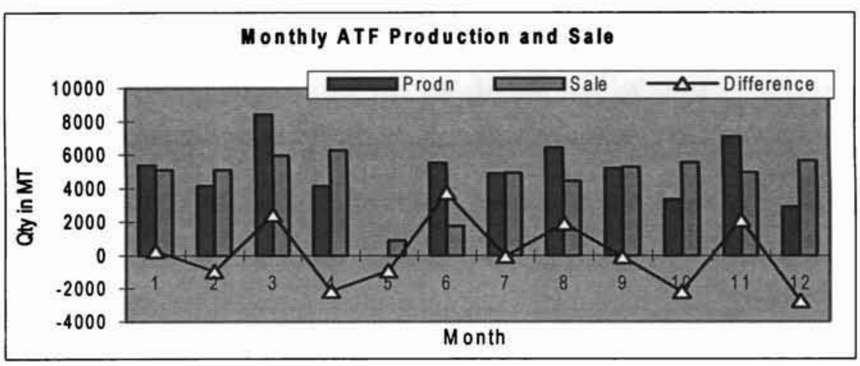


Figure 6.18 ATF Production and sales

JP-5, the aviation fuel used by the defense also shows higher demand during monsoon. In its case the stock builds up and slow depletion can be clearly seen in figure 6.19.

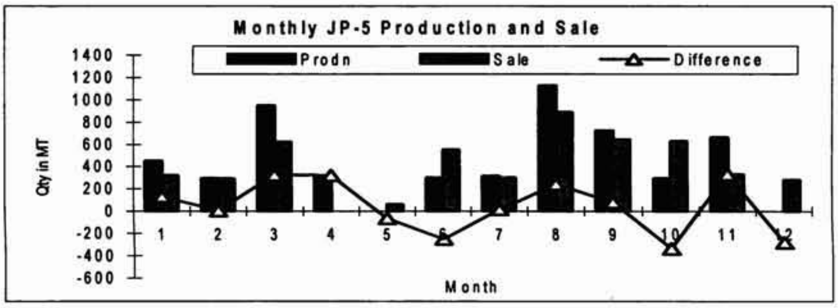


Figure 6.19 JP-5 Production and sales

The production and sale of LDO also varies very much from month to month. It is more in demand during monsoon and winter. The high demand during February could be in anticipation of Price rise. In this case also stock is built up in a month and this is carried till it is consumed in a later month by excess demand.

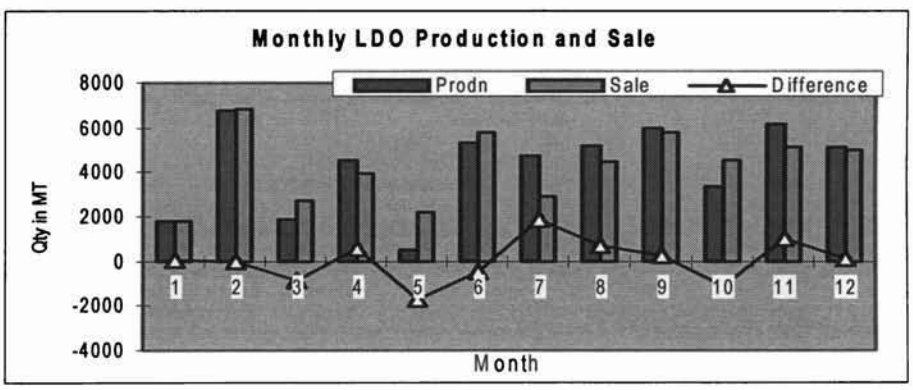


Figure 6.20 LDO production and sales

Figure 6.21 shows monthly production and demand of LSHS are unequal in most months leading to a build up or depletion of stock. The last quarter buying before the budget or increased production for pushing the product into the market before budget. The production and sale of Furnace Oil is much more stable. For this product the strategy seems to be to produce only what is required and the requirement being stable this is easier. Whenever stock depletes due to over demand it is topped up in the next period by more production.

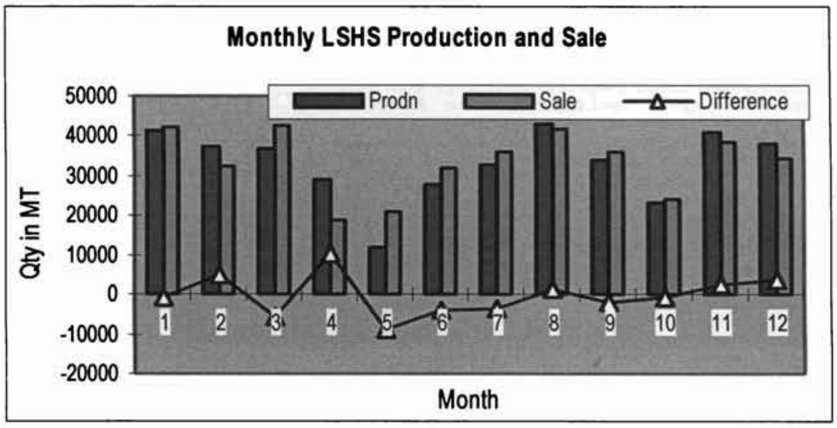


Figure 6.21 LSHS Production and sales

As is expected the demand for Bitumen is highest during the pre-monsoon months. The monsoon months reduce the demand. But strangely it can be seen that there was unnecessary high production July leading to stock build up that could get depleted only after the monsoon was over. This stock buildup could well have been effected during the last month of monsoon or even later in November or December.

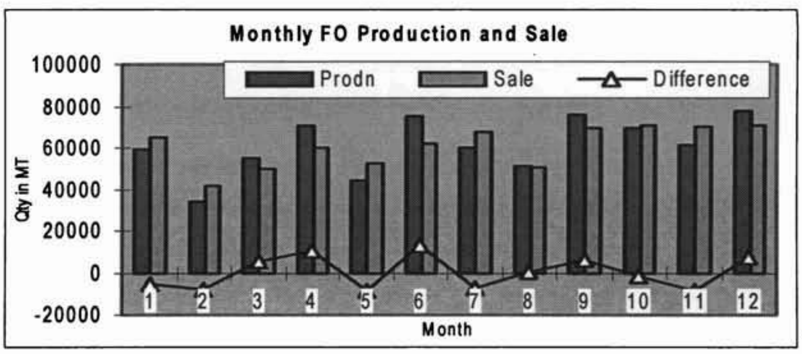


Figure 6.22 FO Production and Sales

The facility creation, the market, and the product demands that were discussed have been developed under the APM. KRL will have to review these as the MDPM comes to force fully. The world over now it is time for strategic alliances. The old days of having many suppliers and marketers, believing that if one of them do not perform the other will deliver the goods, is gone. The relationship in this case is built on mistrust and not trust. Each partner does not believe that everything is at stake in keeping the relationship going since there are alternatives. The current practice is to find suitable partners for the alliance and give the best towards making it a success. In the words of Mark Twain "Keep

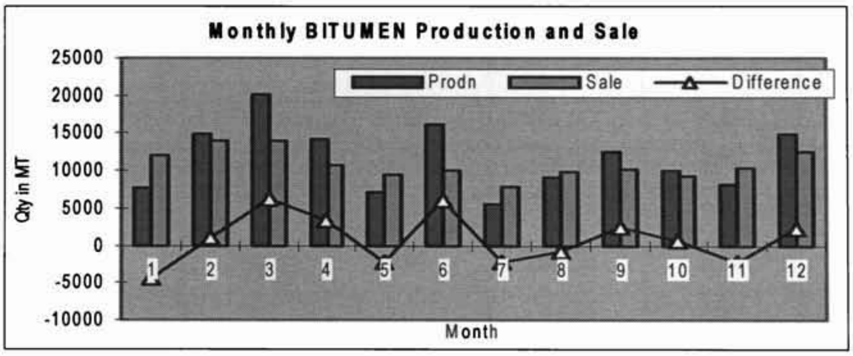


Figure 6.23 BITUMEN production and sales

all your eggs in one basket and watch that basket. Instead of keep all your eggs in different baskets." KRL should try to zero down on fewer marketing partners.

This study is also limited by the fact that the data of product dispatches to take for as representative of market demand. This assumption could be very wrong, since OMCs have significant storage capacity in the distribution network and product off takes could have been for storage purpose in a month. KRL should ask for actual demand data from its marketing partners and together work out a strategy for production planning that helps in keeping the product inventories low, since storage and carrying cost in this business is high. KRL is not far behind in aligning production with demands as in the case of HSD because of the force to do so because of less storage capacity.

6.3.4.2 Storage of Products

The storage of all products except LPG is done in tanks in the tank farm. There are tanks assigned to each product. LPG is stored in spheres. The details of the storage facility available and its adequacy as per OCC norms is indicated in table 6.8. The calculations have been done as per the norms followed by KRL. From the table it can be seen that storage facility at KRL is inadequate for MS, SKO and HSD. It is worth noting that the storage capacity of HSD is nearly half the required amount now. The storage requirement becomes inadequate in the case of LPG also if shutdown is considered. Even if the storage capacities with the Oil Marketing Companies (OMC) at Kochi is taken, the storage capacity of HSD is still inadequate.

