CHAPTER II
THEORETICAL FRAMEWORK OF LOGISTICS MANAGEMENT

Introduction

The birth of Logistics can be traced back to an ancient war times of Greek and Roman empires when military officers, titled as 'Logistikas', were assigned the duties of providing services related to supply and distribution of resources. During the World War II logistics gained importance in army operations, covering the movement of supplies, men and equipment across border. In the United States of America, the army officially used the word, Logistics, after World War II.

Logistics has now evolved itself as an art and science. However, it cannot be termed as an exact science. Logistics does not follow a defined set of tables nor is it based on skills inherited from birth. Any firm exists in an environment of external forces which impinge on its activities which are of direct interest and concern to the distribution division of a firm. They are the location of resources and markets, the competitive environment, the nature of demand, and certain characteristics of the distribution system. Our primary concern is the role of the logistics system in the internal environment and its role in helping to provide good service at low cost.
A logistics manager performs his duties and responsibilities based on his educational experiences, skills, past experiences and intuition. These skills are nourished by a constant application of the same by him for the betterment of his organization. The logistics manager ensures that the company is benefited by an effective and efficient system of logistical management. He also needs to ensure that the right kind of products and services are provided at the right time and for a right price, whether inside the organization's premises or delivery of shipments outside the premises of the organization. The operating responsibility of logistics is the geographical positioning of raw materials, work-in-process, and finished inventories where required, at the lowest cost possible.

Logistics has come to be a kind of relief for many organizations that formerly looked upon it as a burden. Companies nowadays are hiring people with the requisite knowledge to deliver sustainable enhancements in the field of supply chain management. As has been the case throughout most of logistics history, the task of a logistics manager involves a clear vision and a drive within to deliver results under strict deadlines in addition to his usual responsibilities.

Today logistics has acquired a wider meaning and is used in business for the movement of new materials from suppliers to the manufacturers and finally the finished goods to the consumers. Logistics Management has been
identified as the primary challenge for organizations desiring to exploit logistics capabilities to gain and maintain customer loyalty. The concept, based on total cost analysis and total quality control, ties together all logistics activities and views the results as a system that strives to minimize total distribution cost, while achieving desired customers levels through providing satisfaction to customers, and retaining customer loyalty. The fusion of information logistics and transportation technologies provides rapid crisis response to track and shift assets, even while en route, and to deliver tailored logistics packages and sustainment directly at the strategic, operational and tactical levels of operations.

**Definition of Logistics Management**

Bowersox and Closs (2000) opine that logistics involves “A single minded logic to guide process of planning, allocating and controlling financial and human resources committed to physical distribution, manufacturing, support and purchasing operations”.

Robert A. Novack, et al. (1995), define logistics as an “Activity involving the creation of time, place, form and possession of utilities within and among firms and individuals through strategic management with the goal of creating products/services that satisfy customer through attainment of value”.

32
According to Webster’s New Encyclopedia Dictionary (1993), logistics is: The branch of military science having to do with recurring, maintaining and transporting material, personnel and facilities.

In brief, logistics encompasses the total flow of materials, from acquisition of the raw materials and purchased component parts, to delivery of a finished product to the customer.

Logistics adds value when inventory is correctly positioned to facilitate sales. Creating logistics value is costly. For individual firms, logistics expenditures typically range from 5 to 35 per cent of sales depending on the type of business, geographical area of operation, and weight/value ratio of products and materials. Logistics typically accounts for one of the highest costs of doing business, second only to materials in manufacturing or cost of goods sold in wholesaling or retailing. The challenge is to balance service expectations and cost expenditures in a manner that achieves business objectives. In final analysis, logical service is the balance of service priority and cost. One universal process that all firms must successfully complete is the creation of customer value. Such value is essential in gaining and retaining a loyal customer base.

Basic logistical service is measured in terms of:
(1) Availability

Availability means having inventory to consistently meet customer material or product requirements. According to the traditional Paradigm, “higher inventory availability requires greater inventory investment”. Technology is providing new ways to achieve high inventory availability without associated high capital investments. Developments in inventory availability are critical because of its fundamental importance.

(2) Operational Performance

Operational performance deals with the elapsed time from order receipt to delivery. Operational performance involves delivery speed and consistency. Naturally, most customers want fast delivery. However, fast delivery is of limited value if it is erratic. A customer gains little benefit when a supplier promises next day delivery but, more than not, is late. To achieve smooth operations, firms typically seek first to achieve consistency of service and then to improve delivery speed. Other aspects of operational performance are also important. A firm’s operational performance can be viewed in terms of how flexible it is in accommodating unusual and unexpected customer
requests. Another aspect of operational performance is malfunction and recovery. Few firms can promise and perform perfectly in every situation all of the time. It is important to gauge the likelihood of something going wrong. Malfunction refers to the probability of logistical assortments, or inaccurate documentation. When such malfunctions occur, a firm’s performance can be measured in terms of required time to recover. Operational performance is concerned with how a firm handles all aspects of customer requirements, including service failure, on a day in and day out basis.

(3) Service Reliability

Service Reliability involves the quality attributes of logistics. The key to quality is accurate measurement of availability and operational performance. Only through comprehensive performance measurement is it possible to determine if overall logistical operations are achieving desired service goals. To achieve service reliability, it is essential to identify measures to assess inventory availability and operational performance. For logistics performance to continuously meet customer expectations, it is essential that management be committed to continuous improvement. Logistical quality does not come easy: it’s the product of careful planning supported by training, comprehensive measurement, and continuous improvement. To improve service performance, goals need to be established on a selective basis. Some products are more critical than others because of their importance to the
customer and their relative profit contribution. The level of basic logistical service should be realistic in terms of customer expectations and requirements. In most cases, firms confront marketing situations wherein customers have different sales potential and some may require unique services. The managers must realize that customers are different and that services must be matched to accommodate unique preference and purchase potential. In general, firms tend to be overly optimistic when committing to average or basic customer service performance. Inability to consistently meet an unrealistically high basic service target might result in more operating and customer problems than if less ambitious goals had been made at the outset. Unrealistic across-the-board service commitments can also dilute a firm’s capability to satisfy special requirements of high-potential customers.

Logistics is responsible for the movement and storage of materials as they move through the supply chain.

**Logistics in Global Economy**

It is an accepted fact that effective logistics system is important not only for domestic operations but equally important for global manufacturing and marketing. Domestic logistics focus on performing value-added services in a controlled business environment. Global logistics operations must accommodate all domestic requirements and also deal with increased uncertainties associated with distance, demand diversity and documentation.
The operating challenges faced by global logistics systems are significantly within operating regions. The North American logistics vision is one of open geography with extensive demand for land-based transportation and relatively limited need for cross-border documentation. The European logistician, on the other hand, views geography involving numerous political, cultural, regulatory and language barriers. The Pacific Rim logistician has an island perspective that requires extensive water or air shipment to transcend vast distances. These different perspectives require logistics managers who operate globally to develop a wide variety of capabilities and expertise.

In the past, an enterprise could survive with a unique North American, European, or Pacific Rim logistics perspective. Specifically an enterprise could achieve substantial success through regional capability. While this is still true for some firms, those that desire to grow and prosper are finding a regional business strategy is no longer adequate. In order to allow manufacturing and marketing scale economies to support market growth, enterprises are developing global logistics expertise. The extended global capabilities must include international transportation, cultural diversity, Multilanguage capability, and extended supply chain operations requirements that make them unique in comparison to domestic logistics. The overall purpose of the chapter is to compare global and domestic logistical operations. The initial sections focus on forces, barriers and challenges involved in global logistics. Five major forces that are influencing global
logistics are initially reviewed. Attention is then directed to a discussion of perceptions and practices that are barriers to global expansion. This initial section concludes with an overview of the global logistics challenge. Next a comparison is made between nationalistic and stateless perspectives of global logistics. The discussion reviews the management and logistics implications of each perspective. The following section outlines five stages of typical global operations and stresses how major business initiatives change as firm progressively becomes more globalized. The next section discusses the development status in each major trading region of the world. Attention is also directed to selected developing regions that are positioned to become major future trading areas.

Organizations can become global in outlook, buying, storing, manufacturing, moving and distributing materials in a single, worldwide market. As a result, international trade and competition are continuing to rise. Organizations used to look for competitors in the same town, but now they are just as likely to come from another continent.

Efficient logistics makes a global market feasible, and other factors that encourage international trade include less restricted financial systems, consumer demand for imported products, removal of import quotas and trade barriers and the growth of free trade areas. It can be seen that the effects in manufacturing, where producers look for economies of scale in large facilities
located in areas with low production costs. The unit production cost is low, and efficient logistics keeps the delivered price down. This is the reason why German companies open large plants in Poland, American companies work in Mexico and Japanese companies work in China.

Advantages of Globalisation

• Reduced number of suppliers

In the past, organizations have used a large number of suppliers. This encouraged competition, ensured that they got the best deal and maintained secure deliveries if one supplier ran into difficulties. The current trend, however, is, to reduce the number of suppliers and develop long-term relationships with the best.

• Concentration of Ownership

Large companies can get economies of scale, and they have come to dominate many supply chains. There are, for example, many shops and transport companies – but the biggest ones continue to grow at the expense of small ones. The result is a continuing concentration of ownership, which can be seen in many logistics sectors ranging from food wholesalers to cruise lines.
• **Outsourcing**

More organizations realize that they can benefit from using specialized companies to take over part of their logistics. Using a third party for materials movement leaves an organization free to concentrate on its core activities. McKinnon says that, ‘Outsourcing has been one of the dominant business trends of the 1980s and 1990s’ and suggests that around 30 per cent of logistics expenditure is outsourced in the European Union.

• **Postponement**

Traditionally, manufacturers move finished goods out of production and store them in the distribution system until they are needed. When there are many variations on a basic product, this can give high stocks of similar products. Postponement moves almost-finished products into the distribution system, and delays final modifications or customization until the last possible moment. You can imagine this with ‘pack-to-order’, where a company keeps a product in stock, but only puts it in a box written in the appropriate language when it is about to ship an order.

Manufacturers of electrical equipment, such as Philips and Hewlett-Packard, used to build into their products the transformers and plugs needed for different markets. Then they had to keep separate stocks of products destined for each country. Now they make the transformer and cables as
separate, external units. The result, of course, is much lower stocks. In the same way, Benetton used to dye yarn different colours, knit sweaters and keep stocks of each colour to meet varying demand. Now they knit sweaters with undyed yarn, keep much smaller stocks of these, and dye the finished sweaters to meet actual orders.

- Cross-docking

Traditional warehouses move materials into storage, keep them until needed, and then move them out to meet demand. Cross-docking co-ordinates the supply and delivery, so that goods arrive at the receiving area and are transferred straight away to a loading area, where they are put into delivery vehicles. This dramatically reduces stock levels and associated administration.

There are two basic forms of cross-docking. In the first, packages are moved directly from arriving vehicles and onto departing ones. This does not really need a warehouse and a simple transfer point is enough. In the second form there is some additional work as materials arrive in larger packages which are opened, broken into smaller quantities, sorted, consolidated into deliveries for different customers and transferred to vehicles.

Cross-docking can develop to the point where stock on wheels. A related arrangement uses drop-shipping, where wholesalers do not keep stock themselves, but co-ordinate the movement of materials directly from upstream suppliers to downstream customers. As warehousing is expensive and time-
consuming, these methods can give much more efficient flows, and allow methods such as quick response and efficient customer response.

- **Direct delivery**

  More customers are buying through the web, or finding other ways of trading earlier in the supply chain, such as mail order or buying directly from manufacturers. This has the benefits of reducing lead times, reducing costs to customers, having manufacturers talking directly to their final customers, allowing customers access to a wider range of products, and so on. It also means that logistics has to move small deliveries quickly to final customers. This has encouraged the growth of couriers and express parcel delivery services such as FedEx, DHL etc.

