CHAPTER 6

TOTAL QUALITY MANAGEMENT
USING
SUPPLY CHAIN SYSTEM
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6.1 BACKGROUND:

The term "Supply Chain Management" arose in the late 1980s and came into wide spread use in the 1990s. Prior to that time businesses used terms such as "logistics" and "Operations Management" instead. Some broader definitions of supply chain as well as supply chain management are preferable, if one wants to maximize the opportunity to improve performance of an organization. According to stock & Lambert (2001), "Supply chain integrates the key business processes of an organization from end user through original suppliers that provides products, services and information that add value for customers and other stakeholders. "Mohuntey and Deshmukh (2004) describe," A supply chain is a network of facilities and distribution option that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products and the distribution of these finished to customers supply chain exist in both service and manufacturing organizations, although the complexity of the chain may vary greatly from industry to industry and firm to firm. A supply chain consists of all the activities starting from industry sourcing of raw materials or components till delivery of the finished product to the customer. Supply chain management is, there lore, the management of these activities so as to maximize benefit to the organization. Supply chain management takes a holistic view of the working of an organization, without getting unduly obsessed with the performance of individual functions.

Relationship between TQM, SCM and partnering

Based on a literature review, some management principles are useful for improving the performance of a company. They include management principles such as process management (Kanji & Asher, 1993; Zairi, 1997), customer satisfaction (Fornell, 1992; Gorst et al., 1998), teamwork (Scholtes, 1992; Tjosvold, 1993), strategic leadership (Edgeman & Dahlgard, 1998; Kanji, 1996; Tribus, 1998), systems thinking (Senge et al., 1994), continuous improvement (Imai, 1986) and scientific management advocated by Frederick Taylor. For a company to perform well, blending together of these various management principles is required. In fact, TQM is a holistic and integrated approach blending together these various principles that are necessary for a company to achieve business excellence. According to Kanji and Asher (1993), because of the holism, TQM can be distinctive in affording a strong philosophical underpinning to its prescriptions. A company which has adopted TQM will normally make use of the total quality principles to achieve business excellence. Within the company, the top management, the middle management and the operational management will work together towards satisfying the needs of the customers. This is the vertical view of TQM as suggested by Youssef et al. (1996) and the concept of internal partnering of Goetsch and Davis (1997).
On the other hand, in order to perform well, a company has to rely on the performance of its upstream and downstream organizations, i.e. there is a quality chain or value chain linking these organizations with the customers. This is the SCM concept, which focuses on integrating the different parties together in order to meet the needs of the customers. This customer and supplier chain concept is similar to the horizontal view of TQM as advocated by Youssef et al. (1996) and the view of others such as Kanji and Asher (1993), who point out that TQM has to be spread to a company’s suppliers. It is also referred to as external partnering by Goetsch and Davis (1997). Hence, partnering is the key element of SCM, while SCM is the horizontal view or part of a company’s TQM system.

A schematic representation of the supply chain is given in the following figure

(1) (Schematic Representation of a supply chain)

6.2 GENERIC TYPES OF SUPPLY CHAIN:

We describe below a few types of supply chain, which are generic in nature and being implemented in real life situations along with their typical characteristics.

1. Arm’s length, open competition:
   (—Conventional setting, impersonal dealings —
   Competitive Bids, Tenders and Market Testing —
   Emphasize the Rigor and Tough Bargaining —Trust,
   mutual respect may not be present)
2. Commodity Trading
3. Partnering for customer delight
4. From suppliers’ supplier to costumer’s customer
5. Lean supply chains and systems integration
6. Competing constellations of linked companies
7. Interlocking network supply between competitors
8. Asset control supply: dominate or die
9. Virtual supply: No production, only customers
10. Basic single-stage supply chain
11. Multistage supply chain
12. An Example of logistics supply chain.

6.3 VARIOUS DEFINITIONS AND IMPLICATIONS:

A variety of definitions are given below:

- **Beamon (1990)**: An integrated process where raw materials are transformed into final products then delivered to customers.

- **Berry (1995)**: A system whose constituent parts include material supplies, production facilities, distribution services and customer linked together by feed forward flow of materials and feed back flow of information:

- **Mehmet et al. (2002)**: Network of member companies connected via vendor customer relationship from the ultimate supplier to the ultimate customer, entails multiparty co-ordination of logistics planning activities that add value on the chain such as forecasting, planning, scheduling and control.

- **Quinn (1998)**: All of those activities associated with moving goods from the raw-materials stage through to the end user This includes sourcing and procurement, production scheduling, order processing, inventory management, transportation, warehousing and customer service. Importantly, it also embodies the information system necessary to monitor all of those activities.

The objectives of supply chain integration are to supply superior quality goods faster, with more efficient processes and in essence be more responsive to the perceptions of the marketplace and be able to change directions at will, some of the consequences of supply chain integration result in:

- Reduced inventory at all sites of the supply chain
- Reduced costs
- Faster processing speeds
- Reduced lead time
- Reduced warehouse costs
- Reduced obsolescence
- Greater responsiveness to customer changes
- Electronic links to suppliers and customers
- Continuous flow of products and information
- Speeding up the development cycle.
6.4 MAJOR DRIVERS OF SUPPLY CHAIN SYSTEM:

There are five major supply chain drivers as depicted in figure 'A':

Production: This is typically related to issues on what to produce, how to produce (which manufacturing process) and when to produce.

Inventory: Here the decisions and issues may be concerned with how much to make and how much to store as inventory and where to store these items (at the plant itself, warehouse, or at the retailer etc.)

Location: A number of issues regarding location such as where to locate a plant, where to locate a warehouse facility etc. may have significant bearing on the dynamics of the supply chain and in turn may affect the overall costs.

Transportation: The issues may be related to how to move a product from one location to another and by what mode of transportation. One needs to evaluate economies of scale on one hand and the desired level of customer satisfaction on the other hand.

Information: Information is a binding force having critical implications for the supply chain. Information acts as basis for making various decisions in the supply chain. If also acts as an integrator. Unless information flows are handled properly, one may not be able to derive benefits from the supply chain integration.

A supply chain is the process of moving goods from the customer order through the raw materials stage, supply, production and distribution products to the customer. All organizations have supply chains of varying degrees, depending upon the size of the organization and the type of product manufactured.

These networks obtain supplies and components, change these materials into finished
products and then distribute them to the customer. Managing the chain of events in this process is what is known as supply chain management. Effective management must take into account coordinating all the different pieces of this chain as quickly as possible without losing and of the quality or customer satisfaction, while still keeping cost down. Mohanty and Deshmukh (2004) define supply chain management as a loop.

- It starts with the customer and it ends with the customer.
- Through the loop flow all materials, finished goods, information and all transactions.
- If requires looking at the business as one continuous, seamless process.
- This process absorbs distinct functions such as forecasting, purchasing, manufacturing and distribution, sales and marketing into a continuous business interaction.

6.5 **REQUIREMENT OF SCM**:

Companies across the world are looking forward to value innovation as the strategic logic for high growth. World-class value adding performance outputs are as follows:

**Quality**: The quality of products and services should be virtually defect-free line. At many firms, over 50 percent of all quality defects can be traced back to purchased materials.

**Cost**: The supply chain management function must focus on strategic cost management the process of reducing the total cost of acquiring, moving, holding, converting and supporting products containing purchased materials and services throughout the supply chain.

**Time**: Total cycle time requires the examination of every aspect of the firm's operation, meticulously eliminating all redundant of non-value added, but time-consuming activities from the process.

**Technology**: The supply chain management function has two key "responsibilities in the area of technology": It must ensure that the firm's supply base provides appropriate technology in a timely manner, and it must ensure that technology which affects the firm's core competencies is carefully controlled when dealing with outside suppliers and customers.

**Continuity of supply**: Monitoring the trends, developing appropriate supplier alliances and taking such other actions as required to reduce the risk of supply disruptions.

Today, if would be difficult to find an organization, large or small, that doesn't understand the importance of supply chain management and how successful implementation of supply chain management principles can have a positive impact on its overall success. It is one of the major functions common to many types of organizations; the overall goal of supply chain management is to impact the organization's bottom line in a positive way. While it involves a number of actions, the objectives of supply chain management can be summarized around the following major goals:
• Provide an uninterrupted flow of materials, supplies and services required to operate the organization
• Keeps inventory investment at a minimum
• Maintain and improve quality
• Kind or develop competent suppliers
• Purchase required items and services at lowest total cost
• Improve the organization's competitive position
• Achieve harmonious, productive working relationships with other functional areas within the organization.
• Accomplish the purchasing and marketing objectives at the lowest possible level of administrative costs.

The following are the basic components for supply chain management:

1. Plan:
   This is the strategic portion of supply chain management. One needs a Strategy for managing all the resources that go toward meeting customer demand for a product or service. This may include developing a set of metrics to monitor the supply chain so that it is efficient, costs less and delivers high quality and value to customers in the most cost-effective manner.