Table 6.8 Gross tankage requirement for controlled products in Million Tons

Product Stored → / Gross Tankage Required ↓	LPG	MS	SKO	ATF	HSD
DFR Prodn. level	4.95	51.28	59.50	4.49	222.65
DFR level for shutdown	18.98	47.48	75.90	5.23	228.93
Current Prodn. level	5.57	71.20	60.87	5.71	295.22
Tankage Available KRL	8.84	60.69	50.00	6.56	133.90
OMC Tankage at Kochi	0	37.30	23.28	0	72.87
Total Kochi Tankage	8.84	97.99	73.23	6.56	206.77

Table 6.9 Gross tankage requirement for de-controlled products in Million Tons

Product Stored → / Gross Tankage Required ↓	LAN	HAN	LDO	FO	LSHS	BITUMEN
DFR Prodn. level	25.17	49.79	0.55	70.66	22.18	8.11
DFR level for shutdown	13.88	49.86	1.89	97.88	25.67	20.70
Current Prodn. level	59.26	37.81	4.22	64.23	40.70	5.24
Tankage Available KRL	28.97	32.27	3.63	46.37	42.91	12.72
OMC Tankage at Kochi	54.33	0	4.00	27.90	0	0
Total Kochi Tankage	83.31	32.27	7.63	74.27	42.91	12.72

Table 6.9 shows the storage tank requirement and capacity available at KRL and OMCs at Kochi for de-controlled products. A look at the table shows that there is insufficient storage capacity for LAN, HAN, LDO and FO at KRL. Even after considering storage capacity of OMCs at Kochi, the storage capacity is not enough for HAN when normal operations take place at current production levels. This problem is more serious for HAN, FO and Bitumen when shutdowns period is taken.

Recommendations

From the above discussion it is clear that additional product tankage is required. This requirement will only increase with MDPM coming in full effect, because or more jerky product flow resulting from free pricing. An immediate solution to this problem is to crash the time required for tank inspection and repairs. This will increase tank availability in the short term.

6.3.4.3 Despatch of Products

Products are dispatched from the refinery by Pipelines, Rail Wagons or Trucks. Products are also dispatched by sea in Tankers. In the sections below each one of these are separately presented.

6.3.4.4 Despatch by coastal tankers

KRL is located at a port town in the south of India. The location of KRL is ideal for getting crude supplies and for dispatching products by sea. The product demands are distributed throughout the country. For inland and local movement other means of transport have to be used. Since ship transport is most economical for bulk cargo movement, coastal tankers are used to move products to areas where there is greater demand. The major disadvantages associated with coastal tanker transfer of products are **(i)** tankers carry large parcel size ranging from 25,000 T to 45,000 T of product. This necessitates build-up of more inventories of products for making use of this facility. There fore it may be noted that the amount of storage facility required for products moved by tankers will be comparatively higher. **(ii)** The flexibility of cargo movement is severely constrained by ports and the facilities they can provide.

KRL has three product pipelines from the Tank farm at the plant to the Jetty at Kochi Port. One of these lines is used for black oil and the other two are used for white oil pumping. The major products that are dispatched via tankers are HSD, Naphtha, MS, SKO, FO and LDO. Data was collected for monthly transfer of these products for 1998-99 and made separate graphs for each product. The purpose of this is to study the pattern of different product movement by this route. The graph below shows transfer of MS by tankers. From the figure 6.24 it was evident that around 20,000 to 30,000 Metric Tons (MT) of MS was sent every month by tankers. The graph regularly shows a zigzag shape meaning that a 30,000 month will be followed by a 20,000 parcel month, which will be followed by a 30,000 Tons MS parcel month and so on. The exception to this general rule is months that have very low production (possibly due to shutdown). The graph that is presented in figure 6.24 is on monthly dispatch of Naphtha by tanker. The graph shows that Naphtha shipping by tanker is a regular affair with quantity shipped being between 20,000 to 60,000 Tons. The average tends to be around 35,000 Tons.

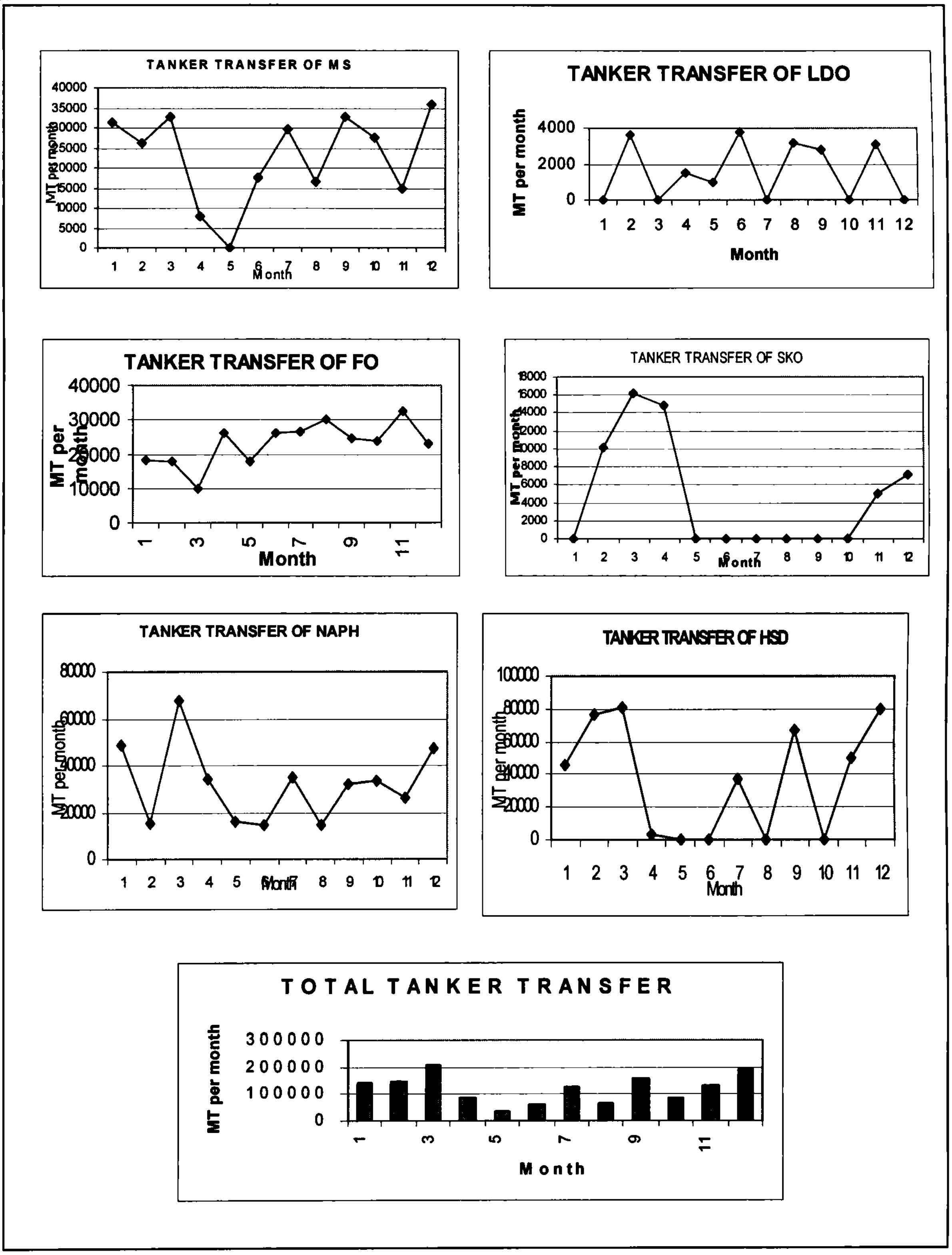


Figure 6.24 Tanker transfer of each product

In figure 6.24 shows the monthly dispatch of HSD by coastal tankers. The parcel size is seen to vary between 40,000 to 80,000 tons. However in some monsoon months this movement is nil. It was seen earlier that the storage capacity for HSD at KRL is low. If coastal tanker movement is planned and there is late arrival of tanker KRL will have ullage problems. Therefore, monitoring of tanker movement is very critical for operations. The next figure depicts the monthly dispatch of SKO by sea. Transfer can be seen to be higher during the first half of the year. There is no SKO movement by sea during monsoon months. The typical parcel sizes are 5,000 10,000 and 15,000 Tons. Since these parcel sizes are uneconomical for sea transport if done alone, product tankers coming to take other products should take this also.

Figure 6.24 shows the monthly transfer of FO by sea. This can be seen to be more regular. Quantities between 20,000 tons and 30,000 tons are being shipped in most months. This graph also shows monsoon does not have any effect of this pattern of shipping and also that in the second half of the year more quantity is shipped. The graph of LDO shipped given below shows that, small quantities of LDO ranging from 1000 tons to 4000 tons is shipped this is to meet the bunker fuel requirements of tankers. The last graph in this series shows the total monthly product movement by sea. From this graph it is clear that in the first quarter of the year movement is much higher. April, May and June were months with very low transfer of products by sea. A maximum of 200,000 tons of products was dispatched by sea during 1998-99. There is evidence of unutilized capacity for product movement from berth occupancy at STB and NTB. Increasing this route of product movement though less expensive in terms of freight will necessitate the augmentation of product storage facility to take care of slips in the large parcels that are planned by tankers.