- **Stock reduction methods**

  Keeping stock is expensive, so organizations continually look for ways of reducing the amount stored in the supply chain. There are many ways of doing this. One approach uses just-in-time operations to co-ordinate activities and minimizes stock levels. Another approach has vendor managed inventory, where suppliers manage both their own stocks and those held further down the supply chain. Improved co-ordination reduces overall costs and can give economies of scale.
• **Increasing environmental concerns**

There is growing concern about air pollution, water pollution, energy consumption, urban development and waste disposal. Logistics does not have a good reputation for environmental protection – demonstrated by the emissions from heavy lorries, use of green field sites for warehouses, call for new road building, use of extensive packaging, ships illegally flushing their fuel tank, oil spillages from tanker accidents, and so on.

On the positive side, logistics is moving towards ‘greener’ practices. Operators use more energy efficient vehicles, control exhaust emissions, reuse packaging, switch to environmentally friendly modes of transport, increase recycling through reverse logistics, add safety features to ships, develop brown-field sites, and so on. They increasingly recognize that careful management can bring both environmental protection and lower costs. A fair assessment might be that logistics is making progress on environmental issues, but it has some way to go.

• **More collaboration along with the Supply Chain**

Organizations in a supply chain increasingly recognize that they have the same objectives which are satisfied final customers. They should not, therefore, compete with each other, but should co-operate to get final customer satisfaction. This is an important point. It means that competitors
are not other organizations within the same supply chain, but are organizations in other supply chain.

**Recent Global Developments in Logistics Management**

Logistics has come into vogue in strategic management in the past decade. Once a traditional industry of moving goods around, cargo transport has been transformed into a modern “logistics” business which creates value by integrating transportation activities and providing supporting services of facilitate the smooth operation of material flow, which constitutes a vital part in supply chain management.

- Technological developments substantially compressing the product life cycle. Make-to-order and zero inventory have become industry benchmarks;

- Changing consumer preferences require mass customization and quick response to market trends;

- Due to price competition, reducing logistics costs is crucial to maintain the profit margin; and

- The rise of e-commerce result in generating scattered/ piecemeal orders and the need for door-to-door delivery services.

In recent years, more and more operations are being explored for better supply chain management. Specialised companies have been developed to
provide third-party logistics services. Approximately two-thirds of all major US consignees now use third-party logistics support.

Sophisticated logistics services are custom-designed to meet specific end-user needs. Customers appear to prefer to use as few services providers as possible, and the general trend is towards fewer and larger providers. Indeed, recent trends are for shippers, consignees and services providers to come together at various parts of the value chain to find common solutions.

**Logistics Network Design**

In addition to enhancing the efficiency and effectiveness of a logistics operation, the redesign of a firm’s logistics network can help to differentiate a firm in the market place. For example, firms may expand or shrink their logistics networks by increasing or decreasing their distribution centres, or consolidate their existing systems to improve logistical customer service and to differentiate their services compared to competition in the market place. Firm consider the impact of such decisions to redesign their logical networks on total logical costs. Also use of currently available information technology, transportation services etc. can enhance responsiveness and the level of service experienced by customers.
The need for Long Range Planning

In the short-run, for a given logistics network and location of the key facilities of a firm, the logistics manager must operate within the constraints imposed by the facility locations. Changing facility locations in the short-run becomes impractical because of site availability leases, contracts and investments. But in the long run, management should consider the logistics network design as a variable factor and should take decisions to change the network to meet the logistics requirements imposed by customers, suppliers and competitive changes.

Further, a facility properly located based on today’s economic, competitive and technologies conditions may not be optimum location under future conditions. Also today’s location decision will have profound effect on future costs in such areas as logistics, marketing, manufacturing and finance. Hence, the facility location must seriously consider anticipated business conditions and recognize the critical need to be flexible and responsive to customer needs as they may change in the future.

The Strategic Importance of Logistics Network Design

All businesses operate in a very dynamic environment in which change is inevitable. Characteristics of consumer, industrial buyer demand, technology, competition, markets and suppliers are constantly changing. As a
result, businesses must redeploy their resources in response to and in anticipation of the ever-changing environment.

Because of the rate at which change is occurring, no existing logistics network can be truly up to date. Hence, any logistics network that has been existing for a number of years needs to be re-evaluated and redesigned.

There are many types of changes that may suggest a need to re-evaluate and/or redesign a firm’s logistics network. They are:

(i) Changing customer service requirements
(ii) Shifting locations of customer and / or supply markets.
(iii) Change in corporate ownership.
(iv) Cost pressures.
(v) Competitive capabilities and
(vi) Corporate organizational change.

These changing elements of the business environment are briefly discussed in the following section:

(i) **Changing Customer Service Requirements:** The logistics requirements of customers are changing in many ways. As a result, the need to reevaluate and redesign logistics networks is of great contemporary interest.
(ii) **Shifting Locations of Customer and / or Supply Markets:** The manufacturing and logistics facilities are positioned in the supply chain between customer and supply markets and any changes in these markets force the firm to reevaluate its logistics network. When the location of customer markets shift geographically, new warehouses and distribution facilities are established following the changing geolocation trends. On the supply side, the service and cost requirements of firms practicing JIT – based manufacturing have forced the suppliers, firms to examine the locations of logistics facilities. Many suppliers have selected nearby points for manufacturing and / or parts distribution faculties.

(iii) **Change in Corporate Leadership:** Ownership-related change associated with a merger, acquisition or divestiture is a common occurrence for a firm now a days. In such instances, many firms choose to be proactive and to conduct a formal evaluation of new logistics networks versus previous logistics networks before implementing such a change this approach will facilitate to ensure that the newly merged or newly independent firm will have fully anticipated the logistics impacts of the change in corporate ownership.

(iv) **Cost Pressures:** Many firms consider today their major priority is to figure-out new and innovative ways to remove cost our of their key
business processes including those related to logistics. A reevaluation of the logistics network and of the functioning of the overall supply chain can help to find new sources of cost savings. Such sources could be transportation, inventory or warehousing. Companies considering modernization needs of plant also benefit from a comprehensive cost analysis along with a revaluation of the logistics network.

(v) **Competitive Capabilities:** Competitive pressures may force a firm to examine its logistics service levels and the costs generated by its network of logistics facilities. To remain competitive in the marketplace or to develop a competitive advantage, a firm should frequently examine the relative locations of its facilities toward the goal of improving service and/or lowering costs.

(vi) **Corporate Organizational Change:** Even when a firm considers any major corporate organizational change such as downsizing, the strategic functioning of the firm’s logistics network is viewed as something that must be protected and even enhanced through the process of organizational change.

**Logistics network design process**

The task of designing an appropriate logistics network should be coordinated closely with the identification and implementation of key corporate and overall business strategies.
The six major steps involved in the Logistics Network Design Process are as follows:

(i) Define the logistics network design process.
(ii) Perform a logistics audit.
(iii) Examine the logistics network alternatives.
(iv) Conducting a facility location analysis
(v) Make decisions regarding network and facility location.
(vi) Develop an implementation plan.

Step 1 : Defining the Logistics Network Design Process

A logistics network reengineering team should be formed and made responsible for all elements of the logistics design process. This team needs to become aware of overall corporate and business strategies and the underlying business needs of the firm and the supply chains in which it is a participant.

Step 2 : Performing Logistics Audit

The logistics audit provides members of the reengineering team with a comprehensive perspective on the firm’s logistics process. Further, it helps to collect essential types of information which will be useful throughout future steps in the redesign process.
The types of information that should become available as a result of the logistics audit are:

(i) Customer requirements and key environmental factors.

(ii) Key logistics goals and objectives.

(iii) Profile of the current logistics network and the firm’s position in the respective supply chain.

(iv) Bench-mark or target values for logistics costs and key performance measurements.

(v) Identification of gaps between current and desired logistics performance (both qualitative and quantitative).

(vi) Key objectives for logistics network design, expressed in term that will facilitate measurements.

**Step 3: Examining the Logistics Network Alternatives**

This step involved application of suitable quantitative models to the current logistics system as well as to the alternative systems and approaches that are being considered. These models provide considerable insight into the functioning and cost / service effectiveness of the various possible networks. Some of the modeling approaches are: (i) optimisation, (ii) simulation and (iii) heuristic approach. While optimization approaches search for the “best” solution, simulation models replicate the functioning of the logistics network.
Heuristic technique can accommodate broad problem definitions but do not provide optimum solutions.

**Step 4: Conducting a Facility Location Analysis**

Once a general configuration of the desired logistics network has been decided, the next task is to carefully analyse the attributes of specific regions and cities for sites of logistics facilities. These analysis will have both quantitative and qualitative aspects. The quantitative aspects include economic (or cost) factors (i.e. land costs, cost of utilities, labour cost, material cost energy cost etc.) whereas the qualitative factors include such considerations as labour attitude, transportation issues (i.e., availability), proximity to market and customers, quality of life, industrial development incentives, supplier networks, and company preference.

A location selection team is formed which will collect information on specific attributes such as those mentioned earlier. Further, this team should be able to examine potential sites in terms of topography, geology and facility design.

**Step 5 : Making Decisions Regarding Network and Facility Location**

In this step, the network and specific sites for logistics facilities recommended should be evaluated for consistency with the design criteria that were identified in step no. 1. This step should confirm the types of change that
are needed to the firm’s logistic network and should do so in the context of overall supply chain positioning.

**Step 6: Developing an Implementation Plan**

The development of an effective implementation plan is a critical activity. This plan should serve as a useful roadmap for moving from the current logistics network to the desired one. It is important that the firm commits the resources necessary to assure a smooth, timely implementation.

**Table 2.1**

**Major Locational Determinants**

<table>
<thead>
<tr>
<th>Regional Determinants</th>
<th>Site-specific Determinants</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Labour climate</td>
<td>(i) Transportation access (e.g., truck, air, water and rail)</td>
</tr>
<tr>
<td>(ii) Availability of Transportation facilities</td>
<td>(ii) Inside/outside metropolitan area</td>
</tr>
<tr>
<td>(iii) Proximity to market and Customers</td>
<td>(iii) Availability of labour (work force)</td>
</tr>
<tr>
<td>(iv) Quality of Life</td>
<td>(iv) Land costs and taxes</td>
</tr>
<tr>
<td>(v) Taxes and incentives</td>
<td>(v) Utilities</td>
</tr>
<tr>
<td>(vi) Supplier networks</td>
<td></td>
</tr>
<tr>
<td>(vii) Land Costs and Utilities</td>
<td></td>
</tr>
<tr>
<td>(viii) Company preference</td>
<td></td>
</tr>
</tbody>
</table>

| Regional determinants and                                  |
| Site-specific determinants.                                 |

Location determinants can be classified as:

(i) Regional determinants and

(ii) Site-specific determinants.
The importance of major locational determinants varies among industries and among individual companies within specific industries.

**Reverse Logistics**

Many organizations and individuals have tried to define Reverse Logistics. We refer to the term "reverse logistics" as all activity associated with a product/service after the point of sale, the ultimate goal to optimize or make more efficient aftermarket activity, thus saving money and environmental resources.

Reverse logistics stands for all operations related to the reuse of products and materials. It is "the process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal. More precisely, reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value, or proper disposal. Remanufacturing and refurbishing activities also may be included in the definition of reverse logistics. The reverse logistics process includes the management and the sale of surplus as well as returned equipment and machines from the hardware leasing business. Normally, logistics deal with events that bring the product towards the customer. In the case of reverse, the resource goes at least one step back in the supply chain."
For instance, goods move from the customer to the distributor or to the manufacturer.