2. Source:
   One has to choose the suppliers that will deliver the goods and services needed to create final product or service. This involves developing a set of pricing, delivery and payment processes with suppliers and metrics for monitoring and improving the relationships. This also involves putting together processes for managing the inventory of goods and services from suppliers, including receiving shipments, verifying them, transferring them to manufacturing facilities and authorizing supplier payments.

3. Make:
   This is the manufacturing step. This involves making schedule for the activities necessary for production, testing, packaging and preparation for delivery. This phase is the most metric-intensive portion of the supply chain, as it requires measurement of quality levels, production output and worker and asset productivity.

4. Deliver:
   Generally, this is referred to as "logistics." This involves coordination of the receipt of orders from customers, developing a network of warehouses, picking carriers to get products to customers and setting up an invoicing system to receive payments.

5. Return/Reverse Flow :
   This refers to the reverse flow of goods from customer back to the manufacturer. This involves creating a network for receiving defective and excess products back from customers and supporting customers who have problems with delivered products. The payment/discount procedures need to be established.
Activities of a SCM professional: Supply chain management is engaged in a host of activities. Table A gives a list of select activity domain of a supply chain management professional.

Table A : Typical activity domain of SCM professionals.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Source selection, development, incoming quality assurance, value analysis.</td>
</tr>
<tr>
<td>2.</td>
<td>Channel management.</td>
</tr>
<tr>
<td>3.</td>
<td>Logistics provider development/evaluation, Third party logistics (3PL), Logistics management and management of reverse logistics, distribution requirements planning (DRP).</td>
</tr>
<tr>
<td>4.</td>
<td>Management of Enterprise Resource Planning (ERP) &amp; other information systems such as point-of-sale (POS), management of bullwhip effect.</td>
</tr>
<tr>
<td>5.</td>
<td>Facility Location : warehouse, distribution centers, plants etc.</td>
</tr>
<tr>
<td>6.</td>
<td>Transportation : Choice and evaluation of mode, cost analysis, development of carriers.</td>
</tr>
<tr>
<td>7.</td>
<td>Management of warehousing function, cross-docking.</td>
</tr>
<tr>
<td>8.</td>
<td>Inventory management : Location, stock levels, information systems, tracking etc.</td>
</tr>
</tbody>
</table>

Types of Industry | Select examples
---|---
Apparel | Madura Coats, Reliance
Automobile | Maruti, Hero-Honda, Telco, Mahindra & Mahindra
Chemicals/Paints | Reliance, Asian Paints, Goodlass, Nerolac
Consumer Durables | Samsung, LG, Godrej
Fast moving | Hindustan Lever, Proctor & Gamble, Coca-cola, Pepsi
Consumer goods | Godrej, Cadbury, Parle, Amul, Dabur
Computers | Wipro, HCL
Newspaper | Bennett Coleman & Co. (Times of India), HT Media Ltd. (Hindustan Times)
Petroleum Pharma | Indian Oil Corporation, Bharat Petroleum, Ranbaxy, Dr. Reddy's Lab.
Informal or Unorganized Sector | Mumbai dabbewala

6.6 SCM IN INDIA

The concept of supply chain is not new. Historically we have moved from physical distribution to logistics management to supply chain management. The major difference seems to be that supply chain management is the preferred name for the actualization of "integrated logistics". With it acting as an enabler, it is now possible to have an integrated process view about the logistics and all the allied process related to business. It is now possible to compress the lead time by recognizing lead time reduction as a strategic issue. Ideally, the supply chain should be a 'seamless' chain as shown in Figure 1. In this study, the term 'integrated logistics' is interpreted in a total system perspective implying linking of
production, distribution and Marketing. Logistics is the science of movement of materials, intermediaries and final products from the producer to the consumer. Its main objective is to fulfill the demand at the right place, at the right time with the right quality at the lowest possible cost. The importance of logistics in our country can be gauged from the fact that logistics and supply chain management

Costs are in the range of 10 to 15 per cent of the GDP for a developing country while it is around 18 to 20 per cent for a developed country (Raghuram, 1992). The difference results in better customer service and parameters and better quality of life in the developed countries.

This concept of integrated logistics consists of two interrelated efforts logistical operations and logistical coordination. The growth of integrated logistics has resulted from an acute need to improve faster movement of goods and storage efficiency. Logistical operations can be basically grouped into physical distribution management, materials management and internal inventory transfer. Logistical coordination pertains to forecasting, order processing, operational planning and product procurement or MRP. This integration is effected through effective information flows.

The supply chain mission of an enterprise is to develop a system that meets service policies at the lowest possible cost. Logistical performance is measured through availability, capability, and quality while the cost of logistic system pertains to the overall cost at which the performance level is achieved. An optimal balance between both is called for.

**Components of Logistical System**

Five components combine to form a logistical system. These are:

1. Facility structure
2. Transportation
3. Inventory
4. Communication
5. warehousing and packaging

These issues have been conventionally examined in isolation in the past though they have interdependences. Integrated systems approach to design, planning and control of logistical
system is a phenomenon of the recent origin, because it is being increasingly recognized that only through a systems approach and effective deployment of IT can various trade-offs be properly balanced.

This study attempts to review the current status of supply chain in India. The approach adopted here is to trace the current logistical scene in our economy identifying the strengths, weaknesses, Opportunities and threats (SWOT) so as to recognize the problems and challenges of logistics in developing countries. Based on this SWOT analysis, future strategies can be evolved in designing an appropriate logistical system for our country.

Logistical Environment
The outer and inner environments of the logistical system play a dominant role and possibly constitute the biggest single factor which distinguishes logistics in developed and developing countries. Supply environment in many developing countries is full of uncertainties and comprises a “just-in-case” (JIC) environment as opposed to “Just-in-time” (JIT) environment being so much talked about now a days. Unless the operating environment and work culture are changed, any force fitting of JIT design in JIC environment will be counter-productive. It may probably be the reason why despite so much publicity to JIT, a really successful JIT system hardly exists in any enterprise in the developing countries.

Logistics in our country
The term ‘logistics’ itself is not very well understood though its individual components are often over-emphasized without seeing the inter relationships. For example in India logistics is the most important aspect given the country’s size, geographical heterogeneity, population pressures, natural calamities, shortage of essential commodities, etc., yet there is no professional society or association which professes integrated systems approach to logistics. The Indian institute of Materials Management (IIMM) was primarily an off-shoot of purchasing and the emphasis is still on that aspect. There are giant governments or public sector organization like the DGS & D, Central Warehousing Corporation (CWC) and Food Corporation of India (FCI) where total logistic system concepts can improve the supply performance with the lowest overall cost. But it is hardly in evidence. Even educational institutions do not emphasize logistics in their curriculum. Unless awareness of the concept spreads, one cannot expect major changes in the existing pattern. Thus, training in logistic systems management is a vital but missing component in countries like India.

Though the concepts of TQM have become popular, the customer hardly plays a role and is invariably at the receiving end literally. Due to the lack of effective consumer protection, competition, and service attitude on the part of those who are supposed to serve, managers of the logistical system hardly realize that the customer is the very cause of their existence. This is particularly true of the state-controlled public Distribution System (PDS) - a network of ‘fair price shops’ supplying rationed commodities of essential nature. Though PDS has recently come under a programme for operational improvement, the bureaucracy of operations and the indifferent attitude of its managers lead to a huge number of man-hours wasted in queuing up to avail those so-called ‘fair price’ or low quality supplies. If the indirect costs of waiting and lower quality of supplies are taken into account, the ‘fair price’ may not really be so fair.
Performance appraisal systems for logistical systems are hardly clear about what constitutes a good performance. Reducing visible cost at the expense of significant increase in invisible (hidden) cost is taken to be a measure of system performance, whereas quality, availability and timeliness of supplies are taken for granted. Even costs are narrowly interpreted rather than on life-cycle cost basis. Short-term gains dominate over total cost considerations.

Quality of service is neither explicitly defined nor is objectively monitored. Optimal level of service quality by judicious balancing of performance and cost is an exception rather than a rule in management of logistics operations.

There is a visible difference in the management styles of public sector logistics systems with its private counterparts. In public sector, supply systems tend to be over-controlled and under-managed, sluggish to accept change, high in overhead costs and low in performance levels, particularly in the quality of service. On the other hand, privately-managed systems consider profits to be the sole corporate objective and tend to exploit the shortage economy by fleecing the customer. Thus in the real sense, none could be considered to be doing very well. A change of attitude is called for, even if attempts are made to privatize the huge PDS structure because without an attitudinal change, an appropriate work culture and concern for the customer, mere change of ownership cannot achieve wonders.

Technological upgradation is an urgent requirement in most logistical operations in India. In transportation, communication, storage and warehousing, the level of technology employed is much lower than India can afford, given the large base of technological institutions and R&D laboratories the country possesses. The extent of mechanization, automation and decision-support systems employed in Indian situation is much lower than required, leading to poor traffic management, delays, wastage of materials, high lead times and excessive inventories. Information Technology (IT) can and should play a vital role in improving logistical performance.