Recommendations

Currently KRL does not involve itself much with product tanker movement since OMCs take care of it. Tanker schedules for movement of products have to be watched closely since, KRL does not have enough tankage to hold the large tanker parcels in stock for too long in case tankers do not come on time.

6.3.4.5 Despatch by Wagons

The largest share of the products produced is dispatched from KRL by railway wagons. At KRL the wagon loading facility consists of four gantries where about 37 wagons each can be placed. Wagon loading facility is used for the dispatch of MS, SKO, HSD, FO and LSHS only. The important steps in loading of wagons are listed below.

1. Vacancy position of the wagon-loading gantry is reported to Irumbanam yard, from where half the rake (nearly 37 wagons) is pushed into the loading gantry. The railways are given about 40 minutes for this.
2. The wagons brought have to be shunted properly with additional gaps between every three of four wagons, so that the filling arms are in correct position. This is required because the gantry was designed for a rake with the old type of coupling, which has been replaced by a new shorter one by the railways. This requires about 30 minutes.
3. After the wagons are placed IOC gives KRL the wagon loading memo containing the wagon numbers, their capacity, the product to be loaded in each with the quantity and dip required noted for each wagon.
4. Based on this the KRL supervisor of wagon loading prepares wagon-loading lists to be given to the workers for filling of wagons.
5. The workers then close the bottom and master valves of all wagons and start to fill the wagons to the dip readings required, care is taken not to overfill.
6. Once filling is over, the IOC and KRL personnel jointly inspect the wagons. Dip readings are taken and topping up is done wherever necessary. The filling pipes and bridges will then be removed and the wagons sealed.
7. The railways are now informed that wagons have been filled and are advised to remove the filled wagons. For this they are given 20 minutes. The time allowed between placement of wagons and reporting to railways about filling over is 300 minutes. If KRL exceeds this an hourly demurrage of Rs.200 per wagon has to be paid by KRL to the railways.

Recommendations

There is need to increase loading of wagons. It was noted during the study, that the operations at the wagon loading yard has since long fallen into a very set pattern of work division between various shifts. Almost everyday operations take place in the same cycle; this convenient arrangement has resulted in a situation that it becomes difficult to improve since, all have adapted to this system and therefore find the present system better. An incentive scheme to motivate personnel to break the old set pattern is one of the options that could be thought of. The first thing however, that will have to be done in this connection is a detailed study of the wagon loading operations to find ways of reducing the wagon loading cycle time.

It is also to be noted that bad wagons are often placed and have to be later taken back without filling. This should not happen. Checking of wagons and their shunting off must be done at the Irumpunam yard itself. This not only decreases the off-takes by wagon it also results in loss of time of loading facility that could be utilized for filling good wagons.

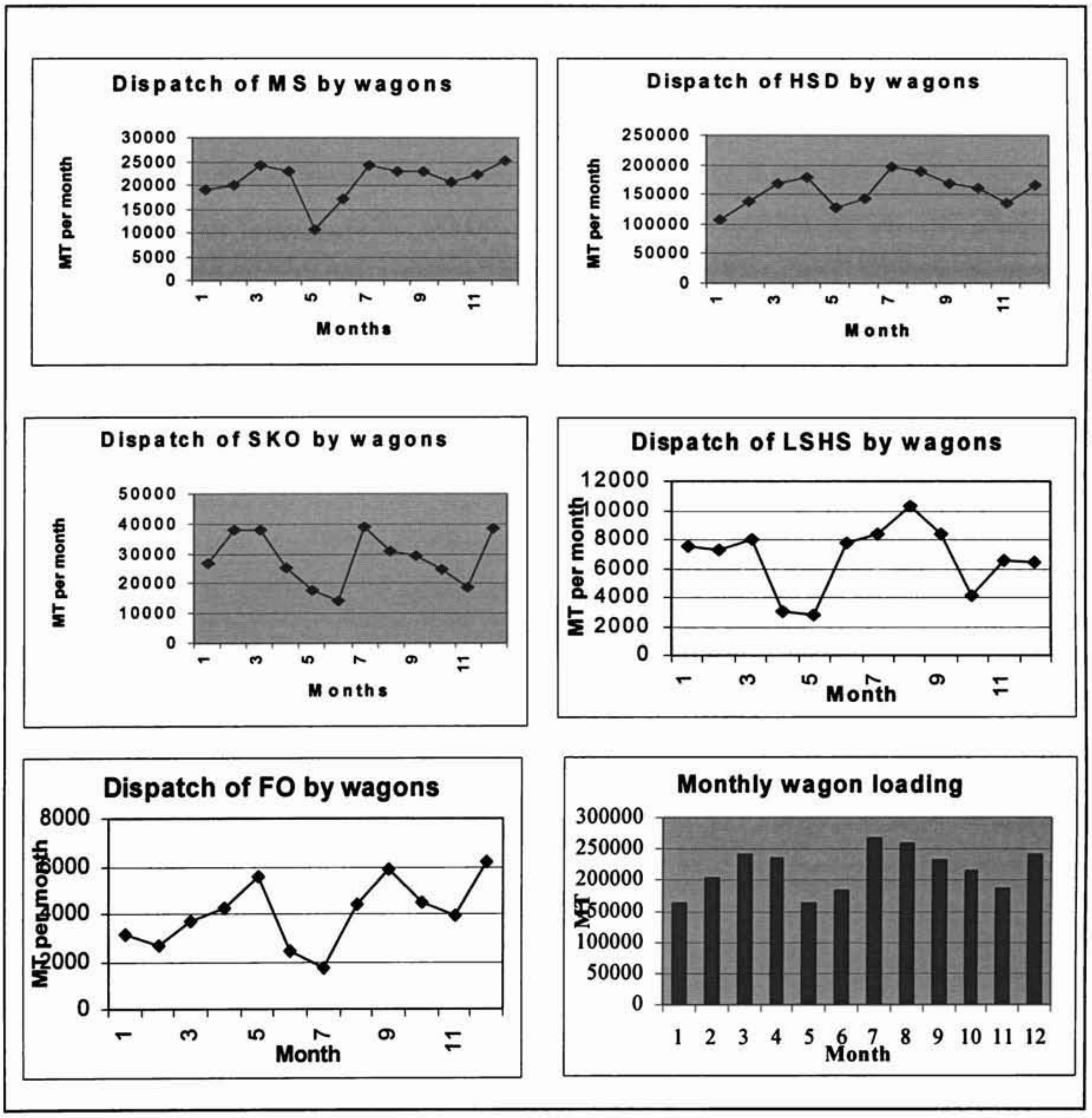


Figure 6.25 Despatch of products using wagons

In order to understand the product portfolio dispatched by wagon and its seasonal variation, wagon dispatch data for 1998-99 was collected and analysed. The figure 6.25 shows the quantity of MS dispatched by wagons during 1998-99. From the graph it can be seen that around 20,000 to 25,000 tons of MS is dispatched by railway wagons every month. These figures become lower only in months when the production is lesser. The next graph presents the tonnage of SKO dispatched every month by wagons. This shows clear seasonal variation with two cycles. The quantity dispatched varies from 12,000 tons to 40,000 tons per month with highs around March and in July the lows are in June and November. The graph that is presented next is about the dispatch of HSD by wagons. This is without doubt the product that is handled in the largest quantity. The monthly dispatch of HSD ranges from 1,00,000 tons to 2,00,000 tons per month. There is seasonality to be seen here also with peaks in April and July. The graphs for transfer of FO and LSHS by wagons are given bellow. The quantity of FO dispatched varies from 2,000 to 6,000 tons while that of LSHS dispatched is higher and is between 2,000 and 10,000 tons.

In order to show the total load of dispatch at wagon-loading the graph showing the total monthly product dispatch by rail from KRL is given. This clearly shows a tendency of peaking towards mid year except that in May and June of 1998 when production was low the dispatch of products were also correspondingly lower.

6.3.4.6 Despatch of Products by Road

Almost all products produced at KRL are dispatched by the road route though in smaller quantities. The graphs showing the dispatch of different products by road in 12 months of a year are shown in figure 6.26.

