Chapter 1

Introduction

1.1 Supply chain defined

A supply chain may be defined as “a network of organizations that are involved through upstream and downstream linkages in different processes and activities that produce value in the form of products and services in the hands of ultimate customers”, Lee and Billington (1992).

The APICS dictionary (8th edition, 1995) defines the term supply chain as either the “processes from the initial raw materials to the ultimate consumption of the finished product linking across supplier-user companies,” or as the “functions within and outside a company that enable the value chain to make products and provide services to the customer.”

The Council of Supply Chain Management Professionals (CSCMP) defines supply chain as follows: “A typical supply chain begins with the ecological, biological, and political regulation of natural resources, followed by the human extraction of raw material, and includes several production links (e.g., component construction, assembly, and merging) before moving on to several layers of storage facilities of ever-decreasing size and increasingly remote geographical locations, and finally reaching the consumer”.

A conventional supply chain (Fig.1.1) is an arrangement of different departments/organizations involved through various stake-holders i.e. supplier, manufacturer, distributor, retailer etc. and linked together through diverse processes and activities producing value added products and services to satisfy customers. A supply chain also includes transporters, factories, warehouses, distribution centers and ultimately the end users, the customers. Various departments e.g. R&D cell, purchasing, finance, operation distribution, marketing and customer service function together to manufacture the requisite product and fulfill the after sales service as per the requirement of the
Fig. 1.1. Supply Chain Network (Lee & Billington, 1992)
customers. Every linkage of a supply chain executes different activities and act together with other stages of the chain. A simple supply chain primarily works on a premeditate cycle comprising of loops and sub-loops. In that cycle customer is both the starting as well as finishing point. A customer of an organization can very well be internal as well as external to it. Supply chain activities start with receiving a customer order and stops when a delighted customer has paid the revenues. In effect, a supply chain sums up the virtual display of a product, or service, flows along a chain from vendors to producers to distributors to retailers to ultimate customers. Practically, a producer may purchase material from different vendors and then supply it to many distributors as shown in Fig. 1.1. Therefore, majority of the supply chain may be truly called as networks (Chopra and Meindl, 2001).

A supply chain comprises of different entities often have their independent and conflicting purposes to fulfill ignoring the others. Every linkage starts thinking themselves as standalone entities and has an inherent tendency to maximize its localized achievement rather than considering the global goal of the overall chain. While doing these, each segment of the chain simply overlook the harsh competitive scenario that they could survive alone. Nowadays competition is not between the members of the supply chain network but supply chain vs. supply chain. The overall objective of the supply chain is paramount even if some stage might be facing a temporary setback. Each stage should compete, coordinate, and collaborate (live & let live) throughout the entire chain so as to optimize their global objectives. It is essential to make the supply chain more competitive through maximization of value addition and minimization of cost reduction. Supply chain management (SCM), a business philosophy by means of which a supply chain can achieve high degree of coordination and collaboration during the flow of materials and information while producing a product or providing a service, thus meeting the objective of the organization.

According to The Council of Supply Chain Management Professionals (CSCMP) definition, “Supply Chain Management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel
partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies. Supply Chain Management is an integrating function with primary responsibility for linking major business functions and business processes within and across companies into a cohesive and high-performing business model. It includes all of the logistics management activities noted above, as well as manufacturing operations, and it drives coordination of processes and activities with and across marketing, sales, product design, and finance and information technology”.

In a supply chain it is not necessary that all the stages are to be present. On the contrary the design of the appropriate supply chain largely depends upon the need of the organization and the customer’s requirement in particular. A supply chain is vibrant and involves seamless flow of material, funds and information between different stages from supplier upstream to the customer downstream. Due course of the transformation phase value is added to the raw-material to finished product in each and every intermediate stage of a supply chain. Value of a product may be defined as some specific features as demanded by the customers or some qualities to be designed into the product or a service. Supply chain hence may also be termed as value chain. Values of a product are closely correlated with profitability of an organization. The basic objective of a supply chain is to maximize the value generation so as to exceed the customer’s delight, enhanced competitive edge and productivity of that organization.

In recent years the importance of a supply chain has gained paradigm shift. Present market scenario has witnessed that the physical cost of raw materials gone up manifold whereas the cost of information nose diving rapidly with the help enabled information technologies. Business leaders now can manage the entire process virtually rather than physical approach and can achieve more coordination. Today, the nature of a business entity can be called truly global as it procure its raw material from one country, manufacture its product in other country and market it altogether to a third country. Probably due to changed business background, competition is no longer restricted within national boundaries but becomes truly global.

There are stiff competitions among every department and every linkages of a supply chain strive for its best in delivering its core competencies. Organization
wholeheartedly put its every resource to manage all the linkages of the chain to ensure its coordination. SCM initially followed dominant functional approach of the departments e.g. purchasing, finance, logistics, transportation, and physical distribution. The focus is now shifted to integral approach, increased visibility through enabled IT, lean concept based cycle time compression. The concept of vendor managed inventory (VMI), cross-docking, supplier-buyer partnership, e-commerce and digital connectivity augmented supply chain synchronization and finally SCM emerges as a global business philosophy to reckon with. Now, SCM beyond its earlier version of logistics function have a paradigm shift to a new complete business solution to the industrial leaders. The significant events that reflect the evolutionary journey of a truly global supply chain from an ancient barter system is mentioned in the next section 1.2.

1.2 Historical evolution of revolution of supply chain philosophy

The chronological evolution of revolution of a supply chain starts almost the commencement of human being. Supply chain is as old as the emergence of trade in the ancient age while human beings fulfilling their basic needs. The ancient people felt the need of merchandising and distribution among themselves. It was the logistic know-how superiority of Alexander the great coupled with his genius generals by which he could conquer most of the world. The path followed by him and his troops during many decisive battles they fought is shown in Fig. 1. The Silk route as shown in Fig.1.3 was also a primeval network of business and cultural communication routes connecting the West and East and being followed by traders, military personals, pilgrims, monks, and travelers, from China and India to the Mediterranean Sea during different phase of time. Even the British lost the war in America due to its inability to match the supply with the demands for their army. Militarily, winning/losing a war could depend heavily upon the reliable and timely delivery to soldiers’ requirements. A lot of attention is provided by the warring countries to strategically choke the supply lines so as to create chaos in the rival campus. Logistics played a very crucial role in winning the enemy campus, conducting trade or ensuring social security in time of natural disaster or drought.
Fig. 1.2 Routes of Alexander and his world-conquering army. Alexander integrated logistics concerns into every facet of his military theory, set of guidelines, approach, and management enabled the support of a world-dominating force. Alexander's division and regrouping of his army is an excellent example of demand-supply synchronization in utilizing his troops during that period. (Source: https://socraticquestions.wordpress.com)

In modern era too, logistics is a principal player in all the activities of production and smooth delivery of the same product to the end users in a supply chain. The old supply
chain concept has undergone a sea change as the time progressed. The technological push and customer pool of the modern business concept propel the managers to coordinate and synchronize the supply chain flow by following SCM philosophy. The philosophy of the supply chain management is not new; it is the evolution of revolution that has brought new interpretation and paradigm shift as shown in Table 1.1 and 1.2.

<table>
<thead>
<tr>
<th>Time period</th>
<th>Proceedings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ancient Times</td>
<td>The barter system developed in ancient era supposed to be known as the first supply chain.</td>
</tr>
<tr>
<td>334 BC</td>
<td>Alexander utilized supply-chain philosophy into his strategic plans to conquer the world.</td>
</tr>
<tr>
<td>300 BC</td>
<td>Trading point established by Caesar in East Asia termed as the first supplier-customer relationship.</td>
</tr>
<tr>
<td>206 BCE-220 CE</td>
<td>Silk Road (6,000 Km.) connecting the East with the West was utilized mainly for trade and cultural communication network.</td>
</tr>
<tr>
<td>700-800 AD</td>
<td><em>Charyacharyavinishchayah</em> concept mentioned in the Bengali <em>Charyapada</em> (Storing surplus amount of paddy in <em>Gola</em>)</td>
</tr>
<tr>
<td>1151 AD</td>
<td>Iceland declared its first plague and fire insurance program.</td>
</tr>
<tr>
<td>1305</td>
<td>Influential European clients got their courier messenger service run by House of taxis (primeval outsourcing)</td>
</tr>
<tr>
<td>1621</td>
<td>Formation of first pretend third party logistic (3 PL) by the Dutch West India Co. with America and West Africa to do business.</td>
</tr>
<tr>
<td>1904</td>
<td>First trace of outsourcing found when Charles S. Rolls became the marketing mediator for cars manufactured by F. Henry Royce.</td>
</tr>
<tr>
<td>1956</td>
<td>An overseas 3PL found when Buffet pioneered the first financing investment partnership after collecting the money from his close relatives and invested that money in Omaha.</td>
</tr>
<tr>
<td>1960-1975</td>
<td>The quintessence of SCM first understood by the business organization in the shape of aggressive inventory “push” era.</td>
</tr>
<tr>
<td>1975-1990</td>
<td>Aggressive inventory push era drastically changed to customer’s demand <em>i.e.</em> “pull” era.</td>
</tr>
<tr>
<td>1980</td>
<td>Business community convinced that the coordination, synchronization and integration of its material and information flow across its organization could dramatically improve the productivity which is the fundamental concept of supply chain management (SCM).</td>
</tr>
</tbody>
</table>
### Table 1.2 Evolution of Supply chain philosophy to post 1980 era

