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

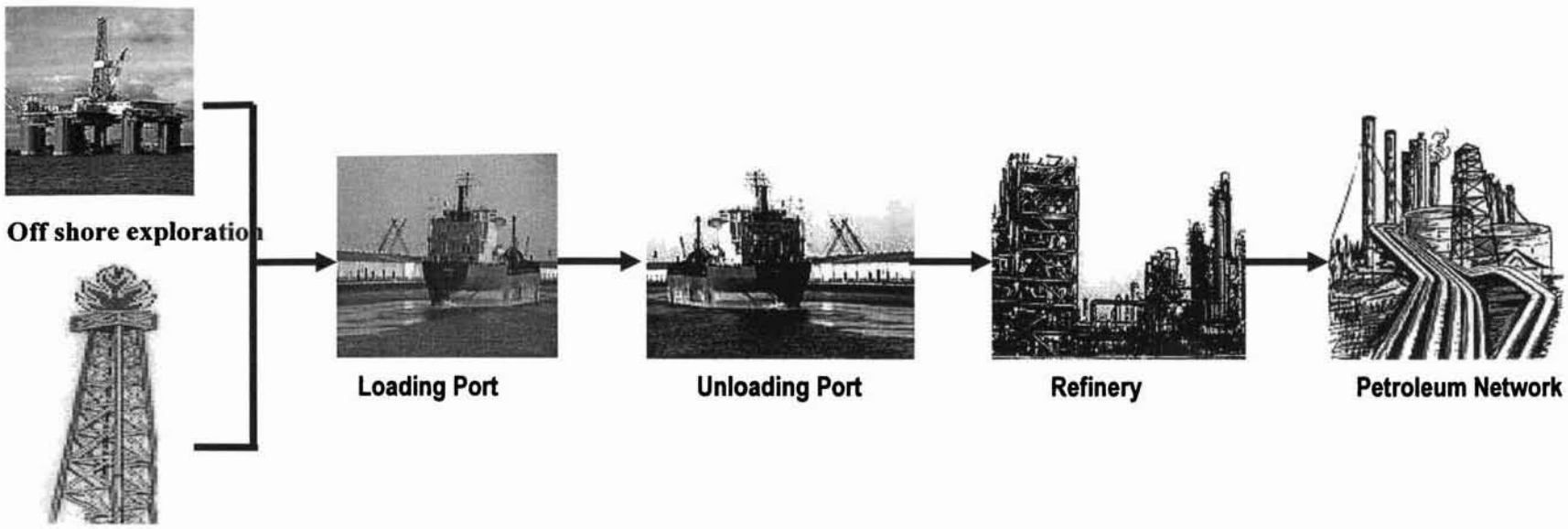
Introduction to the Study

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.

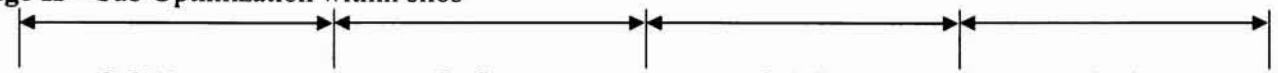
Petroleum refining is a material flow intensive industry where supply chain cost amounts to 40% of total refining and distribution cost. Uninterrupted flow of inputs and outputs including byproducts and wastes with minimum facilities are crucial to cost effective and efficient operation of capital intensive, 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



Stage I - Identification of Silos

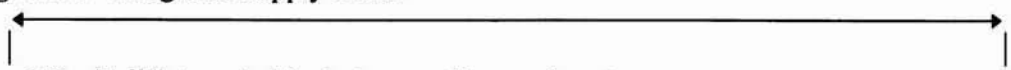
Stage II – Sub Optimization within silos



Stage III a – "Test bed" coordination

Stage III b – " Inter functional" coordination

Stage III c –Integrated supply chain



Stage IV – Full Integrated includes suppliers and customers

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

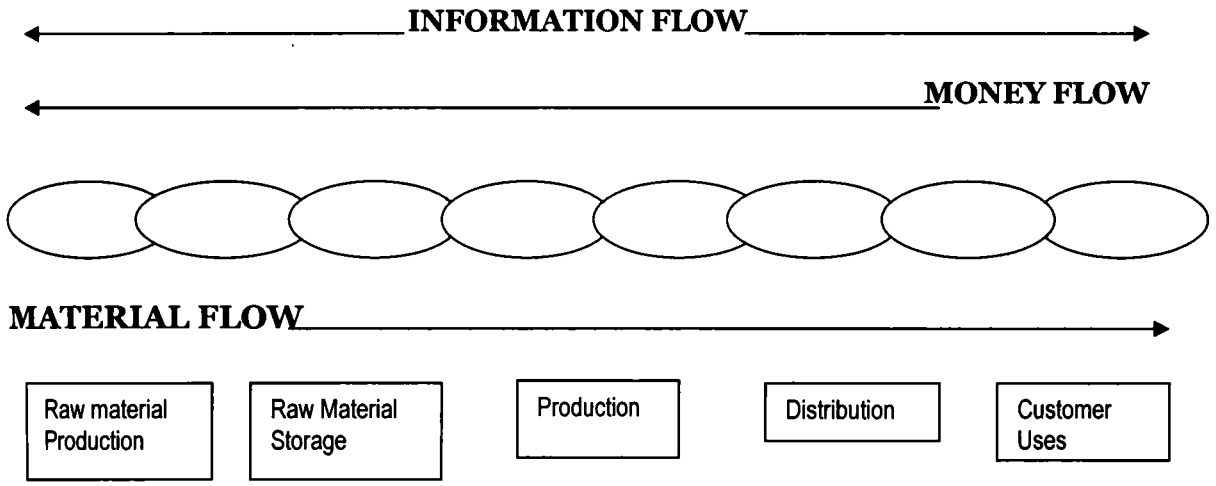


Figure 1.2 Three important flows in a supply chain

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)"

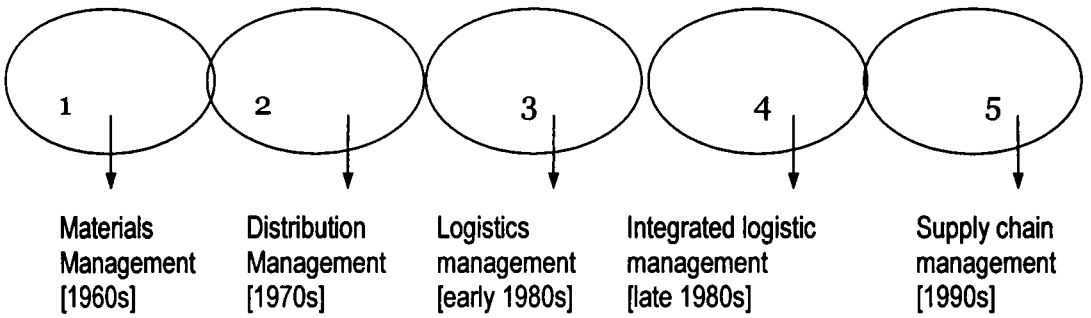
Oliver and Webber [1192] state that the supply chain should be viewed as a single entity that is "guided by strategic decision making". Gentry [1996] included the carriers in supply chain. O'Brien and Head [1995] included governments as part of the chain. Managing the supply chain would include all the 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