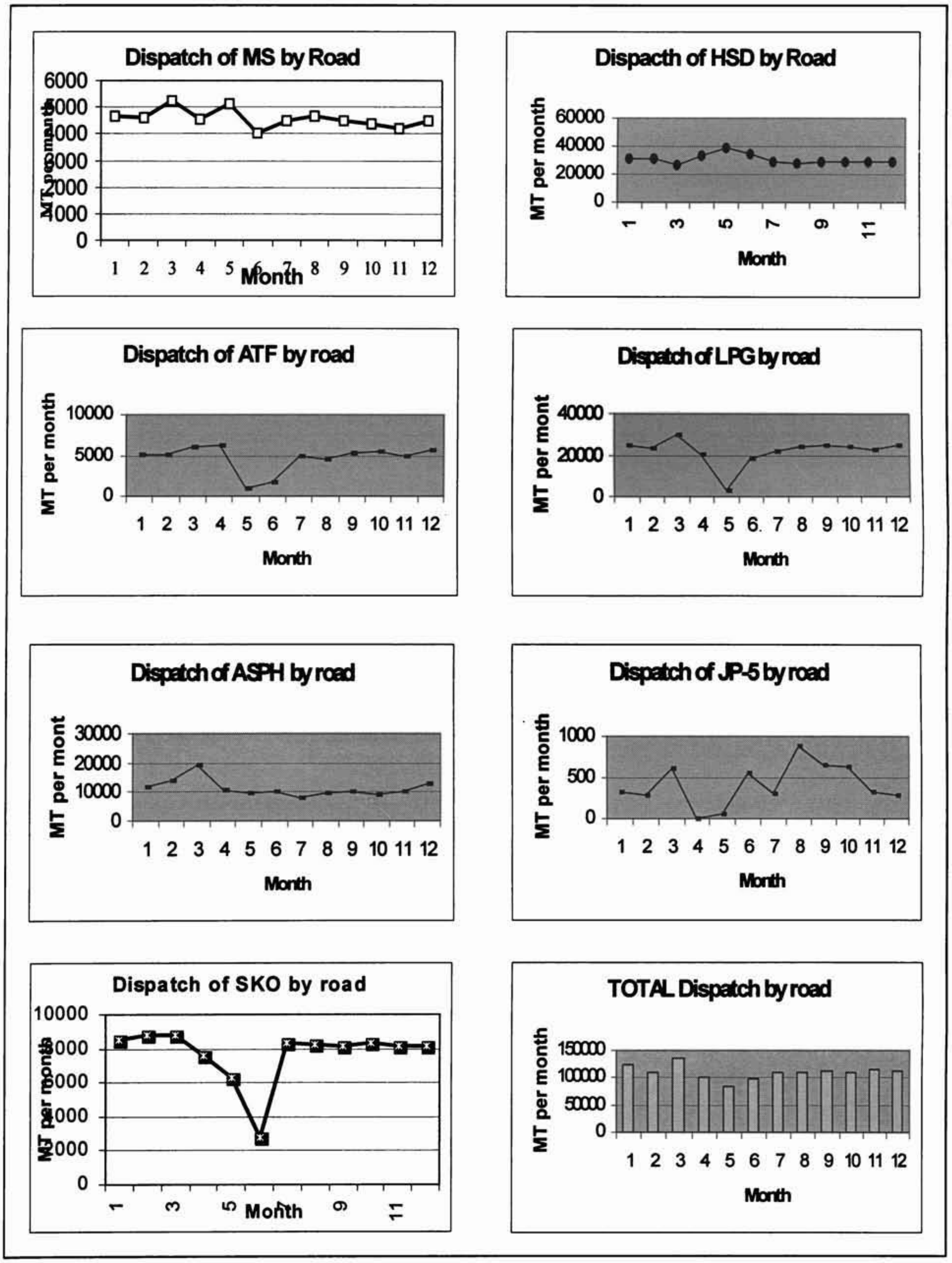


Figure 6.26 Despatch of products by road *contd...*

From the above graphs it is noted that each product has its own peculiar dispatch pattern for the year, and that no two pattern is the same. The total dispatch is however seen to be steady around 1,00,000 tons per month. This could mean that truck loading is a bottleneck, and that, only when the loading of one product goes down it is replaced by another leading to the total loading being nearly the same. Data to check this could not be obtained.

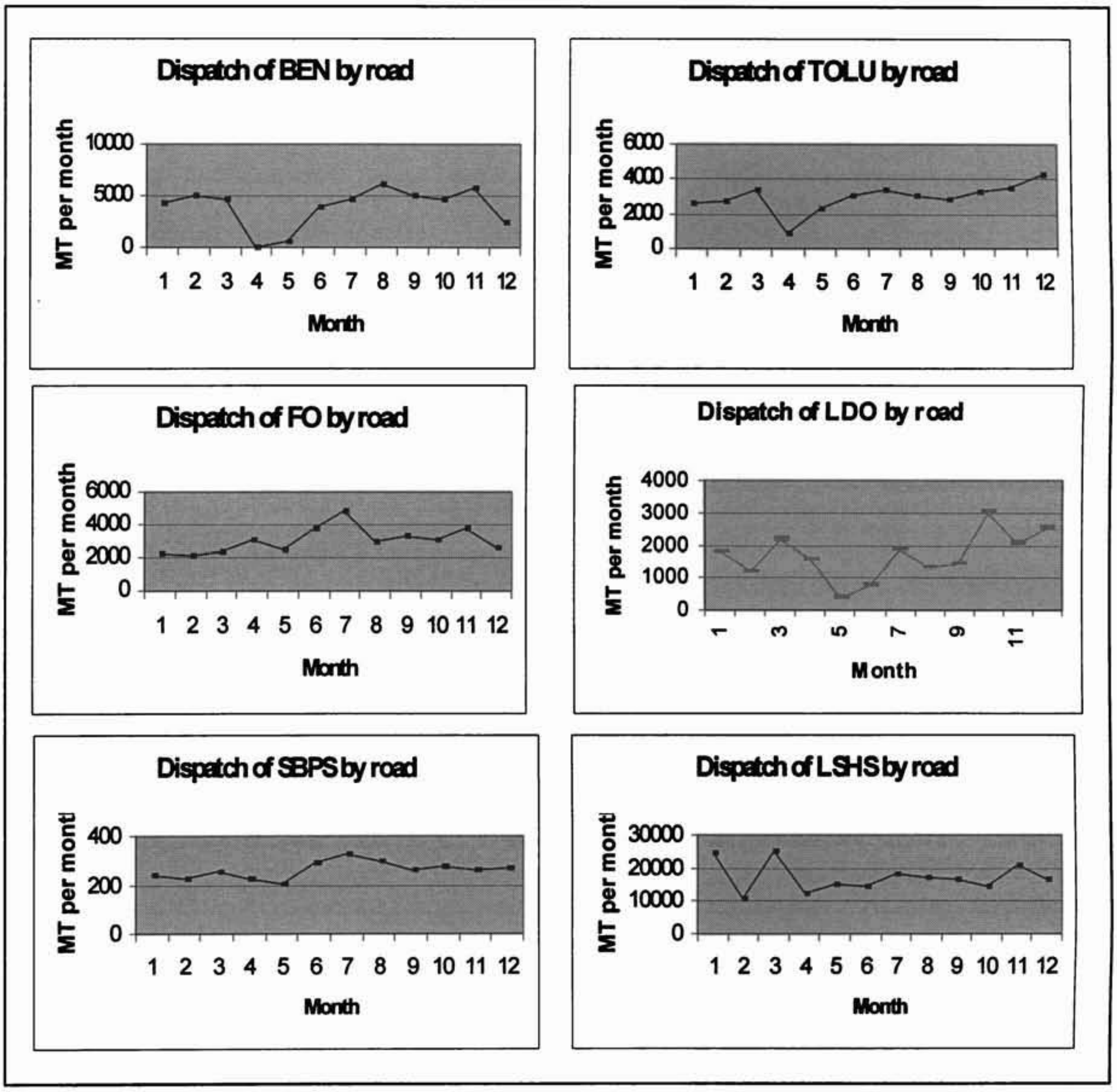


Figure 6.26 Despatch of products by road

With the new truck loading facility up and in use the loading per say seems to have enough capacity as can be seen by the utilization figures of this facility. In light of the automation of truck loading a detailed study has to be done of the complete truck loading operations to locate the bottleneck and decongest it. Indications from the observations reveal that the time before and after loading is still comparatively high. This leads to less utilization of the loading facility. The norms for regulating the inflow of trucks for loading have also to be revised. The bottleneck if any at IOC side in issuing loading memo should also be looked into. The data regarding truck loading available from the new computerized setup was used to make some graphs to show some critical characteristics of the truck loading facility.

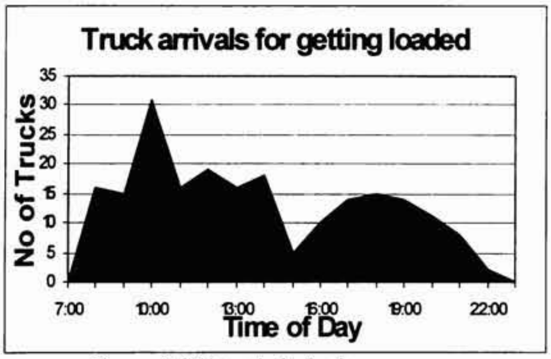


Figure 6.27 Truck Arrivals

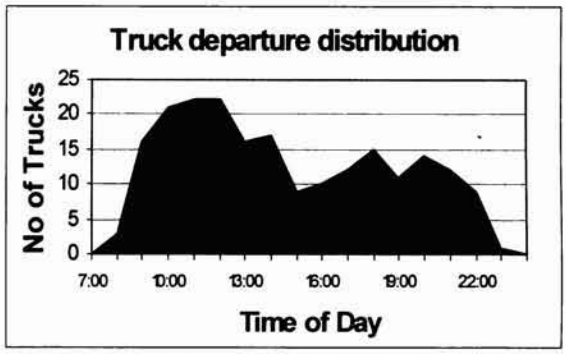


Figure 6.28 Truck Departure

From the figure 6.27 it is clear that Truck arrivals are regulated by the security to follow a peculiar fashion. The arrivals start at 7.00 am and pick up about 8.00 am they reach their peak at about 10.00 am. From 13.00 hrs the incoming of trucks are regulated for shift change at 15.00 hrs. In the evening shift the arrivals do not change abruptly and is steady but the overall number of trucks coming then are much lower than in day shift. The truck departure (figure 6.28) distribution also shows a bulge in the day shift indicating that more trucks depart then.