<table>
<thead>
<tr>
<th>Time period</th>
<th>Proceedings</th>
<th>Philosophy/Focus on</th>
<th>Key driver</th>
</tr>
</thead>
<tbody>
<tr>
<td>1981</td>
<td>First full outsourcing took place when IBM developed a complete computer with almost all of its components purchased from OEMs.</td>
<td>Product driven</td>
<td>Quality</td>
</tr>
<tr>
<td>1985</td>
<td>Cross docking concept developed and implemented by Wal-Mart.</td>
<td>Volume driven</td>
<td>Cost</td>
</tr>
<tr>
<td>1990</td>
<td>Computing technology paradigm shifts the whole business process.</td>
<td>Market driven</td>
<td>Product availability</td>
</tr>
<tr>
<td>1996</td>
<td>Internet radically transformed the i-way and the downstream business system.</td>
<td>Customer driven</td>
<td>Lead time</td>
</tr>
<tr>
<td>1998</td>
<td>E-Commerce concept revolutionized the fundamental of business itself.</td>
<td>Customer driven</td>
<td>Lead time</td>
</tr>
<tr>
<td>2000</td>
<td>T-commerce started and digital TV is designed.</td>
<td>Customer driven</td>
<td>Lead time</td>
</tr>
<tr>
<td>2005</td>
<td>Consolidated Supply chain with affordable and accessible technologies</td>
<td>Infrastructure driven</td>
<td>Faster, better and multi-modal networks</td>
</tr>
<tr>
<td>2010</td>
<td>Digital connectivity concept (data centric): Face book, mobile, social media etc.</td>
<td>Knowledge driven</td>
<td>Information Explosion/Internet driven</td>
</tr>
<tr>
<td>2016 onwards</td>
<td>Multi-country supply chain (Stronger global collaboration with win-win concept)</td>
<td>Better regulatory climate (Post-GST Indian scenario)</td>
<td>Sustainability, activism driven</td>
</tr>
</tbody>
</table>
1.3 A Few variants of Supply Chains

Historical evolution showed the continuous physical and operational changes in the role of a supply chain. Now it is worthwhile to discuss in depth the fundamental variants of supply chain in modern industrial background. In an industry, the configuration of a supply chain naturally a bit complex. The degree of complexity of a supply chain depends upon the number of stages/echelons through which flow of materials and information pass through while transformation of a finished product take place. The design of a typical supply chain largely depends upon the type of products, delivery lead time offered, customer requirements etc. A complex, large supply chain would be unstable if each stage is managed separately. It is important to look into the performance of the total supply chain as a whole which paves the way for SCM. Under the aforementioned reasons, a thorough study on the configuration of a supply chain is deserved. Therefore, few typical supply chains are described here based on their course of activities:

1.3.1 Traditional push based supply chain

This is a classical supply chain configuration where manufacturer used to produce any number of goods on their own without taking the market/customer demand into consideration. The manufacturers used to produce the items themselves in anticipation of the market demand. Their speculation based on their own expertise not on any scientific background. The manufactured products then aggressively thrust upon the customers irrespective of their choice. Manufacturers need not paid attention whether the customers like it or not. It was the monopoly of the producers as number of competitors in the market was very less. The manufacturers used to take the orders from the retailers directly. It was the forceful selling era. A traditional push based supply chain is shown in Fig. 1.4.

![Traditional Push based Supply Chain](image)

**Fig. 1.4. Traditional Push based Supply Chain.**
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1.3.2 Pull based supply chain

This view promotes to a marketing survey approach. During survey, an estimated customer demand is known or factually pulled from the customer’s view in the market. The marketing department used to actively engage themselves scientifically in extracting the real time demand and choice of the customers. In response to this available information of the customer’s order, production unit manufacture those items. Those manufactured items are then delivered to the customers through the retailers. In the case of pull system the activities behave in a reactive manner and are executed by being pulled in response to the customer order. A pull based supply chain is shown in Fig. 1.5.

![Fig. 1.5. A Pull based Supply Chain.](image)

1.3.3 Efficient and Responsive supply chain

Depending upon design of its intended functions towards the customer’s requirement a supply chain can be broadly distinguished into either responsiveness supply chain or efficient supply chain. A supply chain is responsive if it has the functional ability to meet the following:

- Delivery at shorter lead times as and when the customers want.
- Respond to any quantities demanded by the end users.
- Availability of a large variety of products.
- Design innovative items.
- To exceed customer’s delight through very high service level.

To attain responsiveness, a supply chain has to pay a heavy price. The manufacturing cost shoots up. Even to meet the variety of required demand, capacity of the
company has to be appropriately increased that results in increased cost of the manufactured products. A responsive supply chain is a costly affair.

Contrary to that, an efficient supply chain is one which lowers the cost of manufacturing and supplying the product to the customers at a lower price. It is very clear from the definition of the both that supply chain responsive decreases as supply chain efficiency goes up. Comparison of a responsive supply chain with an efficient one is shown in Table 1.3.

Table 1.3. Comparison of Efficient and Responsive Supply Chain

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Efficient supply chain</th>
<th>Responsive supply chain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic goal</td>
<td>Meet demand at the lowest price</td>
<td>React swiftly to demand</td>
</tr>
<tr>
<td>Product design</td>
<td>Performance maximization at minimized cost</td>
<td>Similar group to allow delay in product postponement</td>
</tr>
<tr>
<td>Pricing</td>
<td>Lower margin as price is a prime parameter of customer attraction</td>
<td>As customer is ready to pay price for specific demand, margins may be higher.</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>Higher utilization of resources</td>
<td>Develop and maintain capacity to meet unknown demand</td>
</tr>
<tr>
<td>Inventory</td>
<td>Inventory level is minimum to lower cost</td>
<td>Buffer inventory to meet unexpected demand</td>
</tr>
<tr>
<td>Lead time</td>
<td>Reduced, not at the expense of costs</td>
<td>Radical reduction though costs are high</td>
</tr>
<tr>
<td>Supplier selection</td>
<td>Cost and quality are the selection criteria</td>
<td>Speed, flexibility and quality are the selection criteria</td>
</tr>
<tr>
<td>Transportation</td>
<td>Heavily depends on low cost modes of transportation</td>
<td>Quicker and responsive modes of transportation is desirable</td>
</tr>
</tbody>
</table>

Source: (Fisher, 1997)
Depending solely on production lead time parameter, a supply chain could be categorized and positioned itself in the efficient-responsive spectrum as shown in Fig. 1.6 below.

![Efficient-Responsive Spectrum](image)

**Fig. 1.6. The efficient-responsiveness spectrum**

### 1.3.4 Lean, Agile, Le-agile supply chain

Depending upon the manufacturing strategy, a supply chain could be categorized as lean, agile or le-agile. A lean supply chain essentially focuses on the minimization or even elimination of wastes (muda) during production or providing service. Lean philosophy function well for relatively known and stable demand with low variety (Agarwal et al., 2006). For volatile demand and larger varieties of products, a supply chain must have higher level of agility (Lee, 2002). Agility is defined as the capability of an organization to respond rapidly to changes in demand, both in terms of volume and variety (Christopher, 2000). Organization should acquire the capacity that embrace the mind set up of the management with well designed firm equipped with sound logistic warehouses and information technologies (Power et al., 2001). These three concepts could be combined successfully in a supply chain by strategic positioning the customer order de-coupling point (CODP), named as le-agile supply chain (Naylor et al., 1999). The customer order penetration point (COPP) of a product is defined as the stage/point in the manufacturing value chain, where the product is linked with a special customer order (Mason-Jones et al., 2000a, 2000b; Prince and Kay, 2003). This customer order penetration point (COPP) is suitably positioned in a manufacturing paradigm for a volatile demand downstream yet maintaining level scheduling upstream from the market place (Van Hoek et al., 2001).
Authors attempted to establish an audit of agility in the supply chain. Agility of an organization could be achieved by increasing the responsiveness to the customer’s needs that requires specific capabilities from the part of the firm. Different components of an agile supply chain where measurement metrics are established to increase agility are shown in Fig. 1.7.

![Diagram of Components of an Agile Supply Chain]

**Fig. 1.7 Components of an Agile Supply Chain**

### 1.3.5 A Supply chain based on product customization

A supply chain requires specific facility design in a production system that depends upon the type of product it produces for the customer segment and the strategy it employs to serve its customer. In this respect, customer order penetration point (COPP) defines both production lead time (\(P\)) and delivery lead time (\(D\)) that play crucial role to determine different production strategy to be adopted. Based on these attributes, the production strategies are divided into five clusters: Make to Stock (MTS), Assembly to Order (ATO), Configuration to order (CTO), Make to Order (MTO), and Engineer to Order (ETO). Firms configuration based on product customization are briefly discussed below.
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Make to Stock (MTS) supply chain: In MTS approach, items are manufactured in bulk quantity where high demand is known and constant. This type of chain is similar to push-type supply chain and commands monopoly in the market. This implies that standard goods produced in large quantities would be sold to the customers with ease. Firm following this strategy gets higher productivity and customers expect minimum delivery lead time from them where P/D ratio >> 1.

Assemble to Order (ATO) supply chain: This type of production is similar to MTS to a certain extent with the difference that assembly starts according to demand. Customer is not eager to wait till production, rather opt for the assembled one from the available parts. The unique feature of this system is that quite a large variety of complete products can be obtained from almost same set of components. This type of chain adopts modular parts strategy. It is therefore prudent to manufacture the components in bulk and final assembly is undertaken only when the demand for specific products is forecasted. It follows product customization approach with shorter delivery lead time with P/D ratio > 1.

Configuration to Order (CTO) supply chain: A firm based on CTO approach destined to meet the ever increasing level of product differentiation of the customers. This approach ensures to fulfill the functional requirements of miscellaneous needs of customers in a customized product. Firm designer interacts directly with customer regarding his needs of functional features e.g. color, capacity, size etc. from available components lists. Configure to order strategy accommodates all the intended functional requirements in the expected product for the customer. Here, delivery lead time given by the customer is more or less equal to the production lead time i.e. P/D Ratio ≈ 1.