**Business implications**

In today's marketplace, many retailers treat merchandise returns as individual, disjointed transactions. "The challenge for retailers and vendors is to process returns at a proficiency level that allows quick, efficient and cost-effective collection and return of merchandise. Customer requirements facilitate demand for a high standard of service that includes accuracy and timeliness. It’s the logistic company's responsibility to shorten the link from return origination to the time of resell. By following returns management best practices, retailers can achieve a returns process that addresses both the operational and customer retention issues associated with merchandise returns. Further, because of the connection between reverse logistics and customer retention, it has become a key component within Service Lifecycle Management (SLM), a business strategy aimed at retaining customers by bundling even more coordination of a company's services data together to achieve greater efficiency in its operations. Reverse logistics is more than just returns management; it is "activities related to returns avoidance, gate keeping, disposal and all other after-market supply chain issues". Returns management – increasingly being recognized as affecting competitive positioning – provides an important link between marketing and logistics. The
broad nature of its cross-functional impact suggests that firms would benefit by improving internal integration efforts. In particular, a firm's ability to react to and plan for the influence of external factors on the returns management process is improved by such internal integration. Third-party logistics providers see that up to 7% of an enterprise's gross sales are captured by return costs. Almost all reverse logistics contracts are customized to fit the size and type of company contracting. The 3PL's themselves realize 12% to 15% profits on this business. "Studies have shown that an average of 4% to 6% of all retail purchases are returned, costing the industry about $40 billion per year."

**Return of unsold goods**

In certain industries, goods are distributed to downstream members in the supply chain with the understanding that the goods may be returned for credit if they are not sold. Newspapers and magazines serve as examples. This acts as an incentive for downstream members to carry more stock, because the risk of obsolescence is borne by the upstream supply chain members. However, there is also a distinct risk attached to this logistics concept. The downstream member in the supply chain might exploit the situation by ordering more stock than is required and returning large volumes. In this way, the downstream partner is able to offer high level of service without carrying the risks associated with large inventories. The supplier effectively finances
the inventory for the downstream member. It is therefore important to analyze customers’ account for hidden cost.

**3PSP (Third party service provider)**

3PSP - Third party service providers provide services for OEMs, ODMs and Branded Companies. Some of these services include, but are not limited to: repair, customer service, parts management, end-of-life manufacturing, returns processing order fulfillment, help desk, and many aspects of field service repair.

**3PL (Third Party Logistics)**

3PL - Third party logistics companies provide services for OEMs, ODMs and Branded Companies. Some of these services include, but are not limited to: transportation, (including domestic and international) warehousing, distribution, fulfillment and packaging, customs brokerage, freight payment services and trade compliance.

**4PL (Fourth Party Logistics)**

4pls - Fourth party logistics organizations can also be referred to as depot repair hubs. Typically they are service companies that provide repair services, refurbishment, and liquidation for 3pls, OEMs, ODMs and Branded companies.
Components of Logistics

Following are the major elements/ functions of Logistics management.

1. Inventory Management
2. Warehousing Management
3. Transportation Management
4. Information & Communication

INVENTORY MANAGEMENT

Inventory is defined as any idle resources of an enterprise. It is a physical stock of goods kept for future use. In a factory the inventory may be in the form of raw materials, parts, semi-finished goods. Inventory also includes furniture, machinery etc. Inventory is essential to provide flexibility in operating system or organization. An inventory can be classified into raw materials inventory, work-in-process inventory and finished goods inventory. The raw material inventory removes dependency between suppliers and plants. The work-in-process inventory removes dependency between various machines of a product line. The finished goods inventory removes dependency between plants and its customers or market. The main functions of an inventory are smoothing out irregularities in supply, minimizing the production cost and allowing organizations to cope up with perishable materials.
Inventory decisions are high-risk and high-impact from the perspective of logistics operations. Commitment to a particular inventory assortment and subsequent shipment to a market or region in anticipation of future sales determine a number of logistics activities. Without the proper inventory assortment, marketing may find that sales are lost and customer satisfaction will decline. Likewise, inventory planning is critical to manufacturing. Raw material shortages can shut down a manufacturing line or modify a production schedule, which, in turn, introduces added expense and potential for finished goods shortages. Shortage of raw materials can disrupt planned marketing and manufacturing operations, overstocked inventories also create problems. Overstocks increase cost and reduce profitability through added warehousing, working capital requirements, deterioration, insurance, taxes, and obsolescence losses.

The decisions include inventory tracking, determining when to replenish inventory, and determining the amount to replenish. For each inventory decision, major considerations are reviewed and guidelines are developed. The inclusion of provisions to accommodate freight rates and discounts allows lot sizing to take advantage of operational realities.

**Inventory Functionality**

The ideal inventory process consists of manufacturing a product to a customer’s specifications once an order is placed. This is called a make-to-
order operation and is characteristic of customized equipment. Such a system
does not require stockpiles of materials or finished goods in anticipation of
future sales. While a zero-inventory manufacturing distribution system is not
always practical, it is important to remember that each dollar invested in
inventory must be traded off against other logistics resources and must
demonstrate an effective total cost return.

The inventory function is a major element of the logistics process that
must be integrated to meet service objectives. While a traditional approach
to achieving a higher service level is to increase inventory, other approaches
include use of faster transportation modes, better information management to
reduce uncertainty, or alternatives sources of supply. It is the task of overall
logistics management to meet the prescribed service objectives, inventory
management plays a particular key role.

**Reasons for Maintaining Inventories**

Most of the management decisions regarding the inventory arise
because of the various alternative course of action available with the
enterprise. It is essential for enterprises to have inventory due to the
following reasons.

(i) It helps in smooth and efficient running of the business.

(ii) It provides adequate service to the customers.
(iii) It reduces the possibility of duplication of orders.

(iv) It helps in maintaining economy by absorbing some of the fluctuations when the demand of an item fluctuates or is seasonal.

(v) It helps in minimizing the loss due to the deterioration, obsolescence, damage etc.

(vi) It acts as a buffer stock when raw materials are received late and shop rejections are too many.

(vii) Takes advantages of price discounts by bulk purchasing.

Though the inventories are essential and provide an alternative to production/purchase in the future, it also locks up the capital of the enterprise. It includes the expenses of stores, equipment, personnel, insurance etc., therefore, excess inventories are undesirable. Larger inventories do not necessarily lead to a high volume of output instead if might hamper the production.

Our problem is to balance between the advantages of having inventories and cost of carrying them to arrive at an optimal level of inventories to minimize the total inventory cost. This calls for controlling the inventories in the most profitable way. The basic objective of inventory control is to release capital for more productive use.
Types of Inventory

There are five types of inventory, namely:

(i) Transportation inventories
(ii) Buffer inventories
(iii) Anticipation inventories
(iv) De coupling inventories
(v) Lot-size inventories

Transportation inventories

This arises due to the transportation of inventory items to the various distribution centers and customers form the various production centers. The amount of transportation inventory depends on the time consumed in transportation and the nature of the demand.

Safety Stock Inventory

The average inventory is the stock held to protect against the impact of uncertainty on each facility. This portion of inventory, as noted earlier, is called safety stock. Safety stock inventory is used only at the end of replenishment cycles when uncertainty has caused higher than expected demand or longer than expected performance-cycle times. The basic premise of safety stock is that a portion of average inventory should be devoted to
cover short-range variation in demand and replenishment. Given safety stock, average inventory equals one-half of the order quantity plus the safety stock.

**Anticipation Inventories**

These are built in advance by anticipating or foreseeing the future demand. For example, production of crackers before the Diwali festival, electric fans, or coolers before the on-set of summer season.

**De-coupling Inventories**

The inventories used to reduce the interdependence of various stages of production system are known as de-coupling inventories.

**Lot-size Inventories**

Generally the rate of consumption is different from the rate of production or purchasing. Therefore, items are produced in larger quantities which result in lot-size, also called as cycle inventories.

**Inventory costs**

There are four categories of inventory cost associated with keeping inventories as per the details given below:

(i) Item (or production or purchase) cost
(ii) Ordering or set-up cost.
(iii) Carrying or holding cost.
(iv) Shortage or stock out cost.
**Item cost**

It refers to the cost associated with an item whether it is manufactured or purchased. The purchase price will be considered when discounts are allowed for any purchase above a certain quantity.

**Ordering or Set-up Cost**

These costs include the fixed cost associated with obtaining the goods through pacing of an order or purchasing or manufacturing or setting-up a machinery before starting the production. They include the costs of – purchase, requisition, follow up, receiving the goods, quality control etc. These are also called as order costs or replenishment costs usually denoted by $C_3$ per production run (cycle). They are assumed to be independent of the quantity ordered or produced.

**Carrying or holding cost**

The cost associated with carrying or holding the goods in stock is known as holding or carrying cost. Holding cost is assumed to vary directly with the size of inventory as well as the time the item is held in stock. The following components constitute the holding cost.

1. Invested capital cost: This is the interest charge over the capital invested.
2. Record keeping and administrative cost.
3. Handling cost: These include costs associated with movement of stock such as cost of labour etc.

4. Storage costs.

5. Depreciation costs.

6. Taxes and insurance etc.

**Shortage cost or stock out cost**

The penalty costs that are incurred as a result of running out of stock (ie shortage) are known as shortage or stock out costs.

If the unfilled demand for the goods can be satisfied at a later date, these costs are assumed to vary directly with the shortage quantity and the delaying time both. If the unfilled demand is lost (no back-log case) shortage cost becomes proportional to shortage quantity only.

**Variables in the inventory problem**

The variable involved in the inventory model is of two types:

(i) Controlled variable (ii) Uncontrolled variables

**Controlled variables** - This variable include three basic questions namely –

1. How much quantity of an item that should be ordered?

2. When should the order be placed? I.e. the frequency or timing of acquisition.

3. The completion stage of stocked items.
**Uncontrolled Variables** - These include holding costs, shortage cost and set-up cost.

Demand refers to the number of items required per period. It may be known exactly or known in terms of probabilities or may be completely unknown.

The demand pattern of items may be either deterministic or probabilistic. Problems in which demand is known and fixed are called deterministic problem. Whereas those problems in which the demand is assumed to be a random variable are called stochastic or probabilistic problems.

In case of deterministic demand it is assumed that the quantities needed over subsequent periods of time are known exactly. Further the known demand may be fixed or variable with time. Such demands are called static or dynamic demands respectively.

The probabilistic demand occurs when the demand over a certain period of time is not known with certainty; but it is described by a known probability distribution. A probabilistic demand may be either stationery or non-stationery overtime.

**Lead Time**

The time gap between the placing of an order and the actual arrival of the inventory is known as lead-time. If the lead-time is known and is not
equal to zero, and if the demand is deterministic, that entire one requires to do is to order in advance by the time equal to the lead-time. If the lead-time is zero, there is no need to order in advance.

In case, the lead-time is a variable which is known only probabilistically, then the question of when to order is more difficult. The amount and the timing of replenishment are found by considering the expected costs of holding and shortage over the lead-time required.

**Amount Delivered (Supply of Goods)**

The supply of goods may be instantaneous or spread over a period of time. If a quantity q is ordered or purchased or produced, the amount delivered may vary around q with a known probability density function.

**Order Cycle**

The time period between placements of two successive orders is referred to as an order cycle. The order cycle may be placed on the basis of the following two types of inventory review systems.

**Continuous Review**

The record of the inventory level is checked continuously until a certain lower limit (known as recorder level) is reached when a new order is placed. This is often known as two-bin systems.
Periodic Review

In this the inventory levels are reviewed at equal time intervals and orders are placed at such intervals. The quantity ordered each time depends on the available in inventory level at the time of review.