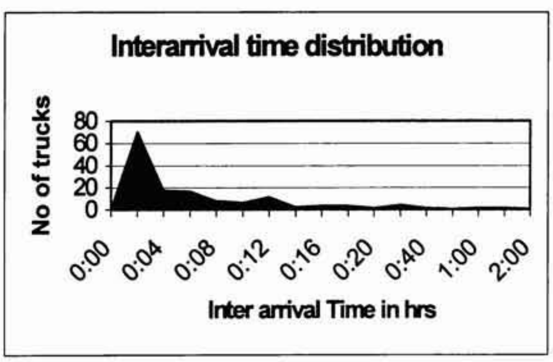


Figure 6.29 Inter-arrival time

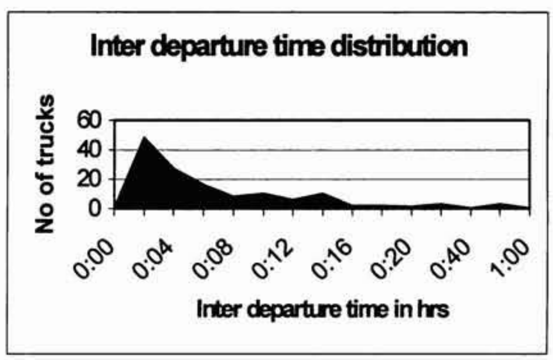


Figure 6.30 Inter-departure time

A study of figure 6.29 and figure 6.30 show that both these follow nearly the same pattern this is not natural. Here the graph is like that since the arrivals of trucks are regulated by the security and only a fixed number of trucks are allowed in for loading at any given time. A better system would have a large peak nearer to 0 and the tail would be minimum indicating that delays in inter-arrivals and inter- departure are uncommon.

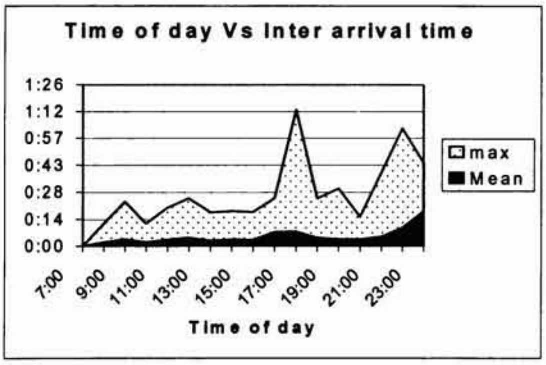


Figure 6.31 Time Vs Inter-arrival time

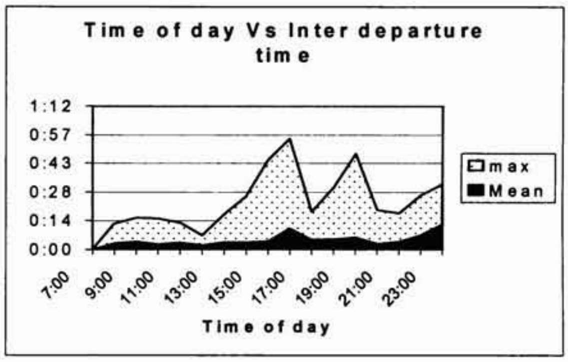


Figure 6.32 Time Vs Inter-departure time

Figure 6.31 and 6.32 shows the difference between the minimum and maximum inter arrival and inter departure times during the day are useful in understanding the variability in the system which is not shown by the mean value graphs shown earlier. This variability should be minimum, since high variability leads to poor service quality. The inter-arrival distribution shows that the difference between minimum and maximum is the highest around 17.00 hrs. This is because at this time the general shift ends and truck movement is restricted to allow personnel carrier movement. This clearly indicates a wrong long-term strategy adopted by KRL to use a common gate opening to a common road for both personnel movement and dispatch of products. Problems due to this are

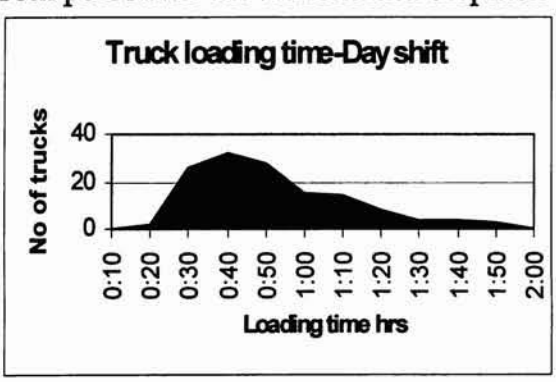


Figure 6. 33 Truck loading time

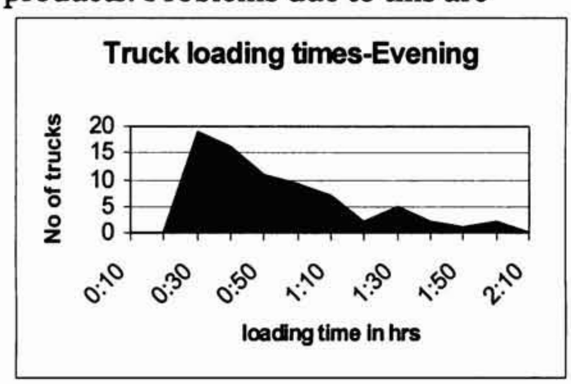


Figure 6.34 Truck loading time

only going to increase in the future. The inter-departure time max shows two peaks one at 15.00 hrs corresponding to shift change and the other at 19.00 hrs. Now, since the new computerized system has got installed the conventional 45 minutes stop of loading can be reduced to around 15 minutes. With the facilities available even shift change without stoppage of truck loading operations may be possible.

Figure 6.33 and 6.34 shows the loading time distributions in the Day shift and the evening shift. From the graph it can be seen that loading time starts from 20 minutes peaks around 40 and is negligible after 1hr 30 minutes during day shift. In the evening shift however the performance is poorer with the minimum being 30 minutes peak at 45 minutes and a larger portion of the distribution after 1hour 30 minutes. This could be because the pressure for loading is seen to be less during the evening. Then the principle "the given work expands to fit the time available" applies.

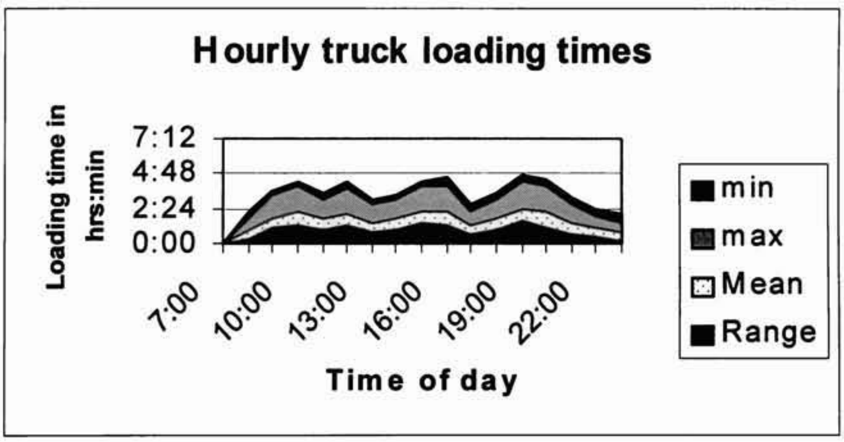


Figure 6.35 hourly truck loading time

From the figure 6.35 it can be seen that the minimum and mean truck loading times is nearly the same during different times of the day. However varies very much is the maximum time required for loading a truck. This variability is an indication of poor service quality. The data collected for the study was for April 1999 and many truck drivers and assistants were getting used to the new system installed therefore the maximums could be higher in the period concerned. But, this is a key parameter to be monitored in future also to see how effective the truck loading implementation has been and whether it has stabilized completely.

Recommendations

From the above study no bottle necks were identified at the truck loading facility. This is shown by the low loading bay occupancy and utilization figures. The bottleneck therefore, should be in the transaction part before or after loading. KRL has already made most of the investment required in setting up the new truck loading facility. This has to be utilized well to increase the return on investments. The utilization of this facility is currently low because of procedural bottlenecks before and after loading. Locating these bottlenecks and removing them will be a challenging task for a manager. This will not require much in terms of investment. Different agencies such as IOC, KRL security, and people at truck loading are involved. The complete process from natural arrivals of trucks in the parking area to their filling and departure has to be studied in detail in collaboration with IOC and the transaction processing bottlenecks found and removed.