Make to Order (MTO) supply chain: A firm follows MTO approach, based on demand-responsive strategy. Manufacturing starts only after a customer's order is received. This strategy is adopted for unpredictable demand and delivery lead time is sufficient enough to start production process on receipt of an order from the customer whose P/D Ratio < 1. This approach is just equivalent to pull-based supply chain as mentioned earlier.
Engineer to Order (ETO) supply chain: This is an extension of MTO where the product is to be manufactured according to the specification given by the customer. Such products are completely new and hence no standard design is available. Depending on the specification, the design is started which is followed by component manufacturing and assembly. The delivery lead time for this category of production is extremely high, hence P/D Ratio $<< 1$. Different supply chains with different P/D ratios, position their facilities in various locations as shown in Fig. 1.8.

<table>
<thead>
<tr>
<th>Design</th>
<th>Manufacturing</th>
<th>Configuration</th>
<th>Assembly</th>
<th>Delivery</th>
<th>P/D Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTS</td>
<td></td>
<td></td>
<td></td>
<td>△</td>
<td>$&gt;&gt; 1$</td>
</tr>
<tr>
<td>ATO</td>
<td></td>
<td>△</td>
<td></td>
<td>△</td>
<td>$&gt;1$</td>
</tr>
<tr>
<td>CTO</td>
<td>△</td>
<td></td>
<td></td>
<td>△</td>
<td>$\approx 1$</td>
</tr>
<tr>
<td>MTO</td>
<td>△</td>
<td>△</td>
<td></td>
<td>△</td>
<td>$&lt;1$</td>
</tr>
<tr>
<td>ETO</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td></td>
<td>$&lt;&lt;1$</td>
</tr>
</tbody>
</table>

**Figure 1.8. Strategic positioning of the order penetration point.**

After preliminary discussion on supply chain aspect, it is quite natural to look a typical supply chain view in real industrial perspective. Schematic representation of a typical manufacturing supply chain is shown in Fig. 1.9. Here, warehouses/storages are suitably positioned at different linkages of the supply chain to get a seamless flow of materials to transform it to finished products and reaches to ultimate customers.
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Fig. 1.9. Schematic representation of a typical manufacturing supply chain.

1.4 Supply Chain coordination through its effective integration

An industrial supply chain configuration generally comprises of multistage and multi echelons that increase the complexity in flow transformation. The success of a supply chain largely depends upon the degree of coordination and collaboration attained throughout the entire chain. Supply chain coordination may be defined as the synchronization and constructive coordination among all its members using suitable enabled IT to improve overall profitability of the organization as a whole. To achieve this, all the stages across the supply chain should act together aiming at meeting its total chain objective. While making decisions for a particular stage, it has immense impact over the others. So, operational/floor level decisions should always be made in line with the global objective. Lack of coordination occurs when different linkages act to fulfill their own and immediate profit, undermining the totality principle of the chain. One of the major fallout of improper coordination in a supply chain is the flow of distorted and filtered information throughout the supply chain causing bullwhip effect. To achieve proper coordination and
organizational objective, a traditional supply chain might be restructured in the following way.

- In-house integration:

  Vertical integration of management hierarchy level (tiers) can be appropriately reduced to achieve prompt and sound decisions.

  Horizontal integration of departments is carried out to achieve cohesive functional outputs in a supply chain to serve the customers effectively.

- Outer-firm integration:

  Outside the firm, a supply chain of a company should make partnership with the concerned customers as well as suppliers within a country. Vendor managed inventory (VMI) concept could be employed to integrate the supply chain. Strategic alliance could be made with the reliable suppliers and customers base by bringing them under one common standard management concept which is highly instrumental to constitute a value chain. All the stakeholders follow a relationship of mutual trust rather than an adversary to enhance the performance of a value chain.

  A supply chain now cross the national geographical boundaries and becomes global. With the advent of liberalization, privatization and globalization (LPG) and GATT agreement, it becomes imperative for a competitive supply chain to build its global presence. In this respect, probable implementation of Goods and services Tax (GST) in India from April 2016 would enhance the consolidation of multi country supply chain practically.

  The successful integration of a supply chain with a paradigm shift of important factors that brings organizational excellence is shown in Table 1.4.
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1.5 Supply Chain Performance and Achieving Strategic Fit

A typical supply chain is basically a network of interconnected business entity working in close coordination among its stakeholders to achieve industrial excellence through seamless flow of materials and information. Industrial excellence in terms of competitive advantages may be in terms of cost savings, value additions, greater customer satisfaction, earning higher revenues and in turn more profitability and higher productivity. These competitive edges can be achieved by properly aligning the competitive strategy of the organization with its own supply chain strategy. Competitive strategy basically depends upon the company’s policies towards its customer’s priorities in terms of the product cost, product delivery, quality and its availability. Supply chain strategy primarily looks after the procurement of raw materials, manufacturing of the products, distributions and delivery to the customers with the promise of prompt service. Decisions regarding inventory, transportation, facilities and enabling information technologies inside an organization comes under supply chain strategies. The fundamental goal of any supply chain manager is to align those two strategies to achieve strategic fit so as to get competitive advantages and enhance overall supply chain performance capabilities. As a consequence, the sources of both the revenues and cost are to be ascertained. The cost incurred while producing a finished product by transforming the raw materials and relevant information from upstream to downstream of a supply chain. Ultimately customers customarily pay for the cost of the same product. Supply chain management philosophy is utilized to coordinate, collaborate and synchronize all those flows among all the stages to increase the profitability and thus ensuring the success of an organization.

<table>
<thead>
<tr>
<th>Traditional success factors</th>
<th>Modern success factors</th>
<th>Traditional success factors</th>
<th>Modern success factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of the firm</td>
<td>Delivery speed</td>
<td>Functional clarity</td>
<td>Flexibility</td>
</tr>
<tr>
<td>Departmentalization</td>
<td>Integration</td>
<td>Control</td>
<td>Creativity</td>
</tr>
<tr>
<td>Passive approach of the industries</td>
<td>Proactive approach of the industries</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Supply chains can be categorized into either efficient or responsive supply chains (Fisher, 1997). Christopher and Towill (2002) made a similar distinction into lean and agile. Strategic positioning of a company in terms of trade-off between a responsive and efficient supply chain is shown in Fig. 1.10. For an existing technology based efficient supply chain, it can be responsive one while increasing its cost and becomes less efficient. On the other side, a responsive chain can move towards the efficient frontier easily. The strategic choice of efficient-responsive chain depends upon the level of responsiveness the company desires to opt for.

Fig. 1.10. Cost responsiveness efficient frontier.

A company must know its design suitability, understand its customer sector and ensure that its supply chain competence align its potential to fulfill the targeted customer sector. In order to achieve strategic fit, it is imperative that competitive strategy in terms of customer’s need be consistent with the level of responsiveness it provides. Customer needs may be represented as implied degree of uncertainty which a responsive supply chain as a strategy should be able to meet. A point in this graph represents a combination of disguised demand of uncertainty and supply chain responsiveness. The disguised demand
uncertainty signifies customer needs or the firm’s strategic position. The supply chain’s responsiveness represents the supply chain strategy. Fig. 1.11 shows for a specific level of performance, an organization should employ it’s both competitive as well as supply chain strategy toward the region of strategic fit. To achieve total strategic fit, a company should align all its functional strategies in line with the competitive strategy.

![Diagram](image)

**Fig. 1.11. Achieving the zone of strategic fit in a firm.**

Gunasekaran et al., (2004) developed a frame work for measuring the strategic, tactical and operational level performance in a supply chain. They used a key performance matrix to emphasize on performance measures dealing with vendors, inventory and logistic costs, delivery performance, and customer service in a SCM and relate them to customer satisfaction.

### 1.6 Drivers of Supply Chain Performance

As per the chosen competitive strategy of an organization, the supply chain design is formulated. The management also opt for the level of responsiveness tailormade to that specific customer needs. Performance of a supply chain largely depends upon several important supply chain drivers as shown in Fig. 1.12. Their roles in evaluating the performance of a supply chain are now discussed below.

**Inventory** may be defined as utilizable but inactive resource in the form of raw materials, parts, components, work-in-process sub-assembly, and finished goods within a
supply chain. It is an important supply chain driver because inventory policies have large impact towards the supply chain efficiency and responsiveness. An organization keeps inventory due to the dissimilarities between the supply and customer’s demand. Material flow time in a supply chain substantially depends upon the type and capacity of inventory. Material flow time is the time that elapses between the points at which the material enters the supply chain to the point at which it exits. Inventory has also large impact on throughput, the rate at which sales occur to the customer.

**Transportation** entails moving raw materials, semi-finished product, parts, components, finished products, man, human resources from one linkage to the other in a supply chain. Transportation modes have a large impact on the supply chain responsiveness and efficiency. Transportation is the significant component of the cost most supply chains incur. The role of transportation in a global supply chain is enormous.

**Facilities** are the places in various stages of a supply chain network where inventory is accumulated, assembled, or fabricated. It has a significant impact on the supply chain performance. A highly efficient distributor might keep smaller number of warehouses to be more efficient despite the fact that this practice will reduce responsiveness.