Recorder Level

The level between the maximum and the minimum stock at which the purchasing (manufacturing) activities must start for the replenishment is known as recorder level.

The inventory model can be classified into two categories.

(1) Deterministic inventory model.
(2) Probabilistic inventory model.

Deterministic Inventory Model

In this model, the demand is assumed to be fixed and completely predetermined i.e. static demand. Such models are referred to as economic lot size model.

There are 4 types under this category, namely,

(i) Purchasing model with no shortages.
(ii) Manufacturing model with no shortages.
(iii) Purchasing model with shortages.
(iv) Manufacturing model with shortages.
Probabilistic Inventory model

Probabilistic model gives only an anticipated inventory and not firm inventory model.

FORECASTING DEMAND

Forecasting demand levels is vital to the firm as a whole, as it provides the basic inputs for the planning and control of all functional areas including the supply chain. Demand levels and their timing greatly affect capacity levels, financial needs, and general structure of the business. Each functional area has its special forecasting problems. Supply Chain forecasting concerns the spatial as well as variation of demand with time, the extent of its variability, and its degree of randomness.

Planning and controlling supply chain activities require accurate estimates of the product and service volumes to be handled by the chain. These estimates are typically in the form of forecasts and predictions. The supply chain professional often finds it necessary to take it upon him or herself to produce forecasts for short-term planning such as inventory control, order sizing, or transport scheduling.

Nature of Forecasting

In business and economics, forecasting has various meanings. There are two distinct quantities involved in forecasting, a forecast and a prediction.
A prediction is a border concept. It is an estimate of a future event achieved through subjective considerations other than just past data; this subjective consideration need not occur in any predetermined way.

In supply chain management, a specific definition of a forecast is adopted, which is given below:

A forecast is an estimate of a future event achieved by systematically combining and casting forward in a predetermined way data about the past.

An analysis of the factors that influence future values determines how future values are estimated. One way to characterise different kinds of forecasting can be based on how far into the future they focus. Detailed forecasts for individual items are generally short-term forecasting. Such forecasts are used to plan the short-run decisions which are used for inventory control, order sizing, or transport scheduling, etc. Aggregate product-demand forecasts are medium term forecasts used to plan for capacity, location and layout over a much longer time span. Long-term forecasts are used for strategic decision making. In this chapter, the focus is on short-term forecasting methods which are of primary importance to supply chain professionals.

The supply chain has both space and time dimensions. That is, the supply chain professional must know where demand volume will take place as well as when it when it will take place. Spatial location of demand is
needed to plan warehouse locations, balance inventory levels across the supply chain network, and geographically allocate transportation resources.

The nature of demand can differ greatly, depending on the operations of the firm and the activity for which the forecast is required. There are two types of demand. The first is when demand is generated from many customers, each of whom purchasing only a small fraction of the total volume. This type of demand is said to be independent. The second type of demand comes into play when the demand is derived from a production schedule. This type of demand is said to be dependent.

Independent demand uses statistical forecasting techniques. These models are based on independence and randomness of demand. In contrast, the demand is known in the case of dependent demand.

**Patterns of Demand**

Time, or temporal, concerns about demand levels are common in forecasting. Demand variation with time is a result of growth or decline in sales rates, seasonality in the demand pattern, and general fluctuations caused by a multitude of factors. Most short-term forecasting methods deal with historical data which is considered the determinant of future demand. This type of temporal variation may have different patterns, these patterns are called a time series. There are five basic patterns that have been identified below:
• **Horizontal**: The demand fluctuates around a constant mean.

• **Trend**: There is a systematic increase or decrease in the mean of the series over a period of time.

• **Seasonal**: There is a pattern of increase or decrease for the product or service, depending on the season or time of day, week or month.

• **Cyclical**: There is a gradual increase or decrease in demand with a change in direction after a period of time. Cycles are normally of long duration.

• **Random**: There is no discernible pattern in the change in demand.

The first four patterns of demand either independently or in different combinations – horizontal, trend, seasonal and cyclical. However, the last pattern, i.e. random variation is due to fortuitous causes and cannot be predicated using an underlying time pattern for demand.


**Figure 2.1: Different Patterns of Demand** (Time Series)
Figure 2.1 shows the different patterns of demand. The turning point shown in the figure refers to the point at which the demand will change. The occurs when there is seasonal for cyclical change in demand. Although it is difficult to predict the exact timing of turning points, some estimates can be established that are useful in establishing demand. The factors affecting demand can also be described in terms of the turning point.

WAREHOUSING MANAGEMENT

A warehouse is typically viewed as a place to store inventory. However, in many logistical system designs, the role of the warehouses is more properly viewed as a switching facility as contrasted to a storage facility. This chapter offers a unified treatment of strategic warehousing throughout the logistical system. The discussion is relevant for all types of warehouses as well as distribution centers, consolidation terminals, and break bulk and cross-dock facilities.

A major problem in logistical operations during the past several decades has been the level of labour productivity. The basic nature of raw materials, parts, and finished goods flowing through and between a vast network of facilities makes logistics a labour-intensive process. Productivity is the ratio of physical output to physical input. To increase productivity, it is necessary either to obtain greater output with the same input or to maintain existing output with a reduction of input factors.
Labour productivity growth is influenced by the boom and recession pattern of business, which has been a traditional characteristic of American industry since the turn of the century. When business is extremely good and the economy approaches full employment, output per worker-hour falls as marginal productive workers are employed. Warehousing operations get more than their fair share of such new employees because few, if any, skills are required to perform many of the manual tasks. When business activity plummets, union labour contract provisions often prohibit a rapid reduction in payrolls. While not all distribution facilities are unionized, logistics activities have traditionally been a union strength. Although separate productivity figures for warehouse workers are not available, it may be assumed that warehouse labour productivity has lagged most other areas in the private sector.

Some warehouses are completely automated, with no involvement of manual work inside. The pallets and products are moved with a system of automated conveyors and automated storage and retrieval machines coordinated by programmable logic controllers and computers. These systems are often installed in refrigerated warehouses where a very low temperature has to be maintained to keep the products from perishing. Defence depots/sheds (warehouse), explosive storehouses are at places fully automatic.
Traditional warehousing has been declining in the last decades of the 20th century with the gradual introduction of Just-in-time – or JIT techniques, designed to improve the return on investments of a business by reducing in-process inventory. The JIT system promoted the delivery of materials straight from the factory of the retail merchant or from parts manufacturers directly to a large-scale factory such as an automobile assembly plant, without the use of warehouses. However, with the gradual implementation of off-shoring in about the same time period, the distance between the manufacturer and the industrial plant grew considerably in many domains, necessitating at least one warehouse per country or per region in any typical supply chain for a given range of products.

Recent developments in marketing have also led to the development of warehouse-style retail stores with extremely high ceilings where decorative shelving is replaced by tall heavy duty industrial racks, with the items ready for sale being placed in the bottom parts of the racks and the created or pallet-borne and wrapped inventory items being usually placed in the top parts. In this way the same building is used both as a retail store and a warehouse.

**Strategic Warehousing**

Everyone is aware of the existence of the State warehousing corporations in India where food grains, sugar, potatoes, etc. are kept mainly for the following purposes:
(a) Public distribution system – Serving public need for distribution of subsidized food grains etc. to citizens of low income group.

(b) Serving public need for disaster management.

(c) Protecting the interests of the farmers against low procurement prices.

Storing of food grains in specially built warehouses/stock yards are known from the Vedic ages. From days immemorial there has been requirement of storage for the period that elapses between bulk production or harvest and retail consumption. Warehouses were designed out of necessity to store materials and products (such as food grains, molasses etc.), which have to be canned and preserved after production. At that time human resources were not as costly as today. There was no shortage of space and local building materials (like wood, bamboos etc.) were available in plenty. The market was also localized.

The importance of a warehouse is constantly increasing due to networking of production planning and transit storage distribution. Another challenge faced by the Logistics Service Provide is market expansion. There is emerging consumerism and change in the file style of people. Twenty years back, television, refrigerator, washing machines and mobile phones were not known, but nowadays these are essentials. Therefore, there may be change of product mix and volume of sales. An expansion program of five to
ten years must be provided for. At the same time, requirement for redesigning, realignment should also be calculated.

After the Industrial Revolution when bulk products were produced and export/import started between continents, commodity warehouses were built near the seaport both for incoming and outgoing materials and products. These warehouses today are mostly found empty, with storage space lefts unutilized.

Larger manufacturing organizations producing consumables, consumer durables, etc., built large warehouses themselves to bring down the cost of transportation and draw advantage from large-scale purchase production. Unilever, Bata etc. had large warehouses. As of now, most of the large warehouses are either rented out or closed.

The Armed Forces had large commodity warehouses near ports of embarkation/place of production (dedicated factories) for commodities like clothing, iron mongery, arms and Ammunition, Vehicles, spares or vehicles, food, fodder etc. From the commodity depots consignments were dispatched to retail/regional/field depots which were composite for all commodities required at regional or field levels. These were short listed into four segments, viz., food, fodder F/O/L, known as supply depots, Ammunition, Composite depots. For one window delivery of clothing, necessities Armament, Optical spares, Vehicle spares, expendables like Gasses, Paint,
iron mongery, etc. were Ordnance Depots and Ordnance Field Depots and Parks. A separate vehicle depots existed for issue of new and acceptance of discarded vehicles. There are also Salvage Depots for unwanted (condemned) stores and also Returned Vehicle Parks.

With advancement of technology and betterment in conditions, movement of consignments and improved communication facilities, integration of logistics services, the manufacturing organizations, armed forces, ports etc. are closing big warehouses. For instance, Bata India has closed its biggest warehouse in India at Santoshpur, Kolkata. Similarly, Kolkata Port Trust has closed a large number of its warehouses. Steel Authority of India has closed some of their yards. The armed Forces have decentralized a lot of materials so save additional storage costs. In the Armed Forces all over the world, studies done and implemented for better and effective warehousing knows no bounds as their customers are the troops who face death.

Drawing advantage of established transportation of raw materials, availability of space and Government subsidy/concession, availability of human resources, etc., mini plants like that of Cement, Steel have come up near retail market, thus reducing the requirement of warehouses. This has also led to reduction in costs of reaching the customers.
In existing business practices can organizations producing Fast Moving Consumer Goods (FMCG) or consumer durable manufacturers get rid of a warehouse? The answer is, of course “NO”, because to create product assortments for shipments to customers, interim storage may be required for a very short period.

There are three distinct advantages:

(a) Advantage of consolidated transportation can be obtained by delivery of assortment of products, thus reducing LSCM cost.

(b) Inventory of slow moving products can be reduced because of the capability to receive smaller quantities as a part of consolidated shipments. Manufactures who provide assorted product shipment can achieve a competitive advantage.

(c) Advantage of flexibility. A manufacturer can respond to the expanding customer demand in terms of product assortment and adopt a distinctive method of delivery of shipments. The economics of scale thus achieved improved information technology, ultimately reduces costs.

**Competitive Advantages**

Full line stocking helps improvement of service by reducing the number of suppliers that a customer may deal with. Combined assortment
contributes to more economical, larger shipments. As depicted in mixing different manufacturers, a supplier from one place or even different places may obtain services of a service provider to distribute to different customers through full line stocking. These may be:

(a) Home delivery

(b) Inventory control.

(c) Kanban

(d) Customer reference

(e) Kitting

(f) Lot Control

(g) Returnable container management

(h) Reverse logistics or returned/unsold/repairable materials handling

(i) Direct stores delivery for disposal/reuse.

**Production support Warehouse**

Traditionally, production support warehouses are established with the following aim:

(a) To maintain safety stock of spares / assembly / sub-assemblies / maintenance materials so that the chances of raw material / production stoppage due to erratic supply is avoided.
(b) To maintain safety stock of maintenance materials and spares thereof so that machinery engaged in production do not go out of action, Or, result is downtime cost.