In projects such as truck loading the importance of facility design for better new operations is important. Designers concentrate on finding out what facilities will be required and in making them available. The fact that these facilities are not independent of each other and that they will have to be stringed together for smooth operations is many a time forgotten. The result being that the increased difficulty in operation so created has to be borne throughout the life of the facility. Thus the operation cost that is recurring goes up or efficiency goes down doing permanent damage. KRL is good at project selection evaluation and finalization of contractors. But, then it seems people loose interest and project implementation attracts less attention. The testing and commissioning though a very important activity is not that well planned and executed. To highlight the point it can be discussed some issues related to the truck loading facility that should have been solved at design stage itself.

- The truck loading control room is on the first floor requiring truck drivers to come up and supervisors to go down often. The waiting space on the first floor is also limited. The air conditioning requirement on the first floor is more. The view to the truck top from the first floor is obstructed since the truck loading gantry roof and other construction comes in the line of sight. The view of the personnel on truck top is better from the ground floor. Hence locating the control room in first floor does not help much.

- The layout of the control room is such that the officers working there have to be constantly move around from one end of the room to the other resulting in higher transaction time, fatigue and confusion. This could have been reduced by better facility design taking into account the operations involved.

The possibility of a new separate entrance for truck loading is to be probed. This new entrance could be made, breaking the wall opposite the present truck parking area. At present the number of trucks loaded every hour changes very much with time. If this is due to the non-availability of trucks that have come for loading it is understandable, but this is not the case here. This uneven pattern is the result of the complex interaction of IOC issuing the loading memo, security regulating the traffic and truck entry to KRL, familiarity of the drivers and helpers with the new truck loading system, and the working pattern of personnel and officers at Truck loading. Efforts have to be taken to have a more regular product loading and dispatch pattern in place. Work-study will be helpful in identifying the bottleneck operation involved here. The shift change over times can also be reduced with the new system. An attempt has been made to compare the handling loss figures or the periods previous to installation of mass flow meters and post installation to find if handling losses had reduced because of better measurement by mass flow meters. However, the comparison gave no conclusive evidence. This is believed to be so because of the lack of correctness of the reported figures.

6.3.4.7 Pipeline transfers

Products such as LPG, MS, SKO, HSD, Naphtha, LSHS, FO and LDO are transferred to HOC and the depots of the OMCs by pipeline. The volume of products transferred by pipeline is about one fourth of the total dispatch. In order to understand the product dispatch pattern. The product-wise monthly dispatch graphs presented below, for the year 1998-99 shall be looked into next.

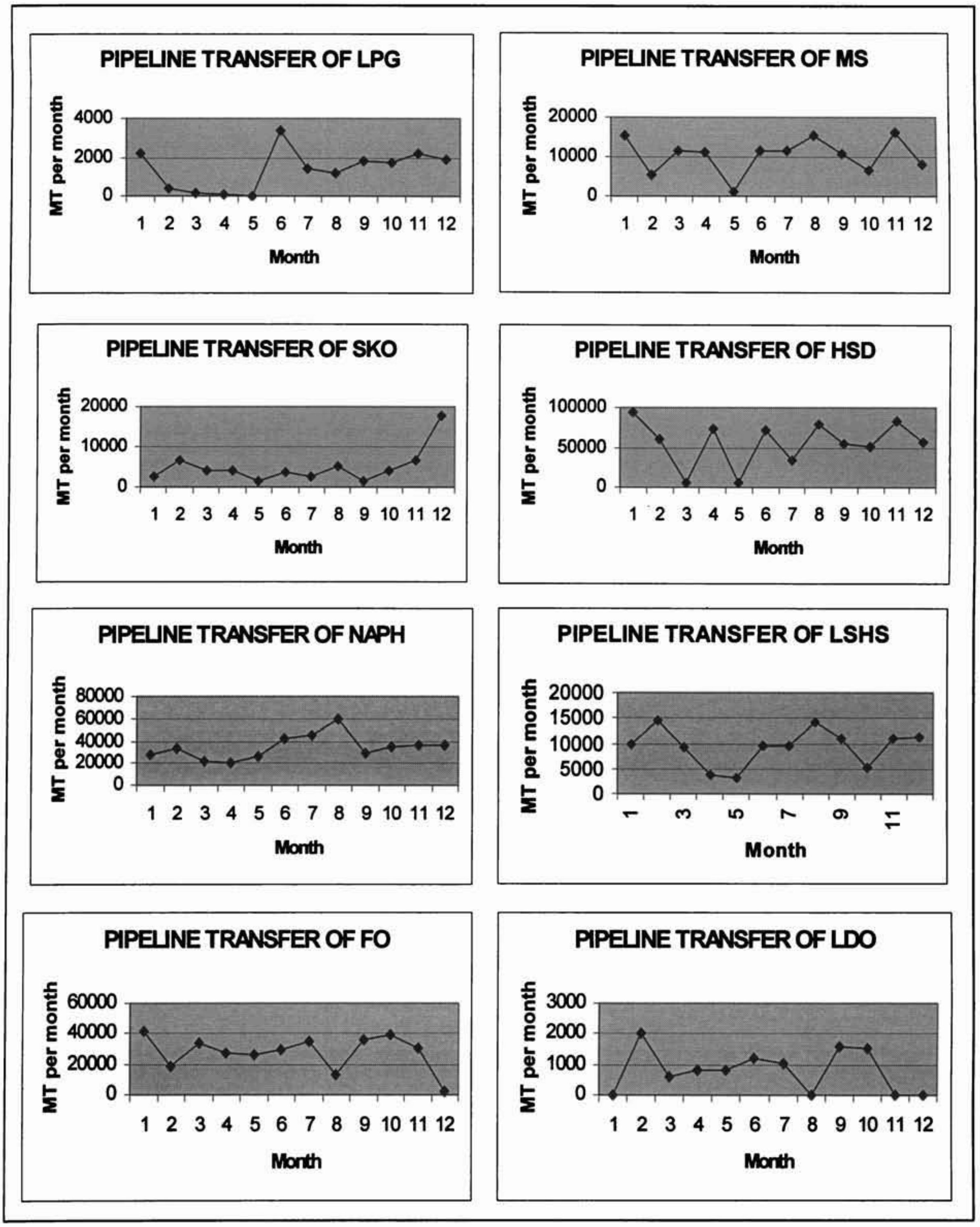


Figure 6. 36 transfer of product through pipeline

A look at the figure 6.36 LPG dispatch by pipeline reveals that quantity of LPG dispatched by pipeline is very low and that it is more during monsoon and winter months. The reading from the MS dispatch graph is that quantity range around 10,000 tons per month with regular ups and downs.

The graph of SKO dispatch shows that it is steady around 5,000 tons per month. A slow peaking occurs during winter with December off-takes by pipeline being three times the normal. In case of HSD transfer it can be seen that there is a clear zigzag pattern meaning that if the dispatch by pipeline were more in a month the next month it would be low the fluctuations are more during March to June.

Graph of pipeline transfer of Naphtha shows that quantity ranging from 20,000 tons to 60,000 tons is dispatched by pipeline every month. More Naphtha is dispatched during monsoon months. The graph of dispatch of LSHS shows that the quantity dispatched is in the range of 5,000 to 15,000 tons with the mean tending to 10,000 tons per month. A clear cycle of period of nearly six months can be seen in this case.

FO dispatch by pipelines is in the range of 20,000 tons to 40,000 tons. There are months where this figure goes much below 20,000 also. The quantity of LDO dispatched by pipeline is between 1000 and 2000 tons per month. Here also, there are months with no LDO transfer by pipeline.

The last graph shows the total product transferred by pipelines. This graph reveals that the total dispatch by pipeline is not steady and that in the first quarter of the year it is comparatively low. Pipeline transfer is more during the monsoon months.

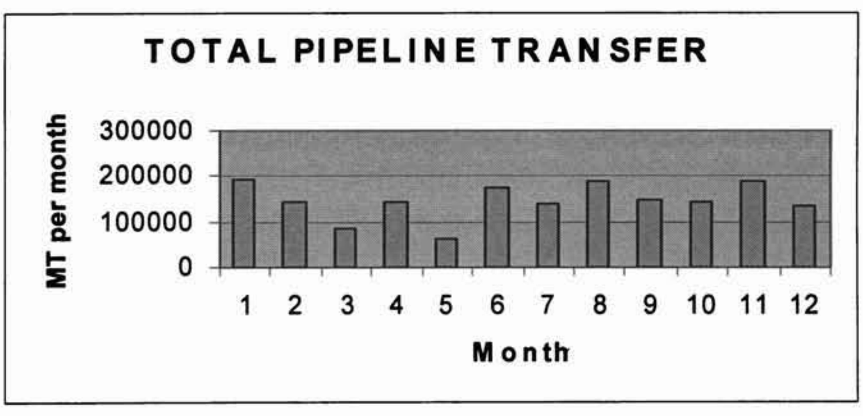


Figure 6.37 Total pipeline transfer

The figure 6.38 shows the relative share of each of the four routes of Rail, Road, Tanker and Pipeline in product dispatch every month. This graph is drawn to see if there is significant substitution of means of transport in some months. The graph shows that road transport is the least. The quantity dispatched by road, rail and sea are more or less uniform throughout the year whereas the quantity dispatched by pipeline takes the beating if the total quantity to be dispatched in a month is low.