**Information** consists of data and analysis regarding inventory, transportation and customer throughout the supply chain. It is potentially the most important driver of performance enhancement of the supply chain as it directly affects all the other drivers. Information helps management hierarchy to make supply chain more responsive and efficient. Information allow the other three drivers to work together to achieve coordination, integration and collaboration within a supply chain. It makes supply chain visible to a manager which helps to improve the supply chain performance. Improved supply chain visibility due to the availability of good information in a global platform enable the supply chain managers to make right decisions which enhance supply chain performance to a large extent.
1.7 Facility as a key supply chain strategy in improving its performance

Strategic facility decisions play a very important role in improving supply chain performance. Facility decisions include:

a. **Facility Role.** It determines the level of responsiveness of the supply chain to meet customer’s demand.

b. **Facility location.** It has a long term impact on a supply chain performance.

c. **Capacity Allocation.** Allocating too much capacity to a location results in poor utilization and hence higher cost (lower efficiency). Allocating too less capacity results in poor responsiveness.

d. **Market and Supply Allocation.** It has a significant impact on total production, inventory, and shipping costs incurred by the network to satisfy customer demand.
1.8 Warehouse location: a key facility strategy under supply chain perspective

Facility location decisions are very crucial and have a strategic impact on the organization. Once a long term decision is taken and implemented, it is very expensive to simply close that facility or relocate to other place. A suitable location decision may be responsive enough and at the same time less costly. On the other side, wrong location selection would be less responsive as well as inefficient, unable to meet competitive strategy of the organization. Supply chain facility design decision has a large impact on the overall design of the network as it affects the other major drivers e.g. inventory, transportation and information. The location of the facility would make the supply chain strategy either responsive or efficient one. The design of a supply chain network has a strong impact on the overall profitability and success of an organization. To achieve optimized supply chain network, facilities such as manufacturing plants, warehousing, wholesale distribution centers (DCs) and local retail outlets should be strategically located (Coyle et al., 2003; Simchi-Levi et al., 2003). Warehouse is the merging points where the finished products from various plants are arranged group wise as required and mutually allocated for transporting to the customers. Appropriate warehouse location assists the management to respond quickly to the demand of the end users. It reduces the supply chain risk and uncertainty, lowers the prices of a better product and improves the customer service. All these strengths and weakness indicate the strategic significance of warehouse location selection that deserve the attention and interest of the academic fraternity.

Global competition in the market place has posed a significant challenge to the very survival of the companies. Requirement of technological push in production, enormous pressure to meet the customer’s ever changing demand, continuous flow production, operator’s safety and increased environmental awareness, warehouse operations have been constantly being upgraded and revolutionized. A global supply chain with shorter delivery lead time to meet the demand makes it imperative for the business community to opt for continuous business solution by positioning warehouses at the right place and with its maximum utilization. Warehouse design development should always be aligned with the
overall supply chain mission. Warehouse design plays a very crucial role in storing in any stage and transporting the inventory to the next without damaging them. For in depth analysis of the impact of warehouses on the performance of a supply chain, it is essential to get the fundamentals of warehouse clear.

1.8.1 Warehouse defined

Human beings have the habit of preserving different types of foods, goods for various reasons from the ancient time itself. As a home maker, mothers used to keep some amount of food grains secretly in a store is an ample idea of home storage. Similarly, businessman also requires some goods in bulk which are not of immediate use to keep in a bigger storage. They may require it in different volume throughout the year. Storage arises for the raw materials, parts, assembly; semi finished parts and finished products at different stages of a transformation process in a supply chain. So, storage may be defined as a proper arrangement for preserving goods from the timing of manufacturing to the moment of its actual consumption. When storage is done for large volume of goods in a proper and specified manner, it is termed as warehousing. Warehousing may be defined as the activities of storage of different valued items on a large scale in a systematic and orderly manner and keep them available easily when required. It has huge time utility as it bridges the gap between the time of production and its actual consumption. Storage generally used for the raw materials, work-in-process (WIP) products and the finished products. Storage and warehouses are the terms utilized inside the plant interchangeably. Warehouses help the industry to supply the goods to the consumers quickly and have a great role in price stabilization of the goods by balancing the supply of goods accordingly.

1.8.2 Info graphic: History of warehouse evolution

The presence of warehouse as a means of storage could be traced back to 9500 BC. From ancient times grains are being preserved in a granary date back to the age of agriculture. Ancient granaries are often made out of pottery and served as first warehouses. As civilization progressed, transportation and intercontinental trade grew that necessitated the transformation of warehouses to store foods and other goods in bulk amount. During
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Medieval era, warehouses are being utilized for industrial purpose also apart from the agricultural need. There had been a continuous evolution of design, purpose and operational requirement. The evolution of warehouse continued in modern era too. Towards late 19th century, the ever increasing demographic need compel the countries to make warehouses specially intended for storage of grains and goods began to multiply. To operate these warehouses properly the concept of warehouse management evolved though the operation was fully a manual process till 20th century. After this period world saw rapid development in this sector through unprecedented technological growth enabled with information technology which empowered the business firm to achieve exceeding customer satisfaction.

A study sponsored by Warehousing Educational & Research Council (WERC), a premier professional organization for the warehousing industry revealed the transformed role of a warehouse from a simple product storage and shipment to multifunctional supply chain solution facility. Firms now want the warehouses to coordinate and synchronize the flow of material and information among different supply chain members and even to take up value addition activities to modify the material for other members of the value chain. Manufacturers started looking warehouse as mini transformation (manufacturing) plant as manufacturing labor is costlier than a warehouse labor. Manufacturers are more inclined to take the advantages of third party logistics providers (3PLP). Warehouse has started to act as a flow center/cross dock operations between and among the other members. Modern warehouses are designed to be cost effective as well as responsive simultaneously. Academics and practitioners emphasize that the warehouses play the role of a resource provider. Instead of a storage centre, warehouses should continue shifting its view to become operation centre. Modern warehouses are expected to handle 99% of the transaction accurately and promptly. Slowly the warehouse management focuses more on service quality rather than concentrating only on being cost-centric. Modern warehouse is seen as the important integral part of a supply chain. Today by virtue of IT and technological growth, warehouse has evolved itself from warehouse only solution towards a complete supply chain solution.
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Today’s warehouse is in control and management of other activities in and around a supply chain. Today’s warehouse has become SMART (Scalable-Mechanized-Accurate-Responsive-Transport friendly) to take up those operations very effectively. SMART warehouses using superior visualization and analytics features could give better and accurate supply chain solution. The features of a SMART warehouse are described in section 1.8.6.4 of this chapter. The interior design of today’s warehouse has also seen a sea change from its single floor utilization to high rise multi-floor storage system to attain many advantages. Warehouse designed with metal racking, pallet racking system, mezzanine floors, and automatic and vertical storage system. Multiple floors to multiply space utilizations are the key to a rational exploitation of the same space. Vertical lift module, horizontal carousels etc. are utilized for semi-automatic storage system. In automatic storage and retrieval system (AS/RS), shuttle technology is used to improve throughput rates. Automated guided vehicles (AGV), robots etc. are used as material handling equipments in modern warehouses to achieve better and accurate warehouse operations. Applications of Radio frequency identification (RFID), bar coding etc. enhance the effectiveness of the warehousing operations and improve productivity. Many corporate sectors have stared utilizing relevant warehouse management software as an integrated approach to get the overall success of a supply chain. A chronological evolution of warehousing design concept is shown in Table 1.5 and a pictorial representation is also shown just after that.

Table 1.5. **Chronological evolution of warehousing design concept**

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Evolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>9500 BC</td>
<td>Oldest granaries yet found in Jordan Valley. Stores were located between the buildings.</td>
</tr>
<tr>
<td>8500 BC</td>
<td>Stores were then moved inside the buildings.</td>
</tr>
<tr>
<td>7500 BC</td>
<td>Storage occurred inside special rooms. The first outside granaries dimension were 3×3 m. and suspended floors to save the grains from insects and rodents. The storage space had the arrangement of proper air circulation.</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Time Period</th>
<th>Evolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>6000 BC</td>
<td>Granaries found in Mehrgarh in the Indus valley</td>
</tr>
<tr>
<td>6000 BC</td>
<td>Ancient Egyptians used granaries to preserve grain in the year of plenty</td>
</tr>
<tr>
<td>6000 BC</td>
<td>Silo pit, a favorite means of storing grain in Turkey and Persia. People used to purchase wheat or barley at cheaper rate and preserve it in hidden pits against scarcity.</td>
</tr>
<tr>
<td>1100 - 600 BC</td>
<td>Ancient pharmaceutical warehouse found near Istanbul, Turkey.</td>
</tr>
<tr>
<td>1000 BC</td>
<td>Storage system seen in China and Korean peninsula</td>
</tr>
<tr>
<td>800 BC</td>
<td>Storage granaries found in Japan.</td>
</tr>
<tr>
<td>Ancient/ Medieval era</td>
<td>In Indonesia, wood and bamboo made granaries are built elevated up on four or more posts to avoid insects and rodents.</td>
</tr>
<tr>
<td>Late 18th Century</td>
<td>In Great Britain, small mushroom shaped granaries are built with timber frame and often had slate roofs. Warehouses especially planned for storing grain began to increase in Great Britain.</td>
</tr>
<tr>
<td>Medieval//Modern era</td>
<td>Warehouses are being utilized both for agriculture as well as industrial purpose.</td>
</tr>
<tr>
<td>1977</td>
<td>Warehousing Education and Research Council (WERC), the association for logistics and warehousing professionals was born.</td>
</tr>
<tr>
<td>1985</td>
<td>The Logistics centre/park is not a new concept – it was first seen 30 years ago in Europe though it faced many difficulties.</td>
</tr>
<tr>
<td>Up-to 2004</td>
<td>Warehouses of India are practically utilized as go-down (only storage of inbound and outbound products/items).</td>
</tr>
<tr>
<td>2004-09</td>
<td>The Government of India (GOI) formulated in the Foreign Trade Policy to set up Free Trade and Warehousing Zones (FTWZ).</td>
</tr>
<tr>
<td>2007</td>
<td>India enacted the Warehousing Development and Regulatory Authority (WDRA, 2007) act.</td>
</tr>
</tbody>
</table>
### Time Period | Evolution
--- | ---
2010 | Enhancement of warehouse productivity draws attention to the researchers/practitioners
2012 | Warehouse management system (WMS) concept came up.
2013 | Racking (verticalization), palletization, modernization of warehouse design started. AS/RS seen as the latest warehouse management approach utilizing warehouse management software.
2014 | Compactness/consolidation of warehouses
2015 | SMART warehouse started using superior visualization and analytics. Warehouse solution becomes supply chain solution.
2016 | Probable implementation of Goods and Service Tax (GST) in India would have paradigm impact in warehousing sector.