Managerial decision-making often does not relate to total system cost considerations. Narrow sub-system segmented considerations and risk-avoiding, 'play-safe' approaches (particularly in public sector systems) hardly lend any degree of professionalism or objectivity to the decision process. Even tools/techniques of decision-making like systems analysis/operation research are more talked about than really used to improve the quality of decisions. Many times, these are used as 'cosmetics' to give signals of a professional image to the outside world or used to 'justify' the pre-designed options rather than seeking truly optimal solutions to problems.

Vendors' reliability and dependability are dubious. Source development and vendor performance play a vital role in improving the supply environment but unfortunately they are by and large an ignored factor in Indian logistical systems.

Inadequate transport facilities, lack of well developed road networks, poor quality of roads and bad maintenance level, paucity of rail-road coordination, poor communication, non-exploitation of water ways and unscientific storage methods constitute major infrastructure bottlenecks/ constraints in efficient logistics. Human element factors—training, skills, motivation, attitudes, value system, work is a major stumbling block. Logistics being
primarily a service system, a high degree of sensitivity and concern for the customer, in short a good service attitude is called for. In the absence of inspiring performance appraisal systems to distinguish performance from non performance, indifference set in. the situation is beyond repair in public systems with assured job security. The lack of concern for the customer can play havoc with systems performance. There is an urgent need to mold these values. Unfortunately, there is not much cause for optimism on this front given the present scenario.

Inventory Control
Inventories may be taken as a barometer of effectiveness of materials function. Inventory turnover ratio in the Indian scenario is very low due to a variety of reasons. This is due to partly a volatile supply environment with excessive lead times and its uncertainties. A case study of a large public sector organization revealed the gigantic nature of the problem. The plant was processing 2, 27,000 different items. The inventory turnover ratio was just 1.6, though 129 executive staff were supposed to be managing the materials management function. There were 8000 vendors to be managed every year and the vendor’s supply reliability can be gauged by the fact that the mean external lead time was 175 days with a standard deviation of 104 days. Internal lead time was 118 days with a standard

<table>
<thead>
<tr>
<th>Strengths</th>
<th>Weakness</th>
<th>Opportunities</th>
<th>Threats</th>
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<tbody>
<tr>
<td>Possible multiple modes of transportation</td>
<td>Poor road quality &amp; maintenance</td>
<td>Distribution planning</td>
<td>Pollution</td>
</tr>
<tr>
<td>Vast rail network</td>
<td>Non-coordinated rail road systems</td>
<td>Exploit water ways</td>
<td>Hazard accidents</td>
</tr>
<tr>
<td>Cheap and abundant manpower</td>
<td>Inadequate transport facilities/equipment</td>
<td>Cost control</td>
<td>Congestion</td>
</tr>
<tr>
<td>Indigenous technology has</td>
<td>Budget constraint</td>
<td>Energy Conservation though better maintenance, Freight consolidation</td>
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<td></td>
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</table>

Deviation of 56 days as an indent to order passes through 20 stage of processing. Mean lead time was 293 days with a standard deviation of 118 days. Compare this scenario with a JIT situation to know the status of inventory control in Indian public sector organizations. The SWOT framework which provides insights into inventory control is as follows:
Future Potential of Supply Chain Management

There is tremendous scope for improvement based on the present status of integrated systems of logistics in India. Some concrete steps in this direction are identified as:

- By appropriate restructuring of the supply chain function in an organization, better understanding can be achieved. This requires a total systems perspective. There is recognition that customer service needs to be measured and monitored if the supply chain performance is to be improved.
- Increasing awareness of integrated logistical systems through training and awareness workshops.
- Creating attitudinal changes to impart service attitude and a sincere work culture on the part of people manning the logistics systems.
- Creating a supply chain management association as a professional society to propagate the philosophy of integrated systems of logistics and act as a facilitator of training, seminars, consultancy, etc., in the field of supply systems.
- Increasing privatization in public distribution systems, with safeguards for the customer.
- Exchanging the technology in hardware of logistics for transportation, warehousing, packaging and increasing usage of IT for logistical operations.
- Vendor development, vendor rating to reduce the volatility of supply environment

These measures will usher in welcome changes in the present supply chain management scenario as only logistics can solve the problems faced by our country.

6.7 MATHEMATICAL MODELING FOR SUPPLY CHAIN

6.7.1 INTRODUCTION:

Wide arrays of technological tools are available to optimize the supply chains. The right supply chain modeling tool can help squeeze cost and inventory out of the supply chain while improving service to customers. Although some companies do an excellent job of
modeling their supply chains, other have barely tapped the potential for improvement. Modeling tools that can help optimize supply chains have been around for years. But, recently they're getting increased attention because of their lower cost and greater capability, coupled with companies quests for improved supply chain.

A variety of modeling tools are available today. Deciding which type is right begins with understanding the environment in which an organization works and how often there is need to change the supply chain. Dynamic environments have products with short life cycles, or use segmented customer fulfillment with multiple service levels lead times, and fulfillment methods require move frequent supply chain reconfiguring. This chapter presents some of the important mathematical models in supply chain.

6.7.2 CONSIDERATIONS IN MODELING SUPPLY CHAIN MANAGEMENT SYSTEMS:

There are three traditional stages in the supply chain: procurement, production and distribution. Each one of these stages may be composed of several facilities in different locations around the world. Frequently, the supply chain for a particular product will cross functional or corporate boundaries.

There are two types of approaches for modeling supply chain. One is the descriptive model and other is the normative model. Descriptive models can be developed to better understand functional relationships in the company and the outside world. Descriptive models include the following:

- Forecasting models.
- Model for cost relationships.
- Models for resource utilization relationship
- Simulation models.

Normative models are generally developed to help managers make better decisions and therefore, can be viewed as a synonym for mathematical programming models. Supply chain models provide support for a large range of applications, such as analyzing bottlenecks, improving customer service, configuring new logistic chains and adapting existing chains to new products and markets. It can be seen as a value-adding process that directly supports the primary goal of the enterprise, which is to be competitive in terms of a high level of customer service. Competitive price and quality and flexibility in response to market demands. The important activities can be divided into:

1. Feed-forward flow of goods, including transportation, material handling and transformation.
2. Feed-back flow of information, including information exchange regarding orders, deliveries, transportation, etc.
3. Management and control, including purchasing, marketing, forecasting, inventory management, planning, sales and after-sales service.

Using resources in the form of equipment, manpower, facilities and financial assets perform all these processes. The entire supply chain process, from the acquisition of raw materials to the distribution of end-customer products, makes up a chain consisting of multiple actors. At the operational level, the issues dealt with should be focused on efficient operation of the logistic chain, such as supply chain performance measurement in terms of inventory investment, service level and supplier performance.
6.7.3 STRUCTURING THE LOGISTIC CHAIN:
An essential element in the development of an integrated logistic chain concept is the redesign or re-structuring of the entire logistic chain. Pooley (1994) introduced the well- known value chain model in which two kinds of logistic activities are identified: Primary, value-adding activities and secondary supporting activities. Generally a logistic system consists of three primal layers:

- Externally received products and raw materials to be subjected to a logistic operation.
- Handling units, indication different internal representations of product units, such as containers batch size and individual products.
- Means of production, transport and distribution.

The following table highlights the various models related to the primary supply chain activities.

<table>
<thead>
<tr>
<th>Activities</th>
<th>Models and techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Promoting Products</td>
<td>Market Interaction</td>
</tr>
<tr>
<td>Observing customer needs</td>
<td>Benefit-cost analysis</td>
</tr>
<tr>
<td>Locating potential suppliers</td>
<td>Facility -location models</td>
</tr>
<tr>
<td>Selecting suppliers</td>
<td>Allocation models</td>
</tr>
<tr>
<td>Locating new/potential customer</td>
<td>Scenario analysis</td>
</tr>
<tr>
<td>Contracting out (purchasing, warehousing, distribution)</td>
<td>Multi-criteria analysis</td>
</tr>
<tr>
<td>Acceptance of custom orders</td>
<td>Logistic Co-ordination</td>
</tr>
<tr>
<td>Arranging supplies of materials</td>
<td>Stimulation / Queuing model</td>
</tr>
<tr>
<td>product/market mix</td>
<td>L.P. model</td>
</tr>
<tr>
<td>Location of warehouses/production facilities</td>
<td>MIP model</td>
</tr>
<tr>
<td>Transportation mode/frequency</td>
<td>Transportation / transshipment model</td>
</tr>
<tr>
<td>warehouse lay-out</td>
<td>Assignment /allocation</td>
</tr>
<tr>
<td>Acceptance of customer orders</td>
<td>Forecasting model</td>
</tr>
<tr>
<td>Choice of information system</td>
<td>Network models (PERT, CPM)</td>
</tr>
<tr>
<td>Order processing</td>
<td>Multi-criteria analysis</td>
</tr>
<tr>
<td>Lading / unloading</td>
<td>Simulation model</td>
</tr>
<tr>
<td>Delivery /Dispatching</td>
<td>Queuing model</td>
</tr>
<tr>
<td>Scheduling transport vehicles / Routing</td>
<td>Allocation</td>
</tr>
<tr>
<td>Inventory Control</td>
<td>Scheduling</td>
</tr>
</tbody>
</table>
6.7.4 OVERVIEW OF THE MODELS:

The models as shown in the following table are briefly described.