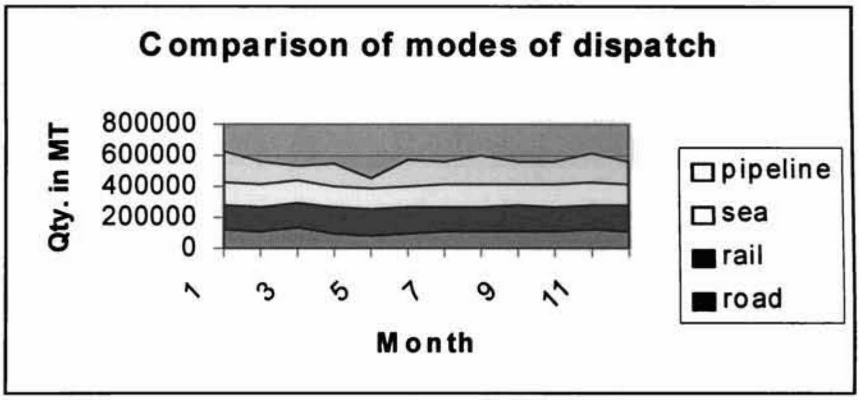


Figure 6.38 Quantity transferred through each mode

Recommendations

The main recommendation dealing with pipeline transfer is that a mechanism of data sharing regarding the ullage available at OMCs depots and dispatch planned must be developed and put in place. This will allow greater flexibility of operations.

6.4 Conclusion

It was proved beyond doubt that crude handling operations, especially the limited crude pipeline capacity is the most serious bottleneck at KRL. Four temporary solutions are suggested were **(i)** Use of drag reducers' **(ii)** Getting suezmax tankers to bring crude and **(iii)** Using the black oil pipeline available to pump in crude when it is not in use for product movement. **(iv)** Install a booster pump in the crude line at the pit-head at the KRL tank farm this will boost pressures from there and will take up the pressure needed to pump the crude into the tanks. The permanent solution to this problem is the Single Point Mooring system that KRL is currently examining. From the past freight data for crude tankers it was seen that R N Tagore, Iswari, Sravanan, BC Chattergi, and S Sarma are relatively more expensive and hence they should be avoided. A peculiar thing noticed was that all foreign crude tankers had lower than average discharge rates, this should be looked into. Other SCI vessels with low discharge rates should also be avoided. The simulation experiments of crude unloading operations show that the cost of unloading operations goes up linearly if more than sixteen tankers bring crude every month.

Crude tank inspection and repair takes a very long time leading to loss of tankage. The loss of tankage on this count is from one third to one fourth the total built up tankage. This will have to be reduced to improve tankage availability. The arrival of crude was such in most months, that one type of crude was there in very high quantity at a given time. A comfortable stock of BH, PG-HS and PG-LS crude was not steadily available throughout most months, limiting processing flexibility. The crude stock build up for monsoon was done too early, the months of March, April and May should be used for it.

It was found that refining is the strong point of KRL. Production and dispatch of most products are well aligned therefore inventory build-up was not very high (this could be because KRL is forced to align production and dispatch because of low product storage facility available). The product tankage requirements for KRL are not sufficient for most products this is most critical for HSD. There is automatic tank gauging system in place, now that was being utilized to a great extent. However, procedures many a time requires manual gauging to be still done, this should be reduced and manual gauging should only be done for calibration and accuracy checking of tank gauges periodically. It was seen that wherever manual blending was done as in KRL only a few regular blending options were tried out. This limits the gain that could be obtained from blending operations. Manual blending offline also requires more tankage for storage. The plan of KRL to go for on line blending systems is a good step in overcoming this problem.

Product dispatch by tankers is crucial for KRL, late tanker arrivals will result in ullage problems, and forced reduction of refinery throughput. Hence KRL should more closely monitor product movement by tanker. A system of sharing data regarding product tank positions between OMCs and KRL can go a long way in enabling KRL to lessen the problems it has due to limited product tankage.

The operations at wagon loading need to be improved. With some streamlining done the amount of products dispatched by this route can be increased. The problem in this area are mainly Human Resource related. There is also the problem of bad wagons coming for loading that has to be sorted with the railways and a solution to the same found.

The new truck loading facility is currently underutilized because of process bottlenecks in the procedures before and after loading. This has to be studied in detail and measures to remove the bottlenecks found and implemented.

The accounting departments face problems because they have to rely on figures of stock and sales reported by Stock and Oil Movement and Computer and Automation departments. These figures are often inconsistent and require modification later. The need to re-key this data in different computers because of lack of an integrated information system is a serious problem here. With changes taking place so fast people need to be trained in areas such as International finance, Oil market operations and shipping and related rules to handle problems in these areas effectively.

CHAPTER VII

Summary, Conclusion, and Scope for Further Work

7.1 Introduction

Objective of the research was to make a detailed study of supply chain management problems for a typical Indian refinery. Methodology used for the study was splitting the problem in to small modules of structured, semi structured, and unstructured parts and then finding suitable solutions for the problem. All those solutions were implemented together with suitable linkages to get the final integrated supply chain for a refinery. The methodology was suitable for finding the solutions and it was established by the application to an existing refinery. Logistics of a refinery is a complicated subsystem in its supply chain. This was studied in detail. The study was started at the beginning of Government decontrol of petroleum industry. Complete decontrol is not yet over. So its impact is not yet completely clear to the industry.

7.2 Summary

Existing literature on SCM related to the present work was reviewed and is given in chapter two. It revealed the scope for SCM application for a refinery. Though many works had been carried out, an integrated approach was not found. Efficiency of SCM is on the integration of supply chain operations. Present work is in the direction of integrating all the operations using information technology. As per the literature, location is the most important factor for a refinery logistics. To identify a location for a refinery, the knowledge on the petroleum refining, quantity of crude oil available, transportation of crude oil, trade practices, place of availability of crude oil, place of consumption of crude oil and products, mode of transportation, pricing mechanism, and methods of refining are essential. So the relevant practices and data were presented in the beginning of chapter three. This gives an insight to the supply chain practices of petroleum refining industry.

The data presented reveals the potential for further addition of refining capacity. For adding capacity the first step is identification of location for a refinery. With that knowledge in trade practices, some locations could be identified all over the world for setting up a refinery. The procedure for selection of location is given below. A method for selecting location for a new refinery was identified. All the locations identified were analysed for the suitability using a pass/fail criteria. At this stage, places which are evidently unsuitable were eliminated. Then the logistic cost for each location was calculated for eliminating with very high logistic cost. Then factors for selection of location were identified. A weightage table was developed for reducing the number of factors. Those selected factors were compared each other and relative score was awarded. Then a preference matrix was developed to find out weightages for each factor. Those weightages were used to compare the locations short listed. From the comparison a weighted score for each location was calculated and location with highest score was selected for starting a new refinery. Once location is finalized, flexibility and configuration plays important role in the performance of supply chain. Flexibility is important because demand pattern changes among products, new products, etc. Areas that require flexibility were identified and the importance of each area was discussed. This is used while setting up a new refinery because flexibility gives more freedom in product pattern and product specifications. Product specification could be made flexible only through proper selection of technology. So the technologies available were analyzed along with their relative cost. A decision on location of refinery, flexibly required, and technology needed to give the required flexibility can finalize the design of a new refinery. Major problem in an existing refinery is related to planning. Next section discusses logistic planning required for a refinery.

Logistic problem was divided in to two stages namely design and planning. Areas, which can not be improved after installation, are design stage problems. Planning is done for both facility design and operation. For improving the effectiveness of planning, it was again sub-classified in to annual plan, rolling plan, and daily plan. Decisions to be taken at each level were identified in the plan zone with respect to inbound logistics, internal logistics, and outbound logistics. A hierarchical planning model was developed for giving a clear picture of decisions to be taken at each stage. This will also give an idea about the source of input data for planning. Source of information can be either from previous plan period or from outside the planning system. Model developed was helpful in maintaining the sequence in planning. Tools required for planning at each stage were identified and separated in to annual planning, short term planning, and daily planning. These were given in table form for the easy reference. Demand forecasting was the first stage in planning. Demand for refined products was not the same every month. It was changing with seasons and socio-economic conditions. So a model was developed to make the forecasting better and more reliable. In the model, consumption of products in the previous years was taken as the input data. A six-step mode of demand forecasting was developed for the implementation in a refinery. Linking of forecast with all planning areas of supply chain was essential for better planning. This six-step approach was helping in achieving it. Crude selection and purchase was another important function in a refinery. Crude selection was made on the basis of product demand and facility constraint in and outside the refinery. Due to the linear nature of the problem a Linear Programming Problem was formulated to solve the problem. Maximizing netback is the objective function. Each refinery will have different set of constraints. An example of Kochi Refinery Limited (KRL) was taken for verifying the application and gain of the models. Bringing crude oil to the refinery was the next important function. This function had a number of variables like tide in the port, seasons, etc. A simulation model was developed for ship scheduling. The model gives the number of ships to be brought and their cost for bringing crude oil. This model was used as DSS for ship selection with minimum demurrage payment to the shipping company. Internal logistics planning procedure was also discussed in this section to reduce starving and blocking of facilities in the refinery. In a refinery, the facilities were tightly coupled so the freedom for flexibility was limited for logistic purposes. Modes of transport for product in outbound logistics were also analyzed and a model was developed for selecting a mode of transport to a particular place for definite quantity and variety of products. These models will help in developing systematic planning procedure in inbound, internal, and outbound logistics. Exponential smoothing method used for calculating demand was found very appropriate and six-step method of demand forecasting was useful for the industry. LPP used for crude oil selection was also found to be very useful for a stand-alone refinery. Simulation model used for ship scheduling can be used as DSS. All these together make the inbound logistic activity of a refinery very strong. Application of information technology in a refinery for the performance improvement in SCM is discussed in the next section.