Some Info-graphic images are presented here to highlight the chronological evolution of the warehousing design and operation concept through Fig.1.13 to Fig. 1.39. These images are categorized as ancient, mediaeval and modern era as shown below.
Fig. 1. 13. **Ancient Egypt granary/storehouse for grain.** A granary is a storehouse or room to keep excessive grain or animal feed. These primitive granaries are most often made out of pottery. Courtesy:https://en.wikipedia.org/wiki/Granary

Fig. 1. 14. **Ancient Greek geometric boxes in the shape of granaries,** 850 BC and are being displayed in the Agora Museum in Athens, housed in the Stoa of Attalos. Courtesy:https://en.wikipedia.org/wiki/Granary.
Fig. 1.15. Old Roman Amphorae in Pompeii Warehouse. These look-a-like jars of the original one, owned by a merchant that survived the eruption of Mount Vesuvius on Aug 24th, 79 A.D. Courtesy: http://warehouse13.wikia.com/wiki/Pompeii_Amphora.

Fig. 1.16. An ancient granary storage found in Iran. Courtesy: http://www.upscavenger.com/wikimedia/kent-barry-granary-kashan
Fig. 1.17. A simple old granary. These granaries are generally made above the ground to keep the stored food away from rats and other animals.
Courtesy: https://en.wikipedia.org/wiki/Granary

Fig. 1.18. Stone made Terekota army of the Republic of China is kept in a warehouse.
Courtesy: http://www.gettyimages.ae/detail/photo/army-of-terracotta-warriors
Fig. 1.19. **Pre-medieval warehouse was found in the fortress in ancient Khiva, Uzbekistan.** Courtesy: http://depositphotos.com

Fig. 1.20. **An ancient storage area whose roof collapsed in a devastating earthquake.**

Courtesy: www.google.co.in
Fig. 1.21. **Ancient rice warehouse of China.** This storage spaces were used by ancient Chinese people for the storage of rice.

Courtesy: http://www.gettyimages.co.uk/detail/photo/rice-warehouse-in-ancient-china

Fig. 1.22. **Grain & Wine Storage warehouse** discovered in Crete—the palace of king Minos in Ancient Knossos (2000 BCE-1700 BCE). Courtesy: https://www.google.co.in
Fig. 1.23. **One of the oldest surviving warehouses in Kent, Britain.** The roof is constructed by timbers brought from the medieval refectory of Faversham, Abbey. Courtesy: [http://www.flickriver.com](http://www.flickriver.com)

Fig. 1.24. **Circle warehouse Beijing, China** is an important juncture at The Great Wall, Juyongguan. Courtesy: [http://www.dreamstime.com](http://www.dreamstime.com)
Fig. 1. 25. **Small Medieval Warehouse.** Courtesy: //www.google.co.in

Fig. 1. 26. **Large Medieval Warehouse.** Courtesy: //www.google.co.in
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Fig. 1. 27. **Medieval industrial warehouse.** Courtesy: https://www.google.co.in

Fig. 1. 28. **Cistercian Monks built this warehouse after the French raid of 1338.** This warehouse was used as a storehouse for wool to be exported to Europe. This was only the surviving medieval warehouse in Southampton. In 18th century it was used as a space for French prisoners of war during the Seven Years War and Napoleonic Wars. Courtesy: https://www.google.co.in
Fig. 1. 29. **One of the big warehouses at the centre of Visby** and being used as 'Gamla Apoteket (The old pharmacy) in Strandgatan. Courtesy: https://www.google.co.in

Fig. 1. 30. **A late medieval shipping warehouse at Poole, Dorset** later being used as a local studies library. Courtesy: https://www.google.co.in
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Fig. 1. 31. A poorly managed warehouse of Food Corporation of India in Hapur, U.P in the wake of high food grain stocks there. A Central Govt. committee submitted its report very recently to reform FCI and NFSA. This was urgently implemented in view of the Supreme Court interventions in the wake of widespread hunger and malnutrition in the country. Courtesy: India

Fig. 1. 32. A warehouse where floor space is utilized singularly without multiple rack system. Courtesy: http://www.gettyimages.in
Fig. 1.33. Modern warehouse with pallet rack storage system. Pallet rack is a material handling storage aid system designed to store materials on these pallets. Different types of pallet racking allow the storage of palletized materials in parallel rows with multiple levels. Forklift trucks are used as an integral part of this system to place the loaded pallets onto the racks for storage. Courtesy: https://commons.wikimedia.org

Fig. 1.34 Westfalia installed automated warehouse solutions for manufacturers and distributors in both conventional existing facilities and new built facilities. Westfalia offer the Automated Storage and Retrieval Systems (AS/RS) in temp. range from -35°F to 110°F for both non-rack and rack supported structures. Courtesy: http://w.w.w.westfaliausa.com
Fig. 1.35. High-Tech Distribution Center for Dairy Products in Vietnam, Southeast Asia. SSI Schaefer has designed and implemented a high-bay warehouse and conveying system with tailored system components for this company. This distribution centre achieved efficient material flows with the help of electric rail guided vehicle system. The company applied intelligent logistics software WAMAS® that provide continuous automated processes with high capacity throughput.

Courtesy: http://www.ssi-schaefer.de

Fig. 1.36. Modern warehouses are nowadays run by autonomous robots to pick the required products from their shelves and send them to the customers. All the robots are programmed about these activities in advance. They pick the right item from the exact shelfe, follow the correct paths and bring it to human operators. They find the time to get themselves recharged and carry out the operations very efficiently and effectively.

Courtesy: http://www.wired.com
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Fig. 1. 37. Cerebos, Thailand installed modern storage solutions to improve warehousing. Cerebos (Thailand) Ltd is the leading manufacturer of Chicken Products in Thailand. Over the years, the company has become one of the largest exporters in Asia of chicken products. Cerebos has relocated its new warehouse in Laemchabang Industrial Estate at Chonburi province being the most suitable location for logistics and transportation to serve the future market.

Courtesy: www.ssi-schaefer.ae

Fig. 1.38. Modern large warehousing spaces equipped with Fire protection and Smoke detection facilities. Large spaces are those with ceiling heights extending ten to hundreds of feet above the floor. Some examples of large spaces are hotel lobbies, shopping centers, warehouses, distribution centers, automated storage and retrieval warehouses, and aircraft hangars.

Courtesy: http://www.systemsensorblog.com
1.8.3 Taxonomy of warehouses

Once warehousing is defined and its design evolution is shown chronologically, taxonomy of warehouses based on the specific need of the industrial houses could be mentioned. Storage needs of different types of goods, commodities and finished products require different sorts of warehouses. They are classified below:

- **Private warehouses**: These warehouses are owned and run by the manufactures to preserve their items near to their factories or agricultural field. The design and facilities provided to the warehouses depends upon the type of products to be stored.

- **Public warehouses**: These types of warehouses are owned and managed by any individual or partnership to stock the items of general public. People have to rent for the use of that storage space and other facilities. The manufacturers, wholesale distributors, exporters, importers govt. agencies can utilize those warehouses.
- **Government warehouses**: Central or state govt. and public corporations run, own and control these types of warehouses. These warehouses *e.g.* Central Warehousing Corporation of India, State Warehousing Corporation, Food Corporation of India are situated throughout the country to store food grains for public distribution systems especially.

- **Bonded warehouses**: These types of warehouses are owned and managed and controlled by the govt. as well as private agencies. Private bonded warehouses (licensed from Govt.) used to store imported items for which import duty is to be paid. These warehouses are generally used by the port authorities and located near the ports.

- **Co-operative warehouses**: These types of warehouses are owned and run by the members of the co-operative body. They provide these facilities to the members of that society at an economical rate.

### 1.8.4 Missions of a warehouse

Strategic positioning of a warehouse is very essential to achieve the overall supply chain success. The mission of a warehouse is to provide a smooth flow to inventories between the stages of a supply chain without causing any harm to the basic shape of the items. Warehouse design has a significant role to make the operations quickly, effectively and accurately. Application of enabled information technologies and physical distribution jointly helps to achieve that objective. The missions of a warehouse can be listed as:

- **Increasing productivity**: Effective utilization of storage space, human resource and material handling equipment together help in increased productivity of the supply chain.

- **Improving order picking**: Maximum time and monetary transactions are employed in order picking to increase productivity. Company should apply better order picking solutions which is very critical in warehouse success.

- **Space utilization**: At the fullest capacity utilization (80%), time requires to locate an item gets longer. Slow moving and fast moving items should be placed at proper place to improve productivity and to avoid spoilage and damage to the product.
• **Utilizing cross-docking:** Wal-Mart pioneered this methodology in which items are not actually stored in the warehouse. Trucks from different suppliers from different destination with varieties of products meet inside a warehouse. Now the goods are separated into smaller lots and then load in a truck quickly to send it to out bound stores with different products (pre-sorting and pre-labeling), some from each supplier truck.

• **Increasing value-added process:** Apart from picking and shipping point, warehouse used to provide service by pre-sorting, pre-labeling, packaging and in actual customization of outbound product to increase customer satisfaction level.

### 1.8.5 Functions of warehouse

Warehouse systematically and orderly store the products and protect them from sun, wind, heat, storm and moisture. It also minimizes the losses due to spoilage and breakage. These functions are carried out in the order as follows:

• **Receiving:** It is the orderly receipt of all materials or goods in correct quantity and quality and disbursing them to the storage or to other stages where it is needed.