<table>
<thead>
<tr>
<th>No.</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Transportation Model</td>
</tr>
<tr>
<td>2</td>
<td>Assignment model</td>
</tr>
<tr>
<td>3</td>
<td>Vehicle routing problem and VOGEL based algorithm</td>
</tr>
<tr>
<td>4</td>
<td>Traveling salesman problem (TSP)</td>
</tr>
<tr>
<td>5</td>
<td>Capacitated Transshipment problem</td>
</tr>
<tr>
<td>6</td>
<td>Shortest Path Problem</td>
</tr>
<tr>
<td>7</td>
<td>Maximal flow problem</td>
</tr>
<tr>
<td>8</td>
<td>Goal programming models</td>
</tr>
<tr>
<td>9</td>
<td>Models for inventory control in a order-Level-Lot size system.</td>
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<td>Make versus buy model</td>
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</tr>
</tbody>
</table>

**Models on Transportation:**

The function of distribution places raw materials in the hands of producers and finished goods in the hands of consumers when and where wanted (i.e. creates time and place utility). Distribution includes a number of issues such as:

- Decisions about warehouses, plants, capacity and transportation.
- Determination and location of number of warehouses and plant.
- Warehouse and plant capacity load ratio.
- Assignment of customer demands to open warehouses.
- Assignment of open warehouses to open plants.
- Choice of transportation mode (rail, truck, air, ship) and choice of type of carriage (common, contract, private)
- Size of shipments (or shipment frequency) and assignment of loads to vehicles.
Transportation problem:
The context for this set of problem can be visualized through the following example.

The Auto excel company makes a variety of battery and motorized uninterruptible electric power supplies (UPSS) to provide backup electric power to institutional customers. Auto Excel has four final assembly plants for their large diesel motor-generator UPSS in Gurgaon, Nandgaon, Limgaon and Tilegaon. As part of Auto Excel's supply chain, the diesel motors used by these UPSS are produced and shipped to regions in Ahmedabad (A), Bangalore (B) and Coimbatore (C) and are then sent to the assembly plants. Production plans for the forthcoming quarter (July to September) have been set. The requirements for motors are shown as below:

<table>
<thead>
<tr>
<th>Assembly Plant</th>
<th>Number of Motors Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Gurgaon</td>
<td>400</td>
</tr>
<tr>
<td>(2) Nandgaon</td>
<td>900</td>
</tr>
<tr>
<td>(3) Limgaon</td>
<td>200</td>
</tr>
<tr>
<td>(4) Tilegaon</td>
<td>500</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,000</strong></td>
</tr>
</tbody>
</table>

The available number of motors at regions (the supply at origins) to be used in the quarter is shown as below:

<table>
<thead>
<tr>
<th>Region</th>
<th>Number of Motors Available</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Ahmedabad</td>
<td>500</td>
</tr>
<tr>
<td>(B) Bangalore</td>
<td>700</td>
</tr>
<tr>
<td>(C) Coimbatore</td>
<td>800</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,000</strong></td>
</tr>
</tbody>
</table>

The unit costs (Rs) to transport a motor from an origin to a destination are listed as follows:

<table>
<thead>
<tr>
<th>Origin</th>
<th>Destination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gurgaon</td>
</tr>
<tr>
<td>(A) Ahmedabad</td>
<td>120</td>
</tr>
<tr>
<td>(B) Bangalore</td>
<td>61</td>
</tr>
<tr>
<td>(C) Coimbatore</td>
<td>102.50</td>
</tr>
</tbody>
</table>
The issue is how many motors to send from each region to each plant to have minimum total cost for Auto Excel.

The symbolic L.P Model:

\[ X_{ij} = \text{Number of motors sent from region } i \text{ to plant } j; \]

<table>
<thead>
<tr>
<th>Origin</th>
<th>Gurgaon</th>
<th>Nandgaon</th>
<th>Limbgoan</th>
<th>Tilegaon</th>
</tr>
</thead>
<tbody>
<tr>
<td>(A) Ahmedabad</td>
<td>(X_{A1})</td>
<td>(X_{A2})</td>
<td>(X_{A3})</td>
<td>(X_{A4})</td>
</tr>
<tr>
<td>(B) Bangalore</td>
<td>(X_{B1})</td>
<td>(X_{B2})</td>
<td>(X_{B3})</td>
<td>(X_{B4})</td>
</tr>
<tr>
<td>(C) Coimbatore</td>
<td>(X_{C1})</td>
<td>(X_{C2})</td>
<td>(X_{C3})</td>
<td>(X_{C4})</td>
</tr>
</tbody>
</table>

Min \((120X_{A1} + 130X_{A2} + 41X_{A3} + 59.5X_{A4} + 61X_{B1} + 40X_{B2} + 100X_{B3} + 110X_{B4} + 102.5X_{C1} + 90X_{C2} + 122X_{C3} + 42X_{C4})\) Subject to

\[
\begin{align*}
X_{A1} + X_{A2} + X_{A3} + X_{A4} & \leq 500 \\
X_{B1} + X_{B2} + X_{B3} + X_{B4} & \leq 700 \\
X_{C1} + X_{C2} + X_{C3} + X_{C4} & \leq 800 \\
X_{A1} + X_{B1} + X_{C1} & \geq 400 \\
X_{A2} + X_{B2} + X_{C2} & \geq 900 \\
X_{A3} + X_{B3} + X_{C3} & \geq 200 \\
X_{A4} + X_{B4} + X_{C4} & \geq 500
\end{align*}
\]

The above model can be easily solved through transportation algorithms available.

**Assignment Problem:**

A special case of the transportation problem is the assignment problem which occurs when each supply is 1 and each demand is 1. In this case, the integrality implies that every supplier will be assigned one destination and every destination will have one supplier. The costs give the charge for assigning a supplier and destination to each other. Note that a balanced problem must have the same number of supplies and demands, so we must add a dummy machine and assign a zero cost for assigning the dummy machine to a plant.

**Vehicle Routing Problem:**

This is a typical problem faced in distribution. There are various locations to be met with given supplies of a particular item or group of items. The issue is how to route the vehicle so that it visits each location with a view to minimize the total cost involved. A typical solution of such problem is identifying the customer location /distribution centers and their respective demands and generating optimal routes between the demand and supply centers.
Vogel's Approximation Method (VAM) Based Heuristic Algorithm for Vehicle Routing:

The vehicle routing problem involves the design of several vehicle tours to meet a given set of requirements for customers with known locations, subject to capacity constraints for the vehicles and distance constraints for vehicle tours. It has been proved that large scale practical problems in vehicle routing cannot be optimally solved. However, heuristic procedures exist and are being used successfully in real life situations to produce cost improvements. A heuristic algorithm is a procedure that uses the problem structure in a mathematical way to provide feasible or near optimal solution. A heuristic is considered effective if the solutions it provides are consistently close to the optimal solution.

Travelling Salesman Problem (TSP):

TSP concerns with scheduling an itinerary with n cities with a starting city and then visiting remaining (n-1) cities so as to minimize the total time or total cost of traveling. For example, consider the following case. There are 5 cities and a salesman must arrange a tour that visits each city exactly once and then returns to the starting city in a minimum total time. Let's i be the source city and j be the destination city, \( t_{ij} \) be the time required to go from city i to city j.

Objective function:

\[
\text{min } Z = \sum \sum t_{ij} x_{ij}
\]

Subject to:

\[
\sum x_{ij} = 1 \text{ for all } i's
\]

\[
\sum x_{ij} = 1 \text{ for all } j's
\]

\[
x_{ij} = 1 = 0 \text{ or } 1
\]
$X_{ij} = 0$, if $ij$ is not part of tour  

$X_{ij} = 1$, if $ij$ is part of the tour, for $i = 1, 2, 3, 4, 5$ and $j = 1, 2, 3, 4, 5$ for $i$ is not equal to $j$

**Capacitated Transshipment Problem**

The context for this type of problem can be visualized through the following example. CARFAST is a manufacturer of automobiles. CARFAST distributes its cars in five regions. Currently, RACER has 10 engines in site 1. These engines must be delivered to two major assembly sites denoted as sites 3 and 4. Three engines are required at site 3 and seven are required at site 4. Because of prearranged schedules concerning driver availability, these engines must be distributed only according to any of the alternative routes connecting various nodes through arcs. They are from site 2 to site 4 is sometimes denoted symbolically as the pair $(2, 4)$. Each site is termed a node of the network. The following table indicates the cost of transporting engines from one site to the other.