(c) Importantly, production support warehouses or yards are an integral part of a producer participating in power sector, even for FMCG manufacturers, or for that matter, rice mill / flower mill / food processor etc.

**Warehouse Designing**

In the contemporary business scenario of competition and growing globalization, warehousing operations comprising of location and designing functions have taken a newer dimension.

As space today is a problem, and land not available, material handling has improved tremendously from what it was ten years back, methods of care and preservation have undergone a sea change during the last fifteen years, storage process, stacking, etc., have distinctly changed throughout the world due to containerization and palletization, combination of warehousing and physical distribution management along with EDI has contributed to economized networking, the design aspect, therefore, has to consider the following parameters:
(a) Business forecast about the types of material that is going to be warehoused in a predetermined period of time, and breaking this to pick and lean periods in the months.

(b) Space required for receiving, sorting, stacking, segregating and assembling, stocking, distributing and an office space for the warehouse.

(c) Space for movement of materials handling equipment.

(d) Space for parking of container trailer, including turning radius of the prime movers along the trailer.

(e) Space for material handling equipments like tackle, electronic gadgets, etc., forklift trucks and cranes.

(f) Forecast of product mixed analysis.

(g) Emphasis are now on horizontal designs, thus contributing to saving space.
### Table 2.2

**Material Handling Considerations**

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Type of Materials</th>
<th>Benefits</th>
<th>Other Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MANUAL</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Racking: Conventional Pallet rack</td>
<td>Pallet loads</td>
<td>Good storage density, good product security</td>
<td>Storage density can be increased further by strong loads two deep</td>
</tr>
<tr>
<td>Drive-in-racks</td>
<td>Pallet loads</td>
<td>Fork trucks can access load, good storage density</td>
<td>Fork truck access is from one direction only</td>
</tr>
<tr>
<td>Drive-through racks</td>
<td>Pallet loads</td>
<td>Same as above</td>
<td>Fork truck access is from two directions.</td>
</tr>
<tr>
<td>High Rise Racks</td>
<td>Pallet loads</td>
<td>Very high storage density</td>
<td>Often used in AS/R systems, may offer tax advantages when used in rack supported building</td>
</tr>
<tr>
<td>Centilever Racks</td>
<td>Long loads drrolls</td>
<td>Designed to store difficult shapes</td>
<td>Each different SKU can be stored on a separate shelf.</td>
</tr>
<tr>
<td>Pallet Stacking frames</td>
<td>Same as above</td>
<td>Can be stacked flat when not in use.</td>
<td></td>
</tr>
<tr>
<td>Stacking Racks</td>
<td>Odd-shaped or parts crushable</td>
<td>Same as above</td>
<td>Can be stacked flat when not in use.</td>
</tr>
<tr>
<td>Gravity-flow Racks</td>
<td>Unit Loads</td>
<td>High density storage, gravity moves loads</td>
<td>FIFO or LIFO flow of loads</td>
</tr>
<tr>
<td>Shelving</td>
<td>Small, loose loads and cases</td>
<td>Inexpensive</td>
<td>Can be combined with drawers for flexibility.</td>
</tr>
<tr>
<td>Drawers</td>
<td>Small Parts and tools</td>
<td>All parts are easily accessed good security</td>
<td>can be compartmentalized for flexibility.</td>
</tr>
<tr>
<td>Mobile racking or shelving</td>
<td></td>
<td>Very high storage density</td>
<td>Come equipped with safety devices.</td>
</tr>
<tr>
<td><strong>AUTOMATED</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit loads AS/RS</td>
<td>Pallet loads, other unit loads</td>
<td>Very high storage density, space by half</td>
<td>May offer tax advantages when rack –supported</td>
</tr>
<tr>
<td>Car-in-lane</td>
<td>Pallet loads, other unit loads</td>
<td>High storage density</td>
<td>Best used where there are large quantities of only a few SKUs.</td>
</tr>
<tr>
<td>Mini-load AS/RS</td>
<td>Small Parts</td>
<td>High storage, density, computer controlled</td>
<td>For flexibility, can be installed in several different configurations.</td>
</tr>
<tr>
<td>Horizontal carousels</td>
<td>Small Parts</td>
<td>Easy access to parts, relatively inexpensive</td>
<td>Can be stacked on top of each other.</td>
</tr>
<tr>
<td>Vertical Carousels</td>
<td>Small Parts and tools</td>
<td>High storage density</td>
<td>Can serve dual role as storage and delivery system in multi-floor facilities.</td>
</tr>
<tr>
<td>Man-made machines</td>
<td>Small Parts</td>
<td>Very flexible</td>
<td>Can be used with high rise shelving or modular drawers.</td>
</tr>
</tbody>
</table>
In today’s concepts, most warehouses are designed with twenty or thirty feet ceiling, although modern and automated high rise facilities effectively use height over hundred feet. Maximum effective warehouse height is limited by safe lifting capability of material handling, equipments such as lifts, cranes, tackles, rack design, fire precaution, etc. In designing these warehouses, free flow of products either through conveyor / gravity roller / fork lift etc., will have to be borne in mind. The product must flow straight, minimizing congestion and redundant handling. In earlier days warehouse was of single floor that eliminated movement of product vertically. But in effect vertical stocking should be avoided as it results in multiple handling of the product. With the advent of vertical design devices, viz., elevator, container stacker, forklifts trucks, vertical movement has become easy, facilitating space saving.

It is not correct to lay down general standards of the layout of a warehouse because layout and material handling are integrated. Special attention must be given to designs on receiving and loading docks. It may be the case that standard size pallet of forty by forty-eight inches and thirty-two by forty inches each are not being used. If the pallet size differs, the cost of movement increases. It is, therefore, incumbent on management to use standard sized pallets.
The second point that comes into play in layout and planning of warehouse is pallet position. The most common practice is positioning pallets in 90 degrees or square placements. In a warehouse receiving, sorting and after sales, service area may be separated but the principal aim remains that movement should be free, flow must not be disrupted.

Warehouse Operation

The basic warehouse operations as follows:

(a) Movement of materials/stores/product.
(b) Storage including care and preservation.
(c) Information transfer
(d) The movement of functions can be further divided into the following handling activities.
   (i) Receiving
   (ii) Transfer
   (iii) Order selection and shipping

Classification of warehouses

Warehouses may be classified on the following criteria:

1. Utility criteria
2. Ownership
3. Conditionality of releases
1. Utility Criteria

(a) **Product**: There may be specific warehouses for particular types of products, viz.,

(i) **Explosive Store House (ESH) and Magazines**: These are specially built with due regard to safety, distance, traversing, hazards and security classification. They may be grouped in a vast area of land – say 3000 acres, mainly managed by the Armed Forces or Mining Organization.

(ii) **FOL Depots with storage tankers** – here also, due regard is placed on construction safety, security, based on hazard classification.

(iii) **Secured Warehouses**: These are a group of storehouses with costly metallic cover, where mostly coins / notes are kept (please note that in a mint, this is much bigger than vaults of banks). May be used for Stamp Papers, Treasury Papers, Court Fee Stamp etc.

(iv) **Yard** – preferred for stocking of iron ore, coal, steel products, returned vehicles, barrels, containers, etc.

(b) **Specialty Service Warehouses**: These are generally cold storage or warehouses for particulars products, Viz grains and pulses. Cold
storage may be used by various producers mainly fish growers, fruit growers, vegetable growers, etc. For dry agricultural products longer warehouses for food grains like wheat, rice, paddy, pulses etc. only are kept. The Food Corporation of India, Warehouses are examples. The medical stores depot, owned by Central and State Governments are also Specialty Service Warehouses.

2. **Ownership:** In general in Asean perspective, warehouses may be classified into three categories:

   (a) **Government:** That is, owned by Government of counties or the States to hold materials for their own use, viz., Ordnance Depots, Ammunition Depots, depots mainly owned by the Armed forces. There are warehousing corporations in semi-Government sector. The Public Works Departments have their own yards warehouses.

   (b) **Public Warehouses:** A public warehouse is like the one owned by Port Trust, Railways etc. These are also rented out to public on a contractual basis for a definite period of time, which may be short term or long term, depending upon the need of the license. It abides by all the warehouse’s regulations on charge basis. These days, warehousing companies are also functioning as joint ventures or operations on assured business with, Logistics Service Providers. Manufacturers tend to save a sizeable capital in availing services of a public
warehouse. The requirement of a warehouse can be tailored to suit market demands.

(c) **Private Warehouse**: In fact, these days private warehouses of the manufacturers are on the decline. Even large scale manufacturers of motor cycles, cycles, shoes, cigarettes, match boxes, etc. are getting rid of their own warehouses. The private warehouses, of course, have a distinct advantage of having various services/controls. Here a distinction should be maintained that herein by term “private warehouse” is meant mostly a dedicated warehouse of a particular manufacturer. In this context, it must be mentioned that Yards, or uncovered secured space, do not come under the definition of warehouses per se. The large yards maintained by organizations producing Steel Frame, Coal, Hume pipes etc., must never be forgotten. Their function and operations are similar to warehouses and these are mostly privately owned by manufacturers like Steel Plants, Coal/Ore producers etc. etc., or are owned/hired by Service Providers interim locations near sea ports.

3. **Classification of Warehouses on Conditionality**

Warehouses may be public or private on a conditionality between the owner and the users, leaser or the leasee, licensor or the licensee. There are leasing of warehouse or warehouse spaces and this practice is often found
with the warehouses owned by the Port Trust or Port Authorities. Leasing of space for warehousing represents an intermediate solution between short-term space rental for any public warehouse and long-term commitment required of a private warehouse. The advantage of leasing obviously lies in the lower rates. However, certain amount of flexibility is lost by the leasee (space user) since the leasee has to guarantee the payment of space rental for a specified period of time.

(a) **Contractual Warehouse**: There are instances where private owners of warehouses at a warehousing hub in vacant land, construct a warehouse for a service provider/manufacturer to their specifications, or a warehouse rented/licenced for a certain period.

(b) **Bonded Warehouse**: A bonded warehouse may be private or public. It is a warehouse in which goods are kept until certain conditions are met, such as payment of duties and taxes or their movement by bonded common carrier to another bonded warehouse or customs area. Bonded warehouse may be utilized sometimes to store goods imported temporarily into the country for transshipment or for consideration for outward shipment – as it is done in Kolkata, Haldia and Paradeep Port for Nepal and Bhutan. Sometimes spare parts of semi finished materials or Completely Knocked Down assemblies (CKD’s) are stored in a bonded warehouse for completion of manufacturing/
assembling operation before the finished product is shifted out to another customs jurisdiction.

The producers of cigarette, liquor, etc. also use bonded warehouses to store their finished products to delay payment of heavy domestic taxes. The manufacturer pays tax when goods are taken out of the warehouse. This helps the producers to conserve working capital which otherwise gets tied up in the prepayment of stationery levies.

(c) **Hypothecated Warehouses.** Another example is seen in bank hypothecation – called “bank godown” – the materials on the strength of which the bank has advanced money as part of working capital funding and which can only be taken out on the release of payment of corresponding amount of money to the bank.

In today’s business climate, the manufacturers/producers are keen to retain short term provider or an integrated logistics services provider to undertake all the formalities – whether with banks or customs, or sorting or assembling or cross docking etc.

**Size of Warehouse**

There are quantitative techniques available to estimate the size of a warehouse, therein also the product mix analysis is done. A rule of thumb is
to provide 10 percent additional space for storing peak period receipts. The quantity of safety stock, buffer stock also needed to be calculated.