• **Inspection and quality control:** Visual and laboratory inspection are carried out to assure the quality of inbound high valued items.

• **Repackaging:** When a bulk amount of products are received from the supplier, they are subsequently repackaged in unit load for easy storage and handling, quicker delivery to the next stage.

• **Put away:** It is the activity which place the goods in storage with proper material handling practices.

• **Storage:** This is the physical containment of goods and awaits its demand from the next stage. The entitlement of the storage space depends upon the quantity and volume of the products.

• **Order picking:** It is one of the most important functions of a warehouse where the products are removed from the storage to meet the required
demand of the customer. The basic design of a warehouse largely depends upon this function.

- **Postponement**: Waiting to perform after the picking process starts to take the advantages of providing more flexibility in the use of current in-hand inventory.

- **Sortation**: Sorting of items carried out in batch when different merchandise is grouped in a single batch.

- **Packing and shipping**: Check thoroughly the order for its completeness. Packaging merchandise in a proper container. After weighting for determining actual charges load them to a truck for out bound customers.

- **Cross-docking**: It is a logistics practice where products through inbound trucks from different suppliers or manufacturing plant are first unloaded and then direct them to a customer or retail chain via outbound transportation with marginal to no handling or storage time. Due course of this minimum interval time in a warehouse, the goods are separated into smaller lots, load in a outbound truck to send it quickly straight to outbound markets/customers. Cross docking describes the process of receiving products through an inbound dock and then supplying them across the dock to the dock.

- **Replenishing**: Fill up the primary picking points with required quantity of goods/merchandise from secondary reserve storage points.

**1.8.6. Warehouse Management in India- Problems & Prospects**

India tops among most of the favorable destination in today’s world economy. Due to the large amount of foreign direct investment in India, warehousing industry is also growing in a SMART way. Though, Indian warehousing industry promising enormous potential to be a key driver in achieving double digit growth, it confronts with some of its limitations. The challenges faced by the emerging warehousing industries are discussed below.
1.8.6.1. Challenges of Indian warehousing industry

In spite of its huge strategic significance in the national economy, Indian warehousing spread over a total area of 3.3 million sq.km of landscape, a seashore line of 7,517 km, with the opportunities of its enormous prospective for development, it confronts several challenges. While the lack of physical superior infrastructure in one hand, the Govt. apathy of time lag between planning and implementing strategies to keep up to international warehousing standards is another. Major Indian warehousing companies face tough strategic and operational challenges and bottlenecks during their lifecycle. The sustainable development of this sector would rely heavily on the effective contribution and collaboration of the government, public and private sectors in the long term. Traditionally, warehousing in India has been seen as just a go-downs made up of small to medium unit size buildings. These go-downs were normally utilized for storage purpose. Management hardly paid attention towards the warehouse facility design as value changer and profit maker in a supply chain. Lack of suitable infrastructure has always slowed down the growth of other business organization that depends upon warehousing and logistics. Proximity of the warehouse to supply-demand hub and quality infrastructure always carries utmost importance. The Miebach India Warehousing 2010 research study reports that three fourth of Indian companies are forced to pull on with poor to average warehousing infrastructure. Probably, warehousing industry could not establish it as a state-of-the-art facility provider as it faces some key challenges. Some key challenges that Indian warehousing players confront are briefly discussed below.

Strategic challenges:

Infrastructure: Indian warehousing industry lacks good quality national highway network, interstate roads and congestion free city roads and multi-modal transportation network. Organized sector have minimum stake so far in this domain and acquire about 8% of the total warehousing space available. The industry is largely unorganized, fragmented and dominated by small and medium players with lower capacities, poor proximity with the national highway network, interstate roads, airways and sea routes.
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**Availability of land:** Re-classification of land by the Government and its procurement policy towards this sector was a major hindrance towards its development.

**High cost of credit:** Being largely dominated by the unorganized sector, banking access and timely credit at a reasonable cost is not adequately provided and face high transaction costs for loan appraisal.

**Fragmented market:** Economies of scale could not be achieved as this sector is largely dominated by unorganized sector comprises of large number of small players with modest capacities spread across India. Cold chain requires consolidation of larger fleet sizes and very big warehouses which remain untouched to the organized sector yet.

**Power outages:** Power outages are a major concern for cold chains results in large amount of agro based products' wastages in India. The ever-increasing cost of electricity adds further to the warehousing operation cost.

**Higher costs due to long transit time:** Lack of proximity to demand-supply hub and poor infrastructure causing longer transit time also increase transportation costs. This leads to the emergence of mini-warehouses distributed across locations thereby defeating the purpose of capacititated distribution.

**Government tax policy:** The existing complex and uncertain nature of tax structures and delay in the implementation of goods and services tax (GST) discourage many players to establish big warehousing industry at par with the developed countries.

**Operational challenges:**

**Stand-alone identity:** Though warehousing is a vital stage of a supply chain, so far warehouses are structured on a standalone basis ignoring its functional alignment with other members. These warehouses are just unable to integrate with others for visibility which negatively impacts its value-based service performances.
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Availability of skilled labor: The warehousing working environment was not lucrative and attractive enough for the young skilled persons. This sector could not operate warehouse management software due to lack of trained personnel.

Lack of IT penetration and resulting process inefficiencies: Indian warehousing sector are handicapped with low technology levels. Poor real-time visibility during manual inventory operations, large paper work induces process inefficiencies of the warehouse industries and lacks competitiveness.

Lack of expertise in warehousing technologies: Indian warehousing sectors confront lack of expertise in warehousing technologies. They simply have the habit of ignoring standard operating procedures while storing, picking, packing and monitoring inventories causing spoilages and higher pilferages.

Slow rate of automation: Indian warehousing sector is still slow in adopting automation for storage and material handling equipments.

1.8.6.2. Opportunities and prospects of Indian warehousing industries

Steady growth of Indian economy (around 7.5 %), globalization, implementation of long due tax reform (GST, 2016) and emergence of better and faster transportation facilities (golden quadrilateral, dedicated freight corridor etc.), India is perfectly poised to take a center stage in global economy. Proactive Govt. policies have taken many initiatives e.g. Make in India, Digital India program to augment it further by allowing the foreign direct investment for the fulfillment of demand of the emergent and affluent Indian middle class market. When world economy slowing down, India stood first in attracting FDI (31 Billion USD) even beating China (29 Billion USD) and U.S.A. (28 Billion USD) in the last financial year. All these are the result of the large scale entry of the international retailers and manufacturing giants. India, being the major source of talented and skilled youth (65% of Indian population are below 35 years), has a potential to emerge as a
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manufacturing hub. The market dynamics aligned with large customer demand likely to witness consolidation and hence large capacity warehouses. These developments would certainly drive for the value based warehouse services that require specific skills includes picking and packing, inventory management, processing, assortment, postponement, uses of material handling equipments and controlling of warehouse management. Major critical drivers e.g. ever increasing customer demand, larger volumes of products, responsiveness from the service providers, increased stock keeping unit (SKU) complexity are behind the urgent development of warehousing sectors to the world level. Though opportunity knocks Indian warehousing sector, it is still at its infancy where the transformation from mere storage to logistic centre excellence has just started. Government has taken many initiatives for the speedy growth of the logistic sector.

**Introduction of GST:** It incorporates uniform tax regime throughout the country that brings rationalization of bigger warehouses. Introduction of GST, destined to revolutionize the entire Indian warehousing sector. This reform would enable the producer to store and allocate goods across the country without any state boundaries.

**Tax breaks/incentives:** Various tax breaks and incentives are provided to the investors and operators so that the organized sectors are pulled as logistic service provider (LSP).

**Supporting 3P models:** Govt. actively supported privatization, private-public-partnership (3P) models in the key infrastructure project for its warehousing sector development.

**Govt. Spending:** Government is directly investing in a very large scale in this sector to improve its warehousing infrastructure to attract the foreign investors.

**Global collaboration:** Collaboration among the developed countries remains the new untapped opportunity to increases the competitive advantages in Indian warehousing industry. Industrial collaborative framework with human behavior and culture as the
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central theme would push the technology decisions in this sector to increase its productivity. This would certainly enhance the firms’ capability to respond to customer and market demands quickly and effectively. A global business collaboration concept to improve Indian warehousing sector is shown in Fig. 1.40.


Promote skill development: The National Skill Development Corporation (NSDC) could play an important role in promoting skill development and arranging vocational training for the workforce. NSDC could advance private partnerships to bridge the skill and talent deficit in Indian warehousing sector.

Developing Free Trade Warehousing Zone (FTWZ): Free Trade Warehousing Zones (FTWZ) were established by the central government to develop infrastructure to facilitate export and import (EXIM) of products and services with unrestricted business transactions with free currency. These zones are located close to dry ports, seaports, airports or, to be easily connected by rail or road. FTWZ are de-facto foreign field to carry on business activities and are visualized to be used as international trading hubs. The minimum area of land required for development under FTWZ is 0.1 million Sq.m., where 100% FDI is allowed.

Logistics parks: A logistics park is a specified territory that facilitates national as well as international business by providing facilities such as cold storage for agro based products, other warehousing, multi-modal transport facility etc. Logistics parks facilitate loading and unloading of cargo for distribution, redistribution, and packaging and repackaging. These territories are established near emerging business/industrial hubs such as Mumbai, Chennai, Kolkata, Hyderabad, Bangalore, and NCR. Industry-specific logistics parks are being constructed such as agriculture, automobile, electronic hardware, pharmaceuticals, and aero industry. These parks are being connected through golden quadrilateral, dedicated freight corridors having multi-modal transport facilities. Logistics
parks are almost similar to FTWZs with the exception that it could accommodate the domestic market.

**Promoting Digital India concept**: Application of information technology and knowledge infrastructure in collaboration with the global giants *e.g.* Google, Face book, Microsoft etc., could provide a boost to the growth and maturity of warehousing players in India.

All the above initiatives would lead the Indian warehouses to grow, compete with the world market and enable them to supersede and sustain the competitive edge in a global supply chain scenario.

![Fig. 1.40 A global business collaboration concept to improve Indian warehousing sector](http://www.genpact.com)
1.8.6.3. Major warehousing hot spots in India

Over the last decade, India has seen a continuous growth in warehousing industry to meet national as well as global business requirements. Different activities in development of warehousing hubs are described below.

- **Classification of Indian warehousing hubs**

Many organized and unorganized sectors of India have developed suitable and customer friendly warehouses in different locations throughout the country. These warehouses build their specific hub in relation to the particular requirements, features and locations. These hubs could be categorized as Front runners, Challengers and Newcomers. The specific features and their site locations of the different warehousing hubs are described in Table 1.6.

Table 1.6. Classification of major warehousing hub in India

<table>
<thead>
<tr>
<th>Class</th>
<th>Specific features</th>
<th>Site location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front runners</td>
<td>Current logistic hubs, major Metros with very large consumer base and tremendous connectivity, Skilled labor availability are high with formidable managerial workforce.</td>
<td>Mumbai, Chennai, NCR, Bangalore, Kolkata, Pune, Hyderabad.</td>
</tr>
<tr>
<td>Challengers</td>
<td>Emerging towns connected by well built roads and new corridors would connect them very soon, Proximity to ports, combined with rural and urban consumers, companies like them, Skilled yet less costly workforce.</td>
<td>Chandigarh, Surat, Ahmedabad, Kochi, Vishakapatnam, Nagpur, Guwahati.</td>
</tr>
<tr>
<td>Newcomers</td>
<td>Major tier-II towns, High labor availability but low managerial workforce, connected to infrastructural projects, and large development activities. Currently not favorable to logistics activities.</td>
<td>Lucknow, Vijayawada, Comatore and Jamshedpur.</td>
</tr>
</tbody>
</table>

Source: The warehouse Hand Book (Miebach Research), Miebach Consulting India Pvt. Ltd.
• **Divisions of warehousing industries**

In tune with the India’s growth story and huge foreign direct investment, rapid industrial growth is imminent. Every supply chain of an industry took it as an opportunity to be more competitive and customer centric by providing them greater satisfaction level. Modern warehouses now have become crucial linkages throughout the supply chain. Warehouses are no more a storage space of yesteryears but have converted itself as overall supply chain solution provider, emerged as warehousing industry. Warehousing hubs integrated themselves into warehousing industry for better coordination and operating itself in effective and regulated way. The Indian warehousing industry is again largely categorized as Laggard, Leader and Niche according to the business environment they face. These divisions of the Indian warehousing industry with respect to different business features are described in Table 1.7.

**Table 1.7. Division of the Indian warehousing industry**

<table>
<thead>
<tr>
<th>Segment</th>
<th>Laggard Type I</th>
<th>Laggard Type II</th>
<th>Laggard Type III</th>
<th>Leader</th>
<th>Niche</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Storage space in systems</td>
<td>Only floor storage</td>
<td>Decks /floor storage</td>
<td>Block storage</td>
<td>Racks/ hybrid storage</td>
<td>Dense racks /hybrid/ auto-mated storage</td>
</tr>
<tr>
<td>3. Height of warehouse (m.)</td>
<td>5 - 6</td>
<td>5 - 6</td>
<td>5 - 6</td>
<td>8 - 9</td>
<td>12 - 16</td>
</tr>
<tr>
<td>4. Area (sq. meters)</td>
<td>1,000 - 2,000</td>
<td>1,000 - 2,000</td>
<td>2,000 - 5,000</td>
<td>5,000 - 10,000</td>
<td>10,000 - 30,000</td>
</tr>
<tr>
<td>5. Power availability</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Very Low, not readily available</td>
</tr>
<tr>
<td>6. Implication for Investors</td>
<td>Cost based segment, not lucrative for new investors or service providers</td>
<td>SMART warehouse and preferred choice of many companies</td>
<td>Would be SMART warehouse of the future, currently only build-to-suit.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: The warehouse Hand Book (Miebach Research), Miebach Consulting India Pvt. Ltd.
Recent investments to logistic parks

Conventionally, warehouses are built by the manufactures themselves. Nowadays, many logistic services provide (LSPs) have joined the logistic industry realizing the benefit of industrial boom. Even the central/state government at national as well as regional level is interested in building different logistic parks at a particular location to avoid traffic congestion and boost business activities. Many logistic parks have already come up to develop standard warehouses to meet the business requirements of different industrial sectors. As fast growing warehousing sector are most sought after in supply chain perspective and have a huge potential of revenue generation, it has attracted many national/global investors to invest their money. Recent investments by different logistics company to Indian warehousing sector to get better rate of return is shown in Fig. 1.41.

**Fig.1.41. Recent investment in Indian warehouses** by different Logistics Company (Source: The warehouse Hand Book (Miebach Research), Miebach Consulting India Pvt. Ltd.).
Post-GST consolidation of warehouse hubs

While large investment is attracted towards the Indian warehousing industries, Government also came forward to make some industrial friendly regulations e.g. FTWZ, GST etc. to promote ease of doing business. A possible implementation of GST would certainly change the whole business scenario of India. A large impact would also be seen in Indian warehousing industries where warehouses consolidates themselves to a limited favorable sites instead of remaining in scattered fashion elsewhere as shown in Fig. 1.42. Modern warehouses then start operating as consolidation center for different locations for handling multiple functions e.g. cross docking, sorting center, assembly facility provider etc.

Fig. 1.42. Probable pre and post GST change in Warehouse network in India.
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1.8.6.4. Automated warehouses- SMART warehouse, a future warehouse of India

**Scalable (S):** A smart warehouse is designed to handle sudden changes in demand. Scalability is often dependent on the warehouse management software chosen. A state of the art software as a service (SAAS) could be helpful in easy attainment of scalability. Customers are interested for complete warehouse solution about their required amount of products and services in a cost effective manner with higher SKUs complexity. They would like to get better consolidation of facilities in a warehouse hub to avoid migration from one place to other for a longer duration.

**Mechanization-compatible (M):** In order to handle larger volume and complexities of products, supply chain managers agreed in principle to make their warehouses completely automated very soon. Warehouses should be run by warehouse management software like ERP etc. to increase the throughput rate and multimodal roles of modern logistic centers. Warehouses are to be built with sufficient quality floor space, column pitches, availability of adequate power supply and equipped with many charging points.

**Accurate (A):** Customers want defect free warehouse operations today. The role of a warehouse is drastically changed from mere simple store keeping to complicated multi-steps approach for value added timely distribution with least spoilage and pilferage. Modern warehouse design should opt for adequate lighting arrangement, quality assurance systems, pilferage control, fire safety measures and vocational training to the staffs for following standard operating practices.

**Responsiveness (R):** Today’s warehouses need to be more responsive to meet the customer’s requirement as and when they demand. Infrastructure has to be suitably designed for extremely fast and fresh service for customers. Warehouses need to train and retain the staff to promote responsiveness. A skilled work force with better working conditions and attractive employment benefits could be the foundation to achieve responsiveness.
Transportation-friendly (T): Warehouse infrastructure should be designed in such a way that it could be conducive to the multi-modal transportation, for containerized loads, of longer trucks and trailers, automated material handling equipment for loading and unloading. Parking space, sufficiently wide roads for turning for trucks and large trailer and adequate facilities for the driver should be provided.

Hence, a go-down of yesteryear has to be radically transformed itself to SMART logistical warehouse center of excellence for India’s sustainable development.

1.8.7. Warehouse performance evaluation: a key management decision making aspect

Rapid industrialization and globalization necessitate warehouse operations to be constantly being upgraded and revolutionized. With better tax reform like GST, warehouses would get consolidated at few specific places in India rather than being distributed almost in each state. Warehouses grow larger in size and it becomes imperative that they require better infrastructure, technology and processes. Business communities are now looking at developing centrally automated fewer warehouses. Fewer large warehouses could be designed for improved efficiency and ease of tracking. Warehouse location decisions are very crucial and have a strategic impact on the organization. Once a long term decision is taken and implemented, it is very expensive to simply close that facility or relocate to other place. A suitable location decision may be responsive enough and at the same time less costly. On the other side, wrong location selection would be less responsive as well as inefficient, unable to meet competitive strategy of the organization. Appropriate warehouse location assists the management to respond quickly to the demand of the end users. It reduces the supply chain risk and uncertainty, lowers the prices of a better product and improves the customer service. All these strengths and weakness indicate the strategic significance of warehouse location selection that deserve the attention and interest of the industrial management. In respect to the above mentioned views, it is paramount to assess, evaluate and select the warehouse location at a strategic level. Even after the implementation of the warehouse design decisions, periodic performance evaluation of
those decisions should also be carried out under dynamic industrial background. It could be a continuous process. The pitfalls of the pre-implementation phase warehouse decisions are considered as valuable inputs in modifying and simplifying the overall decision making process that could act as an effective aid to the industrial managers.

1.8.8. Conventional warehouse performance evaluation/location selection criteria

A company considers a set of requisite and relevant performance evaluation criteria for its warehouse location selection. The nature of these criteria could be strategic, macro-economic, technological, political, social, environmental, infrastructure, competitive, logistical and operational. These conventional selection attributes are very influential in warehouse network design decision. These factors are described in detail.

**Strategic factors**

Every organization has its competitive strategy in place to sustain in highly competitive market scenario. This competitive strategy has an immense impact on the supply chain design decisions. Firm focusing on efficient frontier targeting cost leadership in the global market would find the lowest cost location though it may be far away from the customer base. On the contrary, responsive firms always locate a place near to the customer at a higher investment to meet the customer’s ever changing demand quickly. Convenient store locations always provide easy access to the customers as part of their strategy. Global supply chain provides the locations in different countries in line with their competitive strategy. For the sake of example, Nike has production facilities at China and Indonesia aiming low cost shoes fulfilling the efficient strategy. They got Taiwan as their shoe producing facility keeping in mind for the high cost shoes operating on responsive frontier. It is very important for any company to set its strategy first and design the facility according to that. Ferdows (1997) explained the possible strategic roles for different facility locations in a global supply chain design. They are described below:

- Offshore facility: These are the export oriented low cost supply source to the markets located outside the country. In Asian developing countries, it
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gets cheap labors and other low cost benefits to facilitate low cost production.

- Source facility: It is primarily a source of low cost production facility for the total global markets. They are offered with cheap labor, skilled work force and good infrastructure facility. After experiencing in low cost production, off shore facility would become a source facility.

- Server facility: It is essentially a regional production facility to avail tax incentives, local requirement tariff barrier etc. Maruti Udyog is set up at 1970 in partnership with Suzuki as a server facility and built cars for India only.

- Contributor facility: After some years, a well managed server facility with the capacity for product customization, process improvements, product modification etc. changed to contributor facility. Maruti facility in India nowadays produces cars for both India as well as outside world markets.

- Output facility: These facilities are primarily located to a region (say, Japan), well known for its special skill or knowledge level pertinent to production, ignoring even the high operating costs there. These facilities are utilized to tap that special skill for the entire global supply chain.

- Lead facility: These facilities with enriched/skilled work force, superior technological know-how are able to produce new products, process and state of the art technologies for the entire supply chain.

Technological aspect

Supply chain facility design depends a lot on the grade of available technological state-of-the-art. If the production technology promotes economies of scale; a high capacity facility can be designed with larger investment. For largely inflexible production technologies, region wise different product requirements, number of small capacity facility might be built with smaller investment. Sometimes, facilities with lower fixed cost also go for more number of facilities regionally to avail lower transportation costs.
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Infrastructure

Important elements under infrastructure attribute are availability of land for the site, proximity to transportation terminals, rail, road, airways, sea ports, highways, political stability and local culture etc. Warehouse location largely depends upon the availability of better infrastructure in a given region. Good infrastructure leads to ease of business whereas poor infrastructure adds up the cost doing business in an area. Global companies mostly located their facilities in Shanghai, Guang Zhuo zone of the republic of China due the availability of high grade infrastructure in spite of facing high cost of land and labor. Infrastructure also deals with the basic mode of transportation and communication system prerequisite for the location. This criterion is divided into three sub-criteria: existence of modes of transportation, telecommunication system and quality and reliability of modes of transportation. Speedy transport facilities ensure timely supply of finished goods to the customers. Choice of transport mode and the location will depend on relative costs, convenience, and suitability. Application of telecommunication increases the coordination among the suppliers, producers, and the customers. Quality and reliability of modes of transportation ensures the timely delivery of the goods at the appropriate locations from and to the warehouses in safe manner.

Markets

Markets indicate the distance of the warehouse location from the customers, suppliers, and the producers should be minimum. Proximity to customers implies the fulfillment of its requirement at an early time. Supply time of raw materials or finished products to the warehouse decreases due to the proximity of suppliers and producers. Lead time is the time between placing an order and its receipt whereas responsiveness is the ability to deliver the right product at the right time.

Labor characteristics

Labor characteristics may be defined as the requisite type of labor and their availability for a particular job that governs the warehouse location to a major extent. Importing labor is costly and involve administrative problem. Skilled labors are the trained, efficient, and
Qualified workers for specific purpose. Availability of adequate number of skilled labor varies with location.

**Political stability**

Political Stability means stable political decisions or political change in that region. It ensures the government aids and subsidiaries, favorable industrial policies which attract the attention of many new entrepreneurs and vitally affect the location selection.

**Competitive cause**

During facility design decision, company must think about the competitor’s strategy, size and location in a given situation. A company should pay attention whether they would locate their facilities near or away from their competitors. External factors e.g. availability of raw materials, power requirement etc. sometime influence them in considering a particular decision. Positive aspect of staying near to each other based on collaboration (live & let live) as seen in modern shopping mall, gas stations, and retail stores, increases the demand of the customers, benefitting all. It also leads towards the development of right infrastructure in that area. Sometimes, a firm would also like to capture the market share to a greater extent by staying near to each other as well as to the customer base.

**Delivery time**

Delivery time to customer is another important factor while selecting warehouse location. If customers agree to wait for longer duration for certain product/service, firm can focus on fewer locations with large capacity. On the other hand, a firm targeting a customer segment with shorter response time will go for more number of suitable facility locations with lesser capacity. Thus increase in delivery lead time reduces the number of facilities and vice versa.

**Macroeconomic**

Costs are the sacrifice of resources. It may or may not be in monetary units. It has the major impact over the selection of the warehouse location. Some parts of the cost criteria
vary little with change in locations. The important part of the cost criteria which differ from region to region are labor costs, transportation costs, tariffs, tax incentives and tax structures, financial incentives, and handling costs. Labor costs vary as per the living condition of the region and the location should be towards the centre of cheap labor source. A transportation cost consists of two basic elements: total weight to be transported at the locations and distance to be covered from the location. Cost of transportation should be at the lowest. Transportation cost depends upon the availability and modes of transportation viz. rail, road, water, and air etc. Tax incentives and tax structures vary based on the regions that have priority in development. The credit incentives by the state or private banks, which can be called financial incentives, are realized in various regions (free trade zone). Handling costs incurred due to the storage and the maintenance of goods in a warehouse which involves working capital, man power etc.

**Macro environment**

Macro environment involves the policies of government, industrial regulations laws, and zoning and construction plan of the location to a large extent. In order to have a balanced regional growth, the policies of the governing authorities offer the package of incentives in the form of sales tax and excise duties. Industrial laws, policies and arrangements are relaxed for the location in a special economic zone (SEZ) to implement a development plan.

**Environmental issues**

Nowadays environmental issues are no longer an issue of the environmental experts alone but being treated with utmost attention while considering facility decisions within or outside a country with a special concern for industrial sector. Some of the key elements of the environmental issues are restriction on the use of chemicals, cleaner production, and emission of green house gases, corporate social and environmental responsibility, and pollution control etc. This factor is aggressively followed while developing a facility design framework to facilitate green supply chain management (GSCM) formulation and implementation.
All the above mentioned parameters are considered judiciously while choosing a warehouse location. Now, warehouse performance evaluation could be adjudged by considering the relevant parameters in a logical scale. Some typical combination of parameters for evaluating a warehouse location within a logistic warehousing hub is shown in Fig. 1.43.

![Parameters in a scale of zero to Ten.](image)

**Fig 1.43. Typical warehouse evaluation parameters in (0-10) scale.**

### 1.8.9. Traditional models utilized in warehouse location decisions

Keeping in view of the profitability for a firm while making warehousing design decisions, the decision makers must possess some vital information with them. The information regarding potential location alternatives, suppliers and markets destination, demand forecasting and the relevant costs are essential for making warehouse design decisions. After acquiring the relevant information, supply chain managers might utilize gravity location models and network optimization models for making the strategic design decisions in their firm.

**Gravity location models:**

Gravity location models used to select the facility location based on least transportation costs between the supplier to production site and from production facility to the market. The fundamental assumptions of the model are listed below:
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- Supply site as well as markets is considered to be located as grid points on a plane;
- Distance considered is the geometrical distances between those two points;
- Transportation cost varies linearly with shipped quantities.

Network optimization model:

A supply chain network comprises of various stages which includes supplier, factories, warehouses, distribution centers, retailers and the markets with some intermediate facilities. Besides location, allocation of inventories from supplier to warehouses and warehouses to plants are also to be considered together. Total supply chain cost incurred may be categorized as fixed costs and variable costs. Fixed costs do not vary with the quantity produced whereas variable costs of inventory, transportation varies with economies of scale. This model assumes that all the variable costs vary linearly with quantity of products produced. This model decides a facility design based on minimization of total cost.

1.8.10. Limitations of utilized models and its practical approach in warehouse location decisions

Warehouse location decision in a supply chain is a long term strategic one and is likely to stay intact for several years after installation. The major selection criteria for the facility design decision e.g. demands, cost, price, tariffs, exchange rates and other macroeconomic criteria would definitely fluctuate considerably due course of time. It is paramount to consider this uncertainty while making supply chain decisions. This type of decisions should not be counted for a specific timeframe or for some specific future. Future scenarios can be generated through simulation and a lot of uncertainties might be accommodated by deciding a flexible capacity centered supply chain. While making a facility decision, supply chain managers should follow a practical approach meticulously. They are pointed out below:

- Pay attention to the life span of the facility;
- Focus on tax structures, tariffs and exchange rates carefully;
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- Adhere the quality of life standard of the employees;
- Pay special attention to cultural condition of that local vicinity etc.

Hence, decision support framework for warehousing in a supply chain should be counted as a viable option within the given the scenario.

1.8.11. Need for development of decision support framework in warehousing strategy

In spite of having huge strategic dimensions warehouse location selection has no structured or programmed process (Coyle, Bardi, and Langley, 2003; Simchi-Levi, Kaminsky and Simchi-Levi, 2003). Non-programmed decisions are often unique, ill-structured and at the same time, have immense impact on the organization. In many real life problems, human beings prefer subjective to objective assessment of vague, ambiguous and imprecise data. In a complex industrial scenario, sometimes, objective factors along with crisp sets are unavailable, insufficient and inadequate, subjective assessment is employed for the evaluation of the