<table>
<thead>
<tr>
<th>Destination</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>41</td>
<td>91</td>
<td>95</td>
<td>91</td>
</tr>
<tr>
<td>2</td>
<td>41</td>
<td>-</td>
<td>95</td>
<td>86</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>91</td>
<td>95</td>
<td>-</td>
<td>180</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>95</td>
<td>86</td>
<td>180</td>
<td>-</td>
<td>81</td>
</tr>
<tr>
<td>5</td>
<td>90</td>
<td>50</td>
<td>100</td>
<td>81</td>
<td>-</td>
</tr>
</tbody>
</table>

These costs are per unit costs. The costs are primarily due to fuel, tolls and the cost of the driver for the average time it takes to move the arc. Because of the limitations on the current availability of drivers, there is an upper bound on the number of engines that can be
transported in any given arc. The following table shows this upper bound or the arc capacities.

<table>
<thead>
<tr>
<th>From (Origin)</th>
<th>To (Destination)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

CARFAST’s problem is to find a shipment plan that satisfies the demands at minimum cost, subject to the capacity constraints. The task is to help CARFAST management make the best decision by using the mathematical programming technique.

\[
\text{Min} : \sum C_{ij} X_{ij}
\]

\text{All arcs,}

Subject to:

1. Origin nodes (sources of available supply)
   \[\sum X_{ij} - \sum X_{ij} \leq S_i \text{ (for origin nodes i)}\]
   \text{arc out } \text{arc in}

2. Transshipment nodes (must be emptied)
   \[\sum X_{ij} - \sum X_{ij} = 0 \text{ (for all transshipment nodes) here node 2 is a transshipment node for CARRAST}\]
   \text{arc out } \text{arc in}

3. Destination nodes (demand must be fulfilled)
   \[\sum X_{ij} - \sum X_{ij} = D_j \text{ (for destination nodes j) here node 2 is a transshipment node for CARRAST}\]
   \text{arc out } \text{arc in}

4. Capacity constraints for all arcs in the network
   \[0 \leq X_{ij} \leq U_{ij} \text{ (for all arc (i,j))}\]

\(X_{ij}\) = number of units shipped from node i to node j
\(C_{ij}\) = cost per unit of shipping from node i to node j
\(S_i\) = supply at origin node i
\(D_j\) = demand at destination node j
\(U_{ij}\) = capacities limiting size of shipment from node i to node j
Maximal Flow Problem:
The context for this set of problems can be visualized as follows.
A number of subway systems are being built in a city. A typical problem here is to co-ordinate the construction of the new subway system is being built near the city's beltway, the eastbound traffic on the beltway must be detoured. The planned detour actually involves a network of alternative routes that have been proposed by the highway maintenance department.
The mathematical formulation is as follows:
Max F
subject to:
1. Flow into a node must equal flow out of a node
   \[ \sum_j X_{ij} - \sum_j X_{ij} = F \text{ if } i = 1 \]
   \[ = -F \text{ if } i = n \]
   \[ = 0 \text{ otherwise} \]
2. Flow along an arc must not exceed capacity
   \[ 0 \leq X_{ij} \leq U_{ij} \text{ (for all arc (i,j))} \]

Where,
F = the total flow through the network per unit time. By definition this is equal to the flow per unit time leaving the source, node 1, (the first constraint). This is also equal to the flow per unit time entering the sink, node n, (the second constraint).

X_{ij} = flow per unit of time across the arc (i, j) connecting node i and node j.

Consider the ith constraint, for some fixed value of i. The sum (\( \sum_j X_{ij} \)) is over all j, for which arc (i, j), with i fixed, is in the network. Similarly, the sum (\( \sum_j X_{ij} \)) is over all j for which there is an arc (j, i) in the network (where i is fixed). Thus, it is the total flow into node i.

U_{ij} = Capacity constraint from node i to node j per unit of time.

Goal Programming Models:
Until now, our discussions of optimization methods have considered only one criterion or performance measure to define the optimum. It is not possible to find a solution that, say, simultaneously minimizes cost and maximizes reliability and minimizes time of completion of the project. This, again, is an important simplification of reality, because in many practical situations it would be desirable to achieve a solution that is 'best' with respect to a number of different criteria. One way of treating multiple competing objectives is to select one criterion as primary and the remaining criterion as secondary. The primary criterion is then used as an optimization performance measure, while the secondary criteria are assigned acceptable minimum or maximum values as problem constraints. However, if careful considerations are not given while selecting the acceptable levels, a feasible design that satisfies all the constraints may not exist. This problem is overcome by a technique called goal programming, which is fast becoming a practical method for handling multiple criteria.

In goal programming, all the objectives are assigned target levels for achievement and a relative priority on achieving these goals. Goal programming treats these targets as goals to
aspire for and not as absolute constraints. It then attempts to find an optimal solution that comes as "close as possible" to the targets of specified priorities.

The general form of GP may be expressed as follows:

\[
\text{Minimize } z = \sum_{i=1}^{m} (P_{u,i}d_i + P_{o,i}d_i^*)
\]

Subject to:

\[
\sum_{j=1}^{n} (a_{ij}x_j) + d_i^* - d_i^* = b_i \quad i = 1, 2, \ldots, m
\]

\[
x_{ij}, d_i^*, d_i^* \geq 0 \quad \text{for } i = 1, 2, \ldots, m \text{ and } j = 1, 2, \ldots, n
\]

\(X_{ij}\) = the variable in the goal equations

\(b_i\) = the targets or goals

\(a_{ij}\) = coefficients of basic variables

\(d_i^*\) = represents the under achievement of goal \(i\)

\(d_i^*\) = represents the over achievement of goal \(i\)

\(P_{u,i}\) = the priority associated with \(d_i^*\)

\(P_{o,i}\) = the priority associated with \(d_i^*\)

Models For Inventory Control In a Order-Level-Lot-Size Systems:

Objective: Making optimal decision with respect to an inventory system to minimize the total cost of an inventory system. Decisions are to be made in terms of time and quantity.

Carrying Cost: It is the cost in inventories, of storages, of handling items in storage, of obsolescence etc.

Shortage cost: It is the cost of incurring shortages due to lost sales, of loss of good will, of overtime payments, of special administrative efforts etc.

Replenishing cost: It is the cost of replenishing inventories, the cost of machine set-ups for production runs, of preparing orders, of handling shipment etc.

Order level lot size systems are deterministic systems with constant demand and an \(S, q\) policy (where \(q\) is the order quantity). These are the systems in which carrying, shortage and replenishment of costs are balanced. The total cost equation of these systems can therefore be written as
\[ C(S, q) = C_1(S, q) + C_2(S, q) + C_3(S, q) \]

be controllable variables \( S \) and \( q \) are related to the reorder point \( S \) and the scheduling period \( t \) by

\[
S = S - q \\
t = \frac{q}{r}
\]

where \( r \) is the constant rate of demand. Hence these systems may also be viewed as having a \((t, s)\), \((s, q)\) or a \((s, s)\) policy. We refer the system as having an \( S, q \) policy.

The cost of order level lot size system is

\[
C(S, q) = C_2 \left( \frac{q}{2 - s} \right) + C_3 \left( \frac{r}{q} \right) \quad \text{(if } S \leq 0) \\
= C_2 \left( \frac{S^2}{2q} \right) + C_3 \left( \frac{q - S^2}{2q} \right) + \left( \frac{r}{q} \right) \quad \text{(if } 0 \leq S \leq q) \\
= C_1 \left( \frac{s - q}{2} \right) + C_3 \left( \frac{r}{q} \right) \quad \text{(if } S \geq q) 
\]

Make versus Buy Model:

A typical manufacturing concern has three basic alternatives in sourcing a part or a product that in needs:

1. Buy the part/product completely from an outside source
2. Buy some components /parts or materials and manufactures and assemble others.
3. Manufacture the part or product completely.

This model largely depends on the volume and cost involved. The estimated total cost of production must be considered with the cost of purchase to know the pay-off. In a make or buy decision the purchasing policy or the source of supply don't play a major role. Rather, the consultation and co-operation of production, cost, quality and other technical departments play a major role. These decisions are taken by the top management and the role of materials management is to collect, collate, analyze and interpret the data.

Firstly we need to know the optimum purchase quantity, which will result in minimum cost.

Optimum purchase quality model:

\[
T_c = \text{total annual cost of the item (Rs.)} \\
D = \text{annual demand for the item (units/year)} \\
N = \text{number of purchases during the year (units)} \\
t = \text{time between purchases (day)} \\
Q = \text{purchase quantity (units)}
\]
Cₙ = item cost per unit (purchase cost) (Rs.)
Cₚ = purchase cost per order (Rs/order)
Cₜ = holding cost per unit per year (cost of shortage, rent, taxes, insurance etc.)

Then,
TC = IC + PC + HC
IC = Cₙ(D)
PC = Cₚ(N)

\[ PC = Cₚ \left( \frac{D}{Q} \right) \]

\[ HC = Cₜ \left( \frac{Q}{2} \right) \]

\[ TC = Cₙ(D) + Cₚ \left( \frac{D}{Q} \right) + Cₜ \left( \frac{Q}{2} \right) \]

Optimal solution found out is
\[ Q = \left[ 2Cₚ \left( \frac{D}{Cₜ} \right) \right]^{1/2} \]

We need to find the decision model for optimum production quantity.
TC = total annual cost of the item (Rs/Year)
D = annual demand of the item (units)
N = number of production runs (units)
Q = production quantity (units)
Cₙ = set up cost per production run (Rs./production run)
Cₜ = holding cost per unit per year (Rs/year)
R = production rate (production/day) working on similar grounds
IC = Cₙ(D)

\[ SD = Cₙ \left( \frac{D}{Q} \right), HC = Cₜ(R - D) \left( \frac{Q}{2R} \right) \text{ so,} \]

\[ TC = Cₜ(D) + Cₙ \left( \frac{D}{Q} \right) + Cₜ(R - D) \left( \frac{Q}{2R} \right) \text{ so,} \]

Economic production quality
Model For Vendor Analysis:
The rating of a vendor can be done on the basis of the following factors: Quality performance, Delivery performance and price performance.

**Quality Performance**: A supplier can be judged for quality performance from the viewpoint of rejected lots. Thus, if a supplier has supplied 100 pieces and 10 pieces are rejected form the lot he has a rating of 90% number of lots accepted 100 weightage, number of lots supplied.

**Delivery Performance**: Delivery performance can be made in two ways, one by adherence to time schedule and the other by adherence to quantity schedule.
Number of deliveries made in time 100 weightage
Total number of scheduled deliveries.
Quantity supplied 100 weightage Quantity scheduled

**Price performance**: Price criteria can be worked out as follows: Minimum price offered 100 weightage vendors price.
All these factors can finally be totaled and the vendor with the highest number of points be rated the most reliable and cost effective by just adding his points on each of these above factors.

Vendor Quota Allocation Model:
The vendor selection and quota allocation decisions are an important part of the production and logistics management of many firms. Potential objectives include:

- Minimize the total monetary cost.
- Minimize the number of non-conforming or rejected items.
- Minimize the number of early and or late deliveries.
- Minimize the total number of vendors employed.
- Minimize the orders from unstable (financial or political) reasons.
- Minimize the delivery distance.

The model that we have considered optimizes the cost, delivery and the quality the vendor is supplying. The model formulated taking into account system and policy constraints is given below:
\[ \text{Min} Z = (Z_1, Z_2, Z_3) \]

Subject to:
\[ \sum x_i = D \]

\[ x_i \leq \min(v_i^u, w_i^u) \text{ for all } j \]

\[ x_i \leq \max(v_i^l, w_i^l) \text{ for all } j \]

\[ \sum f_i x_i \geq F \]

\[ \sum y_r x_i \geq V \]

\[ X_j \geq 0 \text{ for all } j \]

\[ z_1 = \sum p_i x_j, \quad z_2 = \sum \lambda_j x_j, \quad z_3 = \sum \beta_j x_j, \]

\[ p_j = \text{per unit net purchase cost for vendor } j \]

\[ \lambda_j = \text{percentage of items late for vendor } j \]

\[ p_j = \text{percentage of rejected units for vendor } j \]

\[ x_j = \text{quantity purchases from vendor } j \]

\[ D = \text{demand aggregate for item over the planning period} \]

\[ v_i^u = \text{maximum amount of business for item to be given to vendor } j. \]

\[ w_i^u = \text{minimum amount of business for item to be given to vendor } j. \]

\[ v_i^l = \text{maximum order quantity from vendor } j. \]

\[ w_i^l = \text{minimum order quantity from vendor } j. \]

\[ F_j = \text{probability} \left( \frac{w_i^l - \text{Davg.}}{\sigma} \right) \leq D \leq \left( \frac{w_i^u - \text{Davg.}}{\sigma} \right) \]

\[ \sigma = \text{standard deviation of aggregate demand} \]

\[ VR_j = \text{Vendor rating evaluated from linear weighted method } 0 \leq VR_j \leq 1 \]

\[ F = \text{net flexibility value (policy decision)} \]

\[ V = \text{Net vendor value (policy decision)} \]

The model is formulated to minimize the total monetary cost of purchases, total number of late deliveries and the total number of rejected units respectively.

**Distributor Model**

The model for quota allocation to the distributor can be designed similarly as in the case of the vendor. The general formulation for the model remains the same. Potential objectives in distributor case are:

- Minimize the dealer margin or monetary cost.
- Minimize the stock returned.
- Minimize the lateness of the payment.
- Maximizing the sale.

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• Maximizing the sale in a particular area
• Maximizing the orders from new regions.

Potential system constraints are:
• The selling capacity of the distributor
• The number of distributors.
• Minimum quantity to be given to a distributor.

Potential policy constraints are:
1. Geographical preferences
2. Minimum or maximum number of distributors.

The model presented below is simplified version of actually complex sales scenario:

$$Min Z = (Z_1, Z_2, Z_3)$$

Subject to:

$$\sum X_j = D$$

$$X_j \leq \min(D_j^u, W_j^u) \text{ for all } j \quad X_j \leq \max(D_j^l, W_j^l) \text{ for all } j$$

$$\sum F_j X_j \geq F, \quad \sum R_j X_j \geq R$$

$$X_j \geq 0 \text{ for all } j$$

$$Z_1 = \sum R_j X_j, \quad Z_2 = \sum \lambda_j X_j, \quad Z_3 = \sum \beta_j X_j$$

$$P_j = \text{net dealer margin}$$

$$\lambda_j = \text{percentage lateness in payment}$$

$$P_j = \text{percentage stocked return}$$

$$X_j = \text{quantity allocated to distributor } j$$

$$D = \text{demand aggregate for item over the planning period}$$

$$D_j^u = \text{maximum amount of business for item to be given to distributor } j$$

$$D_j^l = \text{minimum amount of business for item to be given to distributor } j$$

$$W_j^u = \text{maximum amount of business for item to be given to vendor } j.$$ 

$$W_j^l = \text{minimum order quantity from distributor } j.$$ 

$$F_j = \text{probability} \left\{ \begin{array}{ll}
    \frac{(W_j^l - D_{avg})}{\sigma} & \text{if } \sigma \leq D \leq \frac{(W_j^u - D_{avg})}{\sigma} \\
    0 & \text{otherwise}
\end{array} \right.$$ 

$$\sigma = \text{standard deviation of aggregate demand}$$

$$VR_j = \text{Vendor rating evaluated from linear weighted method } 0 \leq VR_j \leq 1$$

$$F = \text{net flexibility value (policy decision)}$$

$$V = \text{Net vendor value (policy decision)}$$
Data Envelopment Analysis (DEA) Model For Measuring Vendor Efficiency.

Data envelopment analysis (DEA) is an application of linear programming used to measure the relative efficiency of operating units with the same goals and objectives. Mathematically, DEA first identifies an efficient frontier from the observed inputs and outputs of a set of objects to be evaluated, called decision making units (DMU). The efficient frontier is determined by most the efficient DMU under study, based on the notion of Pareto optimality. This concept states that a specific DMU is efficient if there is no other DMU, or combinations of other DMU's that can produce at least the same amounts of all outputs, with less of some resource input and no more of any other resource. In this manner, DEA can measure the relative efficiency of each vendor for purchasing a product based on multiple criteria when compared to the most efficient vendors under investigation. The analysis can be used for vendor rating and vendor evaluation.

Operational Supply Chain Planning Models:

An important step in each logistic chain methodology is to determine performance indicators and critical success factors to evaluate both the behavior of individual infra and inter-organizational logistic processes and the behavior of the total integrated logistic chain. These models can be categorized into two classes: Operational and strategic models.

Factors for operational supply chain planning models:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Operational Models</th>
<th>Strategic Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decisions</td>
<td>Opening and closing of sites. Assignment of equipments to plants, Delivery of products.</td>
<td>Plant or DC openings and closings at location of equipment to manufacturing facilities, selection of a location or locations for manufacture of a new product, or evaluation of changes in the flow of a particular product through the supply chain.</td>
</tr>
<tr>
<td>Objectives</td>
<td>Cost minimization, profit maximization</td>
<td>Cost minimization, profit maximization</td>
</tr>
<tr>
<td>Demand patterns</td>
<td>Stochastic, deterministic</td>
<td>Typically, deterministic demands</td>
</tr>
<tr>
<td>Formulation</td>
<td>Non-linear, Linear, Integer programming</td>
<td>Typically mixed integer programming</td>
</tr>
<tr>
<td>Solution Approach</td>
<td>Dynamic programming, Heuristics</td>
<td>Branch and cut algorithms, primal goal decomposition, Bender's Decomposition, Heuristic</td>
</tr>
<tr>
<td>Network structures</td>
<td>May not be relevant</td>
<td>Over three stages (e.g. plant DC customer), Two stages (e.g. plant -Dc or DC-customer)</td>
</tr>
</tbody>
</table>

Strategic Planning Models:

The majority of strategic planning models are mixed - integer programming based. A mixed-integer program is the minimization or maximization of a linear function subject to linear constraints. A number of researchers have addressed issues of strategic planning without modeling the problem as a mixed-integer program. Some of these models are given below:
Models

- Objective Function:
    Van Duienetal. (1992)
  - Profit Maximization: Cohen and Lee (1988)
- Demand Patterns: Deterministic
- Formulation: Mixed Inter Programming models
- Solution Approaches:
  - Primal goal decomposition: Brown et al. (1987)
  - Benders' Decomposition: Geoffrion and Graves
    Daganzo(1984)
- Products:
  - Multiple Products: Brown et al. (1987)
    Geoffrion and Graves Cohen and Lee
- Network Structures:
  - Over - three stages (e.g. plant - DC - Customer): Geoffhon and Graves
    Van Roy (1989)
  - Two stage (E.g.: Plant - DC or DC-customer): Brown et al.

Coordinated Supply Chain Management:

The coordination and control of the supply chain is required to bring together everything at the right place and time coordination has been defined as an integrative approach towards common objectives or attempts to fully satisfy the concerns of the members involved in the exchange in order to achieve win-win solutions. As a result, firms are moving from decoupled decision making processes towards more coordinated and integrated design and control of all of their components in order to provide goods and services to the customer at low cost and high service levels. The coordination among supply chain members can be achieved when they work together to optimize and control their collective performance in the creation, and support of end product. It may be helpful to think of members as the divisions of a large, vertically integrated corporation, although independent companies in the chain are bound together only by trust, shared objectives and contracts entered into on a voluntary basis.

6.8 APPLICATION OF SUPPLY CHAIN SYSTEM

Case 1 (A) NEWS PAPER SUPPLY CHAIN:

News paper publication in India began in Kolkata in the 1780s and by 1800 there were several dozen newspapers in English, with the numbers increasing periodically. Broadly, NRS (National Readership Survey) shows that Indian newspapers and magazines have continued to grow in both urban and rural areas of the country. Assuming a population of 620 million
According to 2001 figures, adults over the age of 15, as NRS does, that means well over 25 million people in the country have begun to read some newspaper or a magazine for the first time in these two years. However, since NRS based its readership figures entirely on urban residents, without surveying the rural areas, the real growth of print media audiences could in fact be larger than the data at first suggests. While 62 percent of the 183 million Indians in urban areas read a newspaper or magazine each week, NRS records only 29 percent of the 437 million rural residents doing so. This lower rural reach was not factored into NRS.

The number of adults who read a daily overall grew by one percentage point reaching of all adults or some 260 million people. By contrast, evening papers, popular in urban centres, showed a decline in circulation. But magazines marked the real growth in the print media, many adult Indians took to reading a magazine for the first time magazine readers as a percentage of all adults rose from 25 per cent in 1997 to 28 percent in 2001, which in absolute terms means there are some 174 million magazine readers today. The largest publications in the country are regional language publications, not their more high-profile English counterparts. Not a single one of the English newspapers figures as one of the top Indian newspapers.

In India, newspapers are published in about 100 regional languages and dialects other than Hindi and English. Over the years, the number of dailies has steadily increased. Their number increased to 5638 in 2001 from 5364 in the previous year, i.e. by 5.11 percent. The total circulation of daily newspapers was 5,78,44,236 in 2001. hi 2001, The Hindu, an English daily, published from Chennai was the largest circulated single edition daily with claimed circulation of 9,37,222 followed by Hindustan Times, English Daily published from Delhi with a circulation of 9,09,278. Anand Bazar Patrika, Bengali Daily came third whereas, The Times of India, English Daily was fourth.

With such large number of newspapers and such enormous circulation, the supply chain model for the newspaper industry is a challenge in itself. Moreover, due to the perishable nature of the product, its distribution needs all the more importance. The newspaper is an example of a perishable good production and distribution problem. A perishable good is one that either loses significant value if stored or a good that will cause economic loss if delivered late.

**Typical Characteristics of Newspaper Supply Chain**

- Newspaper is a product that is perishable to both the manufacturer and the customer alike.
- Newspaper companies cannot print the new sections of the newspaper in advance because of the requirement that news be timely. The newspaper cannot be produced or purchased in advance for inventory.
- Highly competitive industry: There are national, international and local players.
- A newspaper industry consists of major functional areas: Editorial, advertising, production, administration and circulation.
- Editorial supplies the raw material, which is transformed to the finished product through printing. Advertising performs the marketing function and management is done by administration. The key area of sales of the product is dealt by circulation, hence the
importance of distribution channel in the newspaper industry.

- Responsiveness and efficiency play an important role in newspaper distribution channel.
- Distribution centers rather than warehouses play an important role and production and distribution are necessarily intimately related.
- The total time devoted to both production and distribution may be severely limited thereby further tying together the design and operation of the production and distribution functions.
- With the increase in commuting times, especially in the large, metropolitan markets, late delivery is also not entertained.
- Newspapers are a vehicle to provide news, entertainment and advertising contents to readers and providing an audience to advertisers.
- The two aspects are almost independent from revenue point of view, and cover price takes back seat compared to the advertising in most newspapers. Generally, the newspaper industry gets most of its revenue through print advertisements.
- Broadly, the newspaper industry is divided into two categories: national and regional newspapers.
- There is a potential for reverse supply chain i.e. old papers sold as "raddi".
- There is also a scope for e-commerce applications especially for advertisers.

The main drivers of supply chain are inventory, transportation, facilities and information technology.

**Inventory:**
It exists in the supply chain because of a mismatch between supply and demand. Applying this to the newspaper industry, inventory of the raw material, i.e. newsprint, is maintained based on the safety inventory model. This model states that inventory is held just in case demand exceeds expectation i.e. it is held to counter uncertainty. Moreover, even some of the news items can also be considered as inventory. These may include special columns, weekly columns, obituaries of leading personalities etc.

**Transportation:**
Through transportation, the product is moved between different stages in a supply chain. It bears a large impact on both responsiveness and efficiency. Faster transportation allows a supply chain to be more responsive but reduces its efficiency. Responsiveness is more important for newspaper than efficiency and hence the need for a faster transportation.

**Facilities:**
Deciding where a newspaper should locate its facility constitutes a large part of design of a supply chain. The trade-off here is whether to centralize to gain economies of scale or decentralize to become more responsive by being closer to the customer warehousing in newspaper industry follows cross-docking model to a good extent.

**Information Technology:**
Due to the very nature of the product, use of information technology can cater to the need...
of high responsiveness. The communication of news between various offices of a modern newspaper is achieved through networking. The master newspaper is designed and finalized at the head office of a newspaper. It is then made available on the intranet of the newspaper company.

**Distribution:**

- The overall distribution problem can be viewed similar to the traveling salesman problem. The entire distribution network can be segregated into various hawker point and an optimized route proposed for each of them, based on the vehicle capacity constraints. Starting at the first hawker, newspaper requirements are accumulated until the vehicle limit is reached. At this hawker, another vehicle route starts. The procedure may be continued until all the hawkers are included in some route.

After the routes, that include all the hawkers and that satisfy the vehicle capacity constraints, have been constructed, the time constraints must be checked. The routes describe the distance the vehicle must travel on each route and the sequence in which hawkers on that route are visited. For each route, the distance along the route from the production facility to the last hawker point visited can be calculated. The time the vehicles stop at each hawker also needs to be considered.

- The production schedule can be deduced by arranging the routes in a sequence that will ensure delivery of all the newspapers by the prescribed time. This sequence can be developed by arranging the routes in descending order of the total route length distance from the production facility to the last hawker. Usually, newspapers for the farthest hawkers are produced and shipped first since the total delivery time is greater.

- Costs can be divided into two major categories: costs associated with the actual production and distribution activities and costs directly attributable to the perishability of either an input or an output. The latter costs will be accrued only if the schedule is not feasible. In the newspaper problem an infeasible solution would be one in which not all newspapers are delivered by the deadline. The costs associated with this infeasibility may include the cost of the newspaper a lost opportunity and the cost of processing the complaint. Typically, an Operation Research (OR) based model can be used for solving the stocking problem.

In summary, the distribution of newspaper has number of features distinguishing if from other distribution operations. These distinguishing features increase the complexity of the managing the supply chain effectively.

**Case 1 (B) BOOK PUBLISHING**

After studying the SCM of newspaper, it may be interesting to study the SCM aspects related to book-publishing. Typically book publishing is different business. Generally, it seems that book publishers are beset with the problem of scheduling to get books done on time. One can't predict the demand for the products and avoids manufacturing far more than one needs most of the time. Many of the techniques and understandings that apply to other businesses, even other "media" businesses, fail when they are applied to book publishing, particularly to consumer book publishing. The book publishing industry (BPI) exists in an environment
where each product's income potential is low and the cost of creating one of these products is much lower than would be the case in other industries. All publishing book, magazine and even including non print media is at its core, the business of content. Typically, in this supply chain, the publisher has to connect writers to readers, ideas to seekers, knowledge to learners, information to users. Successfully developing content that appeals to an identifiable market will make a publisher successful.