**Present and suggested models**

Storage may be temporary or semi permanent. Temporary storage is the one which stays for a very short period consisting of a number of days, whereas semi-permanent storages is for longer periods for maintaining safety/buffer stock to meet future demands.

Information transfer is related information about the materials held in the warehouse, in quantity, cost, weight, cubic, handling specification, inventory, location, customer data distribution details; stock limits, etc. Information is vital in warehouse. In nutshell, a warehouse is expected to perform following activities:

(a) Receiving, i.e. unloading, inspection and documentation.
(b) Movements in and out of storage areas.
(c) Replenishment of order picking locations.
(d) Order selection/picking.
(e) Checking/outward inspection.
(f) Packaging and Marking, may be bulk breaking or assembling.
(g) Staging and Consolidation.
(h) Loading for outward movement.
(i) Outward Documentation.
(j) Housekeeping, including security.

(k) Material Handling.

Duty Allocation: The first requirement in a warehouse is to allot clear cut responsibilities and accountability, in writing, by formulation of a Standard Operating Procedure (SOP) enmeshing into all systems (computers) as well as that of the beneficiaries, i.e. principal customer, manufacturer, et al. It is needless to say that full-fledged managerial attention is required in warehouse operations.

Initiating Warehouse Operations

Following activities are essential for ongoing warehousing operations and should be planned by the management:

(a) Initial stocking
(b) Human Resource Development
(c) Work procedures (formulation of SOP)
(d) Warehouse Management System or WMS.

(a) Initial stocking: Main challenge lies in initially stocking a warehouse with quantities of each inventory SKU, which has been determined during warehouse planning. This initial stocking take two to four weeks for completion.

There are two methods of assignments in initial stocking:
(i) **Variable slotting:** This system is also called dynamic slotting. It allows a warehouse location to be changed when each shipment arrives. It provides for efficient utilization of warehouse space. No product under this system occupies a fixed and permanent location in the warehouse continuously. This ensures better utilization of space.

(ii) **Fixed Location System:** A fixed location system assigns a product to a permanent location in the warehouse. The product is stocked in this location as long as it sustains volumes. Staff becomes familiar with the location of this product and hence order picking becomes easy because the product location doesn’t change.

(b) **Human Resource Development:** In LSCM, a major concern in logistical operations over the past several decades is human resource productivity. A warehouse demands a good Quantum of physical work and that too in a not so ideal location. It is difficult to attract human resources. There are drug tests which are required to reduce the liability for personal injury or damage while operating material handling equipments. It is generally planned to develop full workforce. Often test orientations are performed before arrival of the shipment. After orientation, all employees are given specific training.
Once the initial inventory is on hand, simulated orders can be selected and loaded into a delivery truck and then the merchandise may be treated as a new arrival and can be transferred into the stock. This is a very effective system of HR development.

(c) **Warehouse Management System (WMS)**: Warehouse Management System intends to standardize the entire work procedure so that all the employees understand them. In a mechanized warehouse around sixty five percent of the employees are for order picking. There are two methods of order picking:

(i) **Individual Method**: In this method, a single employee completes a customer’s total order. This system is not widely used. Its primary application occurs when a small number of orders are selected for re-pack or consolidated shipment such as an e-commerce/ERP fulfillment.

(ii) **Area Selection**: Each person is assigned responsibility for order picking in a particular location of a warehouse. Established procedures, for receiving and ensuring product entry into inventory records are critical. Personnel working in shipping must have container trailer loading practices. When merchandise changes ownership, items must be thoroughly checked during loading.
(d) **Security**: Since a warehouse stores a large number of materials and products, great care for security has to be ensured for their protection. Protection against merchandise pilferage and deterioration are mainly of the following types:

(i) **Pilferage Protection**: Typical security procedure throughout the business should be standardized. It should be strictly enforced in each warehouse. As a standard procedure, only authorized persons are allowed to enter the warehouse. Visitors can are not allowed to be parked in the warehouse premises or in the area surrounding the warehouse. Use of CCTV, RFID (Radio Frequency Identification Device, etc. are widespread.

(ii) **Shortage**: Shortages are a major concern in a warehouse operation. Many are honest mistakes that happen during order selection and shipment, but the purpose of security is to restrict theft from all angles. The majority of theft occurs during normal working hours.

(iii) **Collusion**: Organized efforts between warehouse personnel and truck drivers are not uncommon and it results in deliberate over-picking of products.

(iv) **Hijacking**: Then there is serious problem of hijacking. Often while the goods are in transit on the road, hijacking of the vehicle
occurs and there lies a scope of huge loss to the companies. Prevention of hijacking is basically the work of the law enforcement authorities, but the manufacturers/warehouse owners/service providers also have to introduce new systems to stop this (GPS, RFID – is in Wide Practice for Prevention of Hijacking).

(e) **Product Deterioration**: The most obvious form of product deterioration is damage from careless material handling and of not following tenets of care acceptable preservation. For example, when pallets of merchandise are stacked in great heights, a marked change in humidity or temperature can cause packages supporting the stack to collapse. Product deterioration from careless handling, and/or lack of proper care and preservation by use of preventives like Nepthalene, silica etc. within the warehouse is a form of loss that cannot be insured against or offset with compensating revenue. Sometimes, forklift trucks are intentionally overloaded by workers in order to gain a shortcut procedure of work when they are not supervised. There have been accidents due to this. Boxes containing goods may fall from the overloaded truck and this can cause damage to any personnel in the vicinity and to the warehouse as a whole. Another form of deterioration is incorporating products wrongly stored or transported. For example, chocolates should be very carefully packaged if they are
transported with chemicals. If the odor of chemicals gets into the chocolates by any chance, the customers will reject them and they will be unsuitable for sale in the market.

(f) **Delivery:** Computer assisted load planning and equipment routing techniques (ERP) are very useful for organizing transportation requirements. Warehouses normally send products to the market by trucks. But exceptions can be found.

(g) **Safety and Preventive Maintenance of Warehouse and Equipments:** The floor of a warehouse may cause accidents if not properly cleaned. Carelessness exposes workers to mechanical or physical hazards. A preventive maintenance program is necessary for materials handling equipments. Unlike production machines, material handling equipments are not stationery. They are continuously in use. So it is a bit difficult to maintain them properly. A preventive maintenance program periodically checks all the material handling equipment and other equipments/gadgets like CCTV, generator etc. should be applied in every warehouse.

**TRANSPORTATION MANAGEMENT**

Transportation is an important part of the nation's economy. Transport in India is both a necessity as well as a convenience. Since the economic liberalization of the 1990s, development of infrastructure within the country
has progressed at a rapid pace, and today there is a wide variety of modes of transport by land, water and air. However, the relatively low GDP of India has meant that access to these modes of transport has not been uniform.

Despite improvements, several aspects of transportation are still riddled with problems due to outdated infrastructure and a burgeoning population, and demand for transport infrastructure and services have been rising by around 10% a year. Taxes and bribes are common between state borders. Although India has only 1% of the world's vehicles, it accounts for 8% of the world's vehicle fatalities. India's cities are extremely congested — the average bus speed is 6–10 km/h in many large cities. Because of the congestion in Indian roads the fuel efficiency of the vehicles is also very low. This increases the overall fuel consumption of the country besides creating huge pollution since the engines run very inefficiently at such low speeds.

India's rail network is the longest and fourth most heavily used system in the world. India's growing international trade is putting strain on the ports in India. The country's overburdened airports have just begun to get a makeover, with modernization work and greater investment in the aviation sector. In general, public transport suffers from outdated technology, incompetent management, corruption, over staffing, and low worker productivity.
Transportation is a very important part of the logistics system. A major focus in logistics is upon the physical movement or flow of goods or upon the network that moves the product. This network is composed of transportation agencies that provide the service for the firm. The logistics manager is responsible for selecting the mode or modes of transportation used in moving the raw materials and finished goods or for developing private transportation as an alternative.

MODES OF TRANSPORTATION

Transportation infrastructure consists of the right-of-way, vehicles, and carrier organizations that offer transportation services on a for-hire or internal basis. The nature of the infrastructure also determines a variety of economic and legal characteristics for each mode or multimodal system. A mode identifies the basic transportation method or form.

The five basic transportation modes are rail, highway, water, pipeline and air. The relative importance of each mode can be measured in terms of system mileage, traffic volume, revenue, and the nature of traffic composition.

The global transportation industry is reshaping itself in response to powerful technological, economic, and consumer forces. Traditional profit centers such as manufacturing and retailing are being squeezed. Consumer and commercial demand is increasingly focused on communications, safety
and comfort. New patterns of freight and product distribution are emerging to take advantage of the e-commerce revolution. And there is a cross-industry response to the environmental and life cycle impacts of vehicles and transportation systems. There are five

**Advantages of Improved Transportation System**

Improved communication facilities have made the world smaller today than it was a few decades ago. These facilities have developed tremendously due to the vast strides in electronics and telecommunication, and consequently information technology, over the last few years. An improved transport system brings the following advantages.

1. Greater economies of scale in production, facilitated by:
   
   (a) Better utilization of production facilities.
   
   (b) Specialization of labour
   
   (c) Selection of production sites with greater geographical advantage.

2. Reduced prices brought about by:
   
   (a) Greater competition.
   
   (b) Reduced costs in transportation, inventories, packaging etc.

3. Better customer service through competition, improvement in transportation time, more space and less cost.
The five basic inter-city modes of transportation (rail, road, air, water and pipe), which sometimes interact with one another as in the case of piggyback trailers, or facilitated by various transportation agencies like freight forwarders etc. handle the bulk of the freight movements in the country.

**Rail Transport**

Railways are composed of a traced path on which the vehicles are bound to ply. They have an average level of physical constrains linked to the types of locomotives and affected by the gradient. Heavy industries are traditionally linked with rail transport systems. Containerization has improved the flexibility of rail transportation by linking it with road and maritime modes. With the passage of time newer types of vehicles like power tracks have been developed all over the world to carry/ferry all sorts of commodities and merchandise. Rising competition with other modes of intermodal transport have forced the railways system over the world to be more competitive in its services-viz. speed, handling, freight and improvement of overall efficiency.

Freight is one of the principal determinants of choice of the modes of transportation. The principle of freight fixation is generally the same the world over.


**Rail transport in India**

Rail transport is a commonly used mode of long-distance transportation in India. Rail operations in India are handled by a state-owned organization, Indian Railways, Ministry of Railways. The rail network traverses the length and breadth of the country, covering a total length of 63,140 kilometers (39,233 mi). It is said to be the 4th largest railway network in the world, transporting over 6 billion passengers and over 350 million tones of freight annually. Its operations cover twenty-eight states and three union territories and also provide limited service to Nepal, Bangladesh and Pakistan.

Railways were introduced to India in 1853, and by the time of India's independence in 1947 they had grown to forty-two rail systems. In 1951 the systems were nationalised as one unit—Indian Railways—to form one of the largest networks in the world.

**Railway Freight Structure**

The Structure of the freight tariff in the Indian Railways does not have linear relationship either with tonnage carried or the distance hauled. This is due to the fact that the Railways, inspite of taking care of its financial viability, are a public utility concern with its own social obligation. In other words, two principles, namely, the value of services principle, which cannot be determined easily, which occurs on the demand side, is juxtaposed against the cost of services principle which is on the supply side.
**Road Transport**

Road Transport are large consumers of space with the lowest level of physical constraints among transportation modes. However, environmental constrains are significant in road construction. Road transportation has an average operational flexibility as vehicles can serve several purposes but are rarely able to move outside roads. Road transport systems have high maintenance costs, both for the vehicles and infrastructures. They are mainly linked to light industries where rapid movements of freight in small batches are the norm.