In a supply chain management system there are three key components. They are information flow, material flow, and cash flow. Success of SCM is the systematic control of all these flows. Standard methods are there for improving material flow. Better technologies are there for faster information sharing and use. Effective banking systems are there for faster transactions. But better monitoring and control is required to reap the benefits of SCM systems. Planning and control functions performed by logistic managers rely on quick and accurate relevant data. Building an Information System for data capture, storage, and use is the pre requisite of a good modern Supply Chain Management System. Information technology is the backbone of integration of information. Information sharing can improve the productivity and reduce level of inventory at all stages. An efficient software system is required to support a well-designed supply chain management system. The software system must have a very good data collection facility from the source of data as much as possible. Single point data entry is the next stage if direct collection is not possible. Software system model must support all the functions in the refinery. The main functions in a refinery are process control and monitoring, operations management, and business management. Identified key features of software system must be there in the software to be finalized. The strength and utility of any software system is the integration of all functions in a refinery. In other words dispensing retail outlet to crude oil and chemical suppliers must be integrated through communication systems to improve the quality of service and reduce the working capital requirement. This will improve the profitability and competitiveness of a refinery. All the processes were subdivided in to small subgroups and information required and generated was analyzed. All those sub groups were joined together to form an integrated information flow model. This will provide reliable and fast information in decision making as well as for operations. Software available in the market was analyzed and a comparative study was included for taking a decision on selection of information system if a refinery is interested in buying one. All those tools developed and selected were used in a stand-alone refinery. Results of the applications are given in the next section.

All the logistics operations performed by Kochi Refinery Limited were analyzed and suggestions were given for improvement. It was started with the selection of crude oil and finished with the retailer out let. It was proved beyond doubt that crude handling operations, especially the limited crude pipeline capacity was the most serious bottleneck at KRL. Four temporary solutions were suggested **(i)** use of drag reducers **(ii)** getting Suez-max tankers to bring crude **(iii)** using the black oil pipeline available to pump in crude when it is not in use for product movement. **(iv)** Install a booster pump in the crude line at the pit-head at the KRL tank farm. This will boost pressures from there and will take up the pressure needed to pump the crude into the tanks. The permanent solution to this problem is the Single Point Mooring system that KRL is currently examining. From the past freight data for crude tankers it could be seen that R N Tagore, Iswari, Sravanan, BC Chattergi, and S Sarma were relatively more expensive ships and hence they should be avoided. A peculiar thing noticed was that all foreign crude tankers had lower than average discharge rates, and this should be looked into. Other SCI vessels with low discharge rates should also be avoided. The simulation experiments of crude unloading operations show that the cost of unloading operations goes up linearly if more than sixteen tankers bring crude every month. Crude tank inspection and repair takes a very long time leading to loss of tankage. The loss of tankage on this account was from one third to one fourth of the total built up tankage. This have to be reduced to improve tankage availability. The arrival of crude was varying in most months, that one type of crude was there in very high quantity at a given time. A comfortable stock of BH, PG-HS and PG-LS crude was not steadily available throughout most of the months, limiting processing flexibility. The crude stock build up for monsoon was done too early, in the months of March, April and May. It was found that refining was the strong point of KRL. The production and dispatch of most products were well aligned that inventory build-up was not very high (this could be because KRL was forced to align production and dispatch because of low product storage facility available). The product tankage requirements for KRL were not sufficient for most products. This was most critical for HSD. There was automatic tank gauging system in place, which was being utilized to a great extent. However, procedures many a time requires manual gauging to be still done, this should be reduced and manual gauging should only be done for calibration and accuracy checking of tank gauges periodically. It was known that wherever manual blending was done as in KRL only a few regular blending options were tried out. This limits the gain that could be obtained from blending operations. Manual blending offline also requires more tankage for storage. KRL must go for on line blending systems in overcoming this problem.

Product dispatch by tankers is crucial for KRL, late tanker arrivals result in ullage problems, and forced reduction of refinery throughput. Hence KRL should more closely monitor product movement by tanker. A system of sharing data regarding product tank positions between oil marketing companies and KRL can go a long way in enabling KRL to lessen the problems it has due to limited product tankage. The operations at wagon loading need to be improved. With some streamlining, the amount of products dispatched by this route can be increased. The problem in this area will be mainly HR. There is also the problem of bad wagons coming for loading that has to be sorted with the railways and a solution to the same must be found out. The new truck loading facility is currently underutilized because of process bottlenecks in the procedures before and after loading. This has to be studied in detail and measures to remove the bottlenecks must be found and implemented. The accounting department faces problems because they have to rely on figures of stock and sales reported by Stock and Oil Movement, and Computer and Automation departments. These figures are often inconsistent and require modification later. The need to re-key this data in different computers because of lack of an integrated information system, is a serious problem here. With changes taking place so fast people need to be trained in areas such as international finance, Oil market operations, and shipping and related rules, to handle problems in these areas effectively.

7.3 Limitations of the Work

Data collection for the case study was mainly done in the time of Administered Price Mechanism scenario. Changes can be expected in post Administered Price Mechanism scenario. This will change the supply chain system. Distillation process is automated in the refinery under study. So optimization of distillation is not attempted. In the refinery, blending of products is done in the storage tank. Online blending at the time of product delivery is suggested for increasing product flexibility. In blending a lot of research had been carried out and standard practices are evolved. So no attempt is made to optimize blending process. Method for solution to the location problem is derived through a sequence of calculations. The whole problem can be solved using a computer programme and it can be converted to a Decision Support System. It is not tried in this research. Flexibility for refinery is solved as sub-systems of the refinery. Even though it is possible to quantify flexibility, it is not attempted in this research work and is one of the limitations of this work. Attempt to make it an integrated solution was also not done. Technology options for a refinery are taken from the published literature only. A detailed survey of technology may give a better result and the cost for adopting technology also will be more realistic. Crude oil selection problem was solved by using data from a stand-alone refinery. The refinery was not permitting to publish the actual data so realistic data is used to solve the problem. Multiple refineries also can be studied for formulating the problem. In the simulation problem discrete arrival of ships were considered but in real life there can be cluster of ship arrival. Seasonality factors like monsoon are not considered in the simulation problem. Supply chain operations related studies have been related to a single refinery. Marketing and distribution networks have not been studied.

7.4 Conclusions of the Study

Location of refinery has great importance in the SCM problem. Selection of location must consider many factors. So a model was developed for finding out the suitability of location with respect to a few other similar locations. This model will help in finalizing the decision on location. Flexibility must be maximum to compete in the international market. Areas which require flexibility were identified and methods for providing flexibility were suggested to compete in the post APM scenario. Process selection was identified as one of the important factors in setting up of a new refinery. Selection procedure and options available for selection as well as suitability of each process in the Indian context were also discussed.

Planning was divided in to four time periods for improving the efficiency of planning. Planning started with the forecast of demand for products. A mathematical model was developed to improve the accuracy of forecasting. Product demand has bearing on selection of crude oil and crude oil selection is based on many factors. So an LPP was developed for selecting crude oil so as to maximize netbacks. Bringing crude oil to the port of unloading is the next major bottleneck. A simulation based DSS was developed for ship scheduling. The DSS will provide comparison of different ship schedules. Separate planning models for inbound logistic, internal logistic, and external logistics are also developed.

Information technology being the backbone of supply chain management, tools available for use in SCM as well as the suitability of each tool was discussed. An information system model for integrated refinery supply chain management was presented. The whole system was divided in to small operational sub modules and information system for each sub module was developed. Finally all the sub modules were joined together to get the integrated information model for

SCM. A stand-alone refinery was selected for collecting data for analyzing each proposed model. A SWOT analysis was done in KRL to identify the strengths, weaknesses, opportunities, and threats for KRL. Important weaknesses were analyzed in detail. Inbound logistics and outbound logistics were found as week areas and suggestions for improvements were given. Information flow and cash flow were analyzed and some suggestions were given in this thesis. Results of analysis was very encouraging and suggestions for improvement of operations of the refinery is also added in this research.

7.5 Scope for Further Work

The study was conducted in the time of APM dismantling. APM dismantling could not continue in the pace at which it was designed. So the full effect could not be taken into account in this study. When the APM is completely removed, similar study can be done in the future. Export possibility for products can be analyzed in detail after full APM dismantling. Development of software package can be made for the integrated model on SCM and it could be developed as a commercial package, which will be of great use to the petroleum refineries in future for better performance. Scope of strategic supply chain partnerships between crude oil suppliers, refiners, and marketers can all be studied since they are possible in future. Exclusive studies related to possibilities and profits from supply chain partnerships and profit sharing in such partnerships are very relevant. Benchmarking type of study to improve supply chain performance can also be done.

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