Typical Characteristics of Book Publishing:

- **Barriers to entry** to simple publishing are very low. Anyone with desktop facility or a PC can theoretically offer a competition. However, barriers to distribution may be significant.
- In spite of consolidation worldwide, publishing is still a fragmented sector.
- This results in many-to-many supply chain contributing to waste and inefficiency.
- Book reading faces a stiff challenge from many other technologies invading leisure of the potential customers: TV, Internet and so on.
- Tremendous pressure on retail shelf space as there are many competing titles on a variety of subjects/topics.
- Value chain is complex and there are pressures to simplify and rationalize the same.
- The whole supply chain faces fundamental changes due both to print on demand and to e-books as these technologies offer the possibility of connecting publishers more directly with the end customers and have a promising possibility of connecting authors directly to the end customers.
- There is a potential scope for reverse supply chain i.e. old books sold as discount or their paper being recycled. There is also a vast scope for e-commerce applications.

Generally BPI is based with the following issues?

- How to game the economics of business?
- How to enhance the role of "brands"?
  
  Like identifying them, nurturing them, capitalizing on them. Examples: Shiv Khera, Shobha De etc.
- How to resolve a number of decisions which is the central bottleneck to efficient distribution of books in their supply chain.

Each book published is an investment in a revenue-generating machine. How profitable the machine will be depends on the publisher finding the market and matching what's manufactured to what is needed in the market place in an efficient way and the way supply chain is organized.

One needs and altogether different approach in dealing with this supply chain. One of the hottest modern concepts in marketing is "branding". Today, one lives in an increasing brand-aware world. Most generic book ideas are seen to be strengthened by association with a known brand in the field. Sometimes the brand association is sought to again the power of the organization behind the brand, which might offer distribution or marketing clout to give the book an advantage in the market place.

For the trade, more typical "one off books-both the distribution company, less so, and the imprint, more so-send influential signals into the market place. They tell the trade whether advance promotional promises are reliable and whether they are likely to sustain their efforts
or quickly pull the plug. They tell reviews whether to expect quality. They tell stores whether to expect fast deliveries and reliable stockholding or whether more stock will be needed by the book store itself to protect against potential success.

The editor is the subtest branding, but it is worth visualizing the editor in this way. A definite success factor for any editor's books is the editor's ability to introduce them to the market place. An editor's "brand" starts having currency within the publishing house itself, where sales and marketing people respond differentially to ideas, even as early as at the acquisition stage, based on the editor's track record, credibility, and in-house clout. And key intermediary influencers of a book's success - book clubs, magazines that serialize, reviewers, endorsers, and providers of jacket blurbs are often brought into a book's corner personally by the editor.

Many a time, authors switch their loyalty and may go to a competitor publisher. Information Technology and web provides a very helpful tool to nurture publishing's multiple brands. Every brand with market value should be identified on the web, preferably with its own domain. Because the industry is so often dealing with small numbers in the trade business, the hand to hand, one-by-one, market building opportunity to talk to the individual "customer" for the publisher, the imprint, the author, the editor, or the series, and to capture permanent online access to them, can have substantial cumulative impact.

Defining a brand strategy and some standard procedures to make use of the Internet sensibly for all their brands would be a productive effort for any publisher. Book publishing is a tough business because marketing all these decisions with multi-departmental implications and keeping track all these details, many of which change at every publisher every day, is a huge logistical challenge. But, it is the cost of decisions not made that imposes the biggest burden of all. Cutting off consideration of more marketing effort for books after pub date, or three months after pub date, is an effective way to reduce the number of decisions required. But as the Cliche goes, "not to decide is to decide". If a policy of that kind, whether explicit or tacit, protects the house from spending costly time and effort on books, which have already had their shot, it also effectively prevents the house from capitalizing on, even from noticing, opportunities that arise later, even though the opportunities may result from earlier marketing efforts.

Case 2 SUPPLY CHAIN IN DISASTER MANAGEMENT

In a country like India, SCM plays an important role in a variety of disaster situations like famine, earthquake, cyclone etc. Occurrence, timing, and place of these situations are difficult to predict. Time element plays an important role. The relief, aid, and rehabilitation functions are to be performed in a timely and responsive manner. In such situations, the following characteristics are of significance.

- Political environment plays a pivotal role in the entire operations.
- Consumer of the final products is not the customer of either the supplier or the carrier.
- These supply chains are highly temporal requiring huge resources.
- Role of voluntary organizations / non-profit organizations is very important, besides
the government agencies.

- Demand forecasting is difficult due to limited information and nature of calamity like earthquake, cyclone etc. There must be allowance for theft / pilferage etc, due to the nature of the situation.
- In such situations, the inbound logistics function as reflected in purchasing function is typically done in an ad-hoc manner. There may not be opportunities for vendor development etc. However, the outbound logistics and distribution function assumes critical importance.
- Inventory management may be difficult to handle due to myriads of non-food commodities such as tools, fuel, shelter and water purification and sanitation requirements.
- Warehousing may also not be done in a professional manner.
- Co-ordination amongst various governmental and NGO / Voluntary organization plays an important role in deciding the 'quality' of the supply chain.

In the Indian Administrative system, the police play a crucial role in the management of all routine situations and have a major role to play during crisis or disaster situation of any kind. Not only does the police get the first information and responds to it in the given circumstances, it is expected to and perform the role of an immediate local manager in any kind of disaster be it man made or natural. The local police not only bear the initial brunt of public wrath but also have to manage it along with its mentioned managerial functions. This situation prevails till relevant administrative departments mobilize themselves and take over. This gap could be up to 2-3 hours or much more. Even after this the police continue to play a major part in the overall co-ordination and handling of relief and rehabilitation of victims. Following are some of these situations where in SCM orientation plays an important role.

**Bhopal Gas Tragedy**

On the intervening night of 2\textsuperscript{nd} / 3\textsuperscript{rd} December 1984 the lethal and poisonous Methyl - Iso - Cyanate (MIC) gas leaked from the Union Carbide Factory located on the outskirts of Bhopal. This gas killed thousands and medically incapacitated many more. This tragedy is remembered amongst the worst chemical disasters in the history of mankind. The local police and district administration played an important role and displayed exemplary courage and devotion to duty by moving into the affected areas immediately and providing relief to the affected and terrified population.

- The local police functioned in the affected area the whole right, as the only manager for medical, physiological and social relief to the terrified populace of Bhopal, and successfully planned and controlled the law and order fallouts with a depleted police force.
- The administration provided relief and assisted in planning of rehabilitation while ensuring logistics provisions for the victims of the poisonous gas.
- Involved in the long term strategic planning for handling the fallouts of the disaster.

**Gujarat Earthquake**

On 26\textsuperscript{th} January, 2001, the Republic Day of India, a massive earthquake hit the State of Gujarat. The intensity was 6.9 on the Richter Scale. Thousands of people died. The administration through Disaster Management initiatives played an important role.
• Various agencies played a significant role in rehabilitation and relief planning.
• Planned and arranged the required logistics (Manpower, doctors, medicine etc.)
• The administration organized sending of large quantity of relief material, including tents, medicines, clothes, blankets etc.

It may be noted that we term these situations as that of supply chain, since they call for a network of organizations suppliers, manufacturers, relief agencies, transporters both national and international and the general public.

6.9 SUMMARY:

The need for supply chain management has risen due to several business challenges including shrinking product life cycle: mass customization, increasing outsourcing, and most importantly the process of globalization. Today's customer has become very much demanding. Business alliances have to be forged on a global basis to derive the optimum benefit from strategic locations in terms of factors like cost, quality and proximity to raw material or markets so as to respond to the demanding class of customers. Supply chain management perspective provides opportunities for organizations to meet the challenges. These challenges have led to the emergence of complex supply chains in all manufacturing sectors and industries including service sectors. Competition between individual has been transformed to competition between their supply chains enterprises. Efficient management of these supply chains has emerged as the biggest differentiating factor between a successful and successful business.

This chapter has presented a variety of mathematical models available in managing the supply chain. These models are quantitative in nature. The effectiveness of these models is heavily based on the quality of assumptions and the data inputs required to run these models. It is expected that a typical SC manager will be able to resolve a number of issues using these models. Today, with the help of software capability, these models are easily amenable to solutions. It may also be noted that these models may be used either singly or as a combination of a variety of models. A Decision Support System (DSS) can be visualized based on these models, which should be capable of answering a variety of “what if” questions that may need to be answered in a typical supply chain scenario. These models are to be viewed as first order, approximations. They provide a very good basis for gaining insight into the underlying supply chain solution.