India has more than 3 million km of road network, making it one of the largest in the world. However, the quality of roads is inadequate and cannot meet the needs of efficient and fast moving transportation. National Highways, which are the prime arterial routes span about 58,112km throughout the country and cater to about 45% of the total road demand.

Road Transport is an essential element in the infrastructure of all facts of economic activity. Farmers produce, dairy products, etc. find a ready market in the urban and semi-urban areas thanks to a network of rural roads in the backward and hitherto unaccessed areas. It has increased movement as well as productivity and opened up the market at national and international levels. Basic amenities like medical facilities and primary education have been make available to remote villages.
At this juncture it must be noted that throughout the underdeveloped world a concerted effort has been taken by all governments to develop roads through the length and breath of each country. Four-lane, six-lane, eight-lane roads are required for uninterrupted traffic flow across countries and adjoining nations for economies on:

(a) More haulage

(b) Reduction of waiting /breakdown /downtime.

**Advantages of Road Freighting**

1. **Through Movement:** The most important advantage is the possibility it affords for through-movements, from consigner to consignee, which obviates the necessity of transshipment, excessive handling and possibility of theft, thereby reducing the costs.

2. **Flexibility:** The operation is more easily controlled. Routes and loading routines can be more easily altered than in any other form of transport. One can arrange one’s own schedules, operate night and day, arrange for a multi-drop delivery, and at all times be in complete control of the movement.

3. **Less Capital Costs:** This is particularly relevant when one thinks of going in for setting up one’s own private fleet.
4. **Fast Turn-Around:** The use of articulated vehicles, i.e. tractor units with detachable semi-trailers contribute to the advantage of road freighting. The relatively inexpensive trailers and de-mountable bodies can be used as standing storage during loading and unloading, while the more expensive tractor or rigid vehicle is kept fully employed. In order to derive the maximum benefit from this idea of “spotting” the trailer, each tractor should generally have the assured availability of a minimum of three semi-trailers – one at each end of the route and one in transit.

5. **Immunity from industrial action:** When a company operates its own road transport, it is not affected by strikes etc. as in the other modes of transport like Railways, Airways etc.

6. **Adaptability in inter-modal operations:** The growth of Roll-on/Roll-off (RO/RO) services has provided another advantage in the through-movement of road vehicles without the need for intermediate handling. The RO/RO ships are specially designed to allow the largest vehicles to drive on board and drive off again at the port of destination.

**Disadvantages**

1. Susceptibility to weather and road conditions.

The most obvious disadvantage is that road freight can be affected by road condition inclement weather etc.
2. Unsuitability for very heavy loads

   Secondly, it is more economic to use rail transport for haulage of bulky goods.

3. Unsuitability for long distances

   The telescopic rates offered by the Railways make it more advantageous to use them for haulage over long distances.

AIR TRANSPORT

Air routes are practically unlimited. Air transport constraints are multidimensional and include the site (a commercial plane needs about 3,300 meters of track for landing and take off), the climate, fog and aerial currents. Air activities are linked to the tertiary and quaternary sectors, notably finance and tourism that require movements of people. More recently, air transportations has been accommodating growing quantities of high value freight.

   Air freighting is regularly used whenever the benefits of fast delivery more than compensates the increased transportation cost. For instance:

   a. High Value Products : These products require less protection because the handling is less rough. The reduced packaging costs and the reduction in in-transit inventory can offset somewhat the increased transport cost.
b. Perishable Products: Because of the short shelf life of the products such as strawberries and cherries, air-freight is the only means of getting them to distant markets.

c. Emergency Products: Medical supplies and spare parts which are critical for the repair of machinery are transported by air, as they are vital for saving lives and preventing financial losses.

d. Live Animals: Race and show horses are often air lifted.

e. Fashion Items: Items which have a short sales life must be brought to market before a shift in the demand takes place, dictated by a change in fashion. Air transportation is the solution.

**Advantages of Air Transport**

(a) Faster mode

(b) Reduction in cost in other logistics components like inventory

(c) Broad service range

(d) Increasing capabilities

**Disadvantages**

(a) High cost

(b) Effect of weather conditions on flight schedules

(c) Limitations in respect of extremely heavy consignments.
WATER TRANSPORTATION

Main maritime routes are composed of oceans, coasts, seas, lakes, rivers and channels. However, maritime circulation takes place on specific parts of the maritime space. The Atlantic Ocean is very important since it accounts for 78% of the global trade, 68% of its value and for 75% of the maritime trade. The construction of channels, locks and dredging are attempts to facilitate maritime circulation by reducing discontinuity. Comprehensive inland waterways systems include Western Europe, the Volga/Don system, St. Lawrence/Great Lakes system, the Mississippi and its tributaries, the Amazon, the Panama/Paraguay and the interior China. Maritime transportation has high terminal costs, since port infrastructures are among the most expensive to build, maintain and improve. High inventory costs also characterize maritime transportation. More than any other mode, maritime transportation is linked to heavy industries, such as steel and petrochemical facilities adjacent to port sites.

Water transportation is generally divided into inland waterways (rivers, canals, great lakes), domestic coastways and seaways. Water transport is resorted to for high bulk, low value commodities because of low cost per ton kilometer, which is of greater importance than speed of delivery. Basic bulk commodities and raw materials such as iron ore, coal, chemicals, petroleum products, cement etc. are extensively transported by this mode.
**Inland Water Transport**

Though it is recognized the world over that water transport consumes the least amount of energy per tonne kilometer, the mechanical inland water transport started in India as early as in 1823. This mode gradually started losing traffic over the years in India and other developing countries. The reason for this is manifold, as for instance lack of clarity on the administrative responsibility for the development of waterways, lack of expertise, lack of awareness of the role of waterways etc. The National Transport Policy Committee, set up by the Government, submitted its report in 1980, recommending many measures, like declaration of certain important rivers as National Waterways, setting up of an Inland Waterways Authority of India, determination of a viable policy with regard to costs and revenue, etc.

Following are the major waterways of inland water transportation in India:

- Ganga and the Brahmaputra rivers and their tributaries.
- Godavari and Krishna Rivers and their canals.
- Buckingham Canals in Andhra Pradesh and Tamil Nadu.
- Mandovi and Suravi rivers in Goa.
- Backwaters and canals of Kerala.
Advantages of Water Transport

- Mass movement of bulk commodities.
- Lower cost
- Large capabilities
- Preferred mode for long haul movement of low value commodities.

Disadvantages

- Suitable only for certain types of commodities.
- Not suited for quick transit.

Pipeline Movement

A pipeline is an ideal means for transporting large quantities of liquids and gases over long distances. They have also gained importance in the transportation of solids (in the form of slurry-as for instance in the case of movement of iron ore from Kudremukh to Mangalore Port), particularly of coal, iron ore, limestone, copper concentrates etc. Pipelines are now the main mode of transport for petroleum products, gases, crude etc.

Major advantages of this mode over other modes are as under:

(a) Energy consumption is least in Pipeline transportation and it is most suited mode of transportation for conservation of energy.

(b) Cost of transportation is least, for large volumes and over long leads.
(c) Pipeline transportation is highly environment friendly. Its impact on environment during the stages of construction, operation and maintenance is negligible, compared to other modes.

(d) Safety is an intrinsic feature of pipeline transportation. Vagaries of nature like floods, breaches etc. do not disrupt pipeline transport systems.

(e) In pipelines, the carrier is stationery. Thus, the wasteful use of energy and infrastructure for transportation of empty carrier (as happens in the case of rail and road transportation) is totally avoided.

(f) Petroleum products are volatile in nature. Thus, handling of products results in evaporation losses. In the case of rail and road, such losses are as high as 0.3 to 0.5% of the volumes transported. In comparison, transportation losses in pipeline are only about 0.1%.

(g) While railways need different types of wagons for different classes of products, a single pipeline can transport a large number of products. The developments in technology would also allow transportation of propane and butane in the same pipeline making this mode still more versatile.

(h) Increase/decrease of transportation volume can be effected in pipeline with lower time delay, disturbance and cost. Quantity variation within
certain limit is possible without compromising on safety, economic and operational considerations.

(i) Pipelines can traverse highly difficult terrain where laying railway lines would be almost impossible.

Disadvantages

(a) The most obvious disadvantage lies in the fact that this means cannot be used for transportation of all solids, heavy equipment etc.

(b) The initial costs of laying the pipeline are very high.

(c) Prone to sabotage in disturbed areas.

Ropeways

The most important technical and economic advantage of ropeway system as a mode of transport is that it can connect two places with a large differential of altitude without much difficulty. The rate of rise, i.e. the difference in altitude it can gain within a horizontal distance, is much higher than that for a road or a rail line.

The highest incline that a mountain road can have, according to general standards, is one in twenty. The permissible gradient is much less and the cost of construction is also very high. A ropeway can, however, be constructed, with a length of as little as two kilometers, depending upon the
contour of the terrain, with an altitude difference of one kilometer, since this mode permits a gradient of even one in two. Further, the ropeway also has the advantage of causing least damage to the ecology of the region. Another main advantage lies in the fact that it can transport bulk materials over short distances. Besides, indigenous capacity exists for design engineering, fabrication and installation of the ropeways.

The ideal method of using this means of transport in the hilly regions is to have a combination of ropeways, with a road coursing its way along the mountainside, with the usual incline, serving as a truck route, with collection points at appropriate distances, and a series of ropeways “perpendicular” to the road, to transport horticultural produce and other finished products from higher altitudes from where they are produced.

The ropeway is an ideal means of transport in the following cases:

(a) Hilly and otherwise inaccessible areas.
(b) The long and circuitous routes with streams and deep valleys
(c) Commodities capable of transportation in ropeway buckets.
(d) Short haulage, say less than 50 kms.
(e) Areas which render the other means of transport uneconomic.

**Disadvantages**

(a) Heavy initial investment.
(b) Limitations as to size and quantity of haul.
Ropeways are ideally suited for transport of coal, iron ore, limestone etc. in mining areas and near steel plants and thermal power stations.

**Transportation Problem**

Transportation problem is a special kind of linear programming problem in which goods are transported from a set of sources to a set destinations subject to the demand of the source and destination, respectively, such that the total cost of transportation is minimized.

The objective function minimizes the total cost of transportation between various sources and destinations. The constraint \( i \) is less than or equal to its supply. The constraint \( j \) in the second set of constraints ensures that the total units transported to the destination \( j \) is greater than or equal to its demand.

**INFORMATION AND COMMUNICATIONS**

The application and development of Information and Communication Technologies (ICT) have already had significant effects on many industries, especially in the field of logistics. Because of it, the style of business operation, up/downstream partnership and customer relationship are changing. The application of computers, internet, and information communication systems can be seen in almost every activity in the logistics
industry, such as transportation, warehousing, order processing, material management, and procurement.

The function of LIS can be defined as “Logistics Information System is an interacting structure of people, equipment, and procedures which together make relevant information available to the logistics managers for the purposes of planning, implementation, and control”.

Information and Communication Technology has been promoted as a means to enhance logistics competitiveness. It is one of the few factors which have been proved to have the capability of increasing logistics competence and decreasing its costs simultaneously. The application of ICT in logistics management is relatively recent, it lets real-time/online information communication and data exchange through the entire operation chains become realistic speaking of time and cost.
A schematic representation of transportation is shown below:

Figure 2.2: Schematic diagram of simple transportation problem
**Mathematical model for transportation problem**

In this section, a linear programming model for the transportation problem is presented.

Minimize \( Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} X_{ij} \)

**Generalized Format of the Transportation Problem**

<table>
<thead>
<tr>
<th>Source (i)</th>
<th>1</th>
<th>2</th>
<th>( \cdots )</th>
<th>( j )</th>
<th>( \cdots )</th>
<th>Destination (j)</th>
<th>( n )</th>
<th>Supply</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>( c_{11} )</td>
<td>( c_{12} )</td>
<td>( \cdots )</td>
<td>( c_{1j} )</td>
<td>( \cdots )</td>
<td>( c_{1n} )</td>
<td>( a_1 )</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>( c_{21} )</td>
<td>( c_{22} )</td>
<td>( \cdots )</td>
<td>( c_{2j} )</td>
<td>( \cdots )</td>
<td>( c_{2n} )</td>
<td>( a_2 )</td>
<td></td>
</tr>
<tr>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \cdots )</td>
<td>( \vdots )</td>
<td>( \cdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td></td>
</tr>
<tr>
<td>( i )</td>
<td>( c_{il} )</td>
<td>( c_{i2} )</td>
<td>( \cdots )</td>
<td>( c_{ij} )</td>
<td>( \cdots )</td>
<td>( c_{in} )</td>
<td>( a_i )</td>
<td></td>
</tr>
<tr>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td>( \cdots )</td>
<td>( \vdots )</td>
<td>( \cdots )</td>
<td>( \vdots )</td>
<td>( \vdots )</td>
<td></td>
</tr>
<tr>
<td>( m )</td>
<td>( c_{m1} )</td>
<td>( c_{m2} )</td>
<td>( \cdots )</td>
<td>( C_{mj} )</td>
<td>( \cdots )</td>
<td>( c_{mn} )</td>
<td>( a_m )</td>
<td></td>
</tr>
<tr>
<td>( b_1 )</td>
<td>( b_2 )</td>
<td>( \cdots )</td>
<td>( b_j )</td>
<td>( \cdots )</td>
<td>( b_n )</td>
<td>( \frac{\text{Supply}}{} )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Subject to

Demand \( \sum_{j=1}^{n} X_{ij} \leq a_i, \quad i = 1, 2, 3, \ldots, m \)

and \( \sum_{i=1}^{m} X_{ij} \geq b_j, \quad j = 1, 2, 3, \ldots, n \)

The objective function minimizes the total cost of transportation \( (z) \) between various sources and destinations. The constraint \( i \) in the first set of constraints ensures that the total units transported from the sources \( i \) is less than or equal to its supply. The constraint \( j \) in the second set of constraints
ensures that the total units transported to the destination \( j \) is greater than or equal to its demand.

**Types of transportation problems**

The transportation problem can be classified into balanced transportation problem and unbalanced transportation problem.

**Balanced Transportation Problem**

If the sum of the supplies of all the sources is equal to the sum of the demands of all the destinations, then the problem is termed as *balanced* transportation problem. This may be represented by the relation:

\[
\sum_{i=1}^{m} a_i = \sum_{j=1}^{n} b_j
\]

Example 10.1 represents a balanced transportation problem.

**Unbalanced Transportation Problem**

If the sum of the supplies of all the sources is not equal to the sum of the demands of all the destinations, then the problem is termed as *unbalanced* transportation problem. That means, for any unbalanced transportation problem, we have

\[
\sum_{j=1}^{n} b_j \neq \sum_{i=1}^{m} a_i
\]
Methods to solve transportation problem

The solution procedure for the transportation problem consists of two phases:

1. Finding the initial basic feasible solution is the first phase.

2. Second phase involves optimization of the initial basic feasible solution which is obtained in Phase 1.

These are discussed in the following sections.

Finding the initial Basic Solution

There are three types of techniques available to find the initial basic feasible solution. The solution using these techniques may be optimal:

1. Northwest corner cell method

2. Least cost cell method

3. Vogel’s approximation method (VAM)/penalty method.

The three techniques motioned above are in the increasing order of their solution accuracy. The cost of the initial basic feasible solution through VAM will be the least among all the three techniques. Algorithm for each of the three techniques for finding the initial basic feasible solution is presented now.
Algorithm for northwest-corner cell method

**Step 1:** Find the minimum of the supply and demand values with respect to the current northwest corner cell of the cost matrix.

**Step 2:** Allocate this minimum value to the current northwest-corner cell and subtract this minimum from the supply and demand values with respect to the current northwest-corner cell.

**Step 3:** Check whether exactly one of the row/column corresponding to the northwest corner cell has zero supply/demand, respectively. If so, go to step 4 otherwise, go to step 5.

**Step 4:** Delete that row/column with respect to the current northwest-corner cell which has the zero supply/demand and go to step 6.

**Step 5:** Delete both the row and the column with respect to the current northwest-corner cell.

**Step 6:** Check whether exactly one row or column is left out. If yes, go to step 7 otherwise go to step 1.

**Step 7:** Match the supply/demand of that row/column with the remaining demands/supplies of the undeleted columns/rows.

**Step 8:** Go to phase 2.
**Algorithm for least cost cell method**

**Step 1:** Find the minimum of the (undeleted) values in the cost matrix (i.e. find the matrix minimum).

**Step 2:** Find the minimum of the supply and demand values (X) with respect to the cell corresponding to the matrix minimum.

**Step 3:** Allocate X units to the cell with the matrix minimum. Also, subtract X units from the supply and the demand values corresponding to the cell with the matrix minimum.

**Step 4:** Check whether exactly one of the row/column corresponding to the cell with the matrix minimum has zero supply/zero demand, respectively. If yes, go to step 5 otherwise, go to step 6.

**Step 5:** Delete that row/column with respect to the cell with the matrix minimum which has the zero supply/zero demand and go to step 7.

**Step 6:** Delete both the row and the column with respect to the cell with the matrix minimum.

**Step 7:** Check whether exactly one row or column is left out. If yes, go to step 8 otherwise, go to step 1.

**Step 8:** Match the supply/demand of that row/column with the remaining demands/supplies of the undeleted columns/rows.

**Step 9:** Go to phase 2.
Algorithm for Vogel’s approximation method

Step 1: Find row penalties, i.e. the difference between the first minimum and the second minimum in each row. If the two minimum values are equal, then the row penalty is zero.

Step 2: Find column penalties, i.e. the difference between the first minimum and the second minimum in each column. If the two minimum values are equal, then the column penalty is zero.

Step 3: Find the maximum amongst the row penalties and column penalties and identify whether it occurs in a row or in a column (break tie randomly). If the maximum penalty is in a row, go to step 4 otherwise, go to step 7.

Step 4: Identify the cell for allocation which has the least cost in that row.

Step 5: Find the minimum of the supply and demand values with respect to the selected cell.

Step 6: Allocate this minimum value to that cell and subtract this minimum from the supply and demand values with respect to the selected cell and go to step 10.

Step 7: Identify the cell for allocation which has the least cost in that column.
Step 8: find the minimum of the supply and demand values with respect to the selected cell.

Step 9: Allocate this minimum value to the selected cell and subtract this minimum from the supply and demand values with respect to the selected cell.

Step 10: Check whether exactly one of the rows and the columns corresponding to the selected cell has zero supply/zero demand, respectively. If yes, go to step 11; otherwise go to step 12.

Step 11: Delete the row/column which has zero supply/zero demand and revise the corresponding row/column penalties. Then, go to step 13.

Step 12: Delete both the row and the column with respect to the selected cell. Then, revise the row and the column penalties.

Step 13: Check whether exactly one row/column is left out. If yes, go to step 14, otherwise, go to step 3.

Step 14: Match the supply/demand of the left-out row/column with the remaining demands/supplies of the undeleted columns/rows.

Step 15: Go to phase 2.
Optimizing the Basic Feasible Solution Applying U-V Method

**Step 1:** Row 1, row 2, …., row \( m \) of the cost matrix are assigned with variables \( U_1, U_2, \ldots, U_m \), respectively and the column 1, column 2, …., column \( n \) are assigned with variables \( V_1, V_2, \ldots, V_n \), respectively.

**Step 2:** Check whether the number of basic cells in the set of initial basic feasible solution is equal to \( m + n - 1 \). If yes, go to step 4, otherwise, go to step 3.

**Step 3:** Convert the necessary number of non-basic cells into basic cells to satisfy the condition stated in step 2 (while doing this, sufficient care should be taken such that there is no closed loop formation with the inclusion of the new basic cell(s). The concept of the closed loop is explained in step 8.

**Step 4** Compute the values for \( U_1, U_2, \ldots, U_m \) and \( V_1, V_2, \ldots, V_n \) by applying the following formula to all the basic cells only.

\[
U_i + V_j = C_{ij} \quad \text{(assume} \ U_1 = 0)\]

**Step 5:** Compute penalties \( P_{ij} \) for the non-basic cells by using the formula:

\[
P_{ij} = U_i + V_j - C_{ij}
\]
Step 6: Check whether all $P_{ij}$ values are less than or equal to zero. If yes, go to step 12, otherwise, go to step 7.

Step 7: Identify the non-basic cell which has the maximum positive penalty, and term that cell as the new basic cell.

Step 8: Starting from the new cell, draw a closed loop consisting of only horizontal and vertical lines passing through some basic cells. 
(Note: Change of direction of the loop should be with 90 degrees only at some basic cell.)

Step 9: Starting from the new basic cell, alternatively assign positive (+) and negative (-) signs at the corners of the closed loop.

Step 10: Find the minimum of the allocations made amongst the negatively signed cells.

Step 11: Obtain the table for the next iteration by doing the following steps and then go to step 2.

(i) Add the minimum allocation obtained in the previous step to all the positively signed cells and subtract minimum allocation from all the negatively signed cells and then treat the net allocations as the allocations in the corresponding cells of the next iteration.
(ii) Copy the allocations which are on the closed loop but not at the corner points of the closed loop, as well as the allocations which are not on the loop as such without any modifications to the corresponding cells of the next iteration.

**Step 12:** The optimality is reached. Treat the present allocations to the set of basic cells as the optimum allocations.

**Step 13:** Stop.

**Trans-Shipmet Model**

In generalized transshipment model, items are supplied from different sources to different destinations. It is sometimes economical if the shipment passes through some transient nodes in between the sources and destinations. Unlike in transportation problem, where shipments are sent directly from a particular source to a particular destination, in transshipment problem, the objective is to minimize the total cost of shipments, and thus the shipment passes through one or more intermediate nodes before it reaches its desired destination.

Logistics information systems are the threads that link logistics into an integrated process. The integration builds on four levels of functionality: transaction, management control, decision analysis, and strategic planning systems.
The most basic level, the transaction system, initiates and records individual logistics activities. Transaction activities include order entry, inventory assignment, order, selection, shipping, pricing, invoicing and customer inquiry. The order entry transaction initiates a second transaction as inventory is assigned to the order. A third transaction is then generated to direct the material handlers to select the order. A fourth transaction directs the movement, loading and delivery of the order.

Network of three of the functional areas of logistics-information, transportation and inventory can be engineered into variety of operational arrangements.

The information systems satisfying the concept above can be regarded as Logistics Information Systems (LIS). The function of LIS can be defined as "Logistics Information System is an interacting structure of people, equipment, and procedures which together make relevant information available to the logistics managers for the purposes of planning, implementation, and control" (Stefansson, 2002).

The application and development of Information and Communication Technologies (ICT) have already had significant effects on many industries, especially in the field of logistics. Because of it, the style of business operation, up-/downstream partnership and customer relationship are changing. The application of computers, internet, and information
communication systems can be seen in almost every activity in the logistics industry, such as transportation, warehousing, order processing, material management, and procurement. It is suggested that passing information to all businesses in the supply chains via ICT will improve performances (Disney et al. 2004). ICT has been promoted as a means to enhance logistics competitiveness. It is one of the few factors which has been proved to have the capability of increasing logistics competence and decreasing its costs simultaneously (Closs et al., 1997; Stock et al., 2001). Today, besides enterprises, governments around the world and the global organizations such as OECD, are all devoting their efforts to searching for chances of new development or application of information and communications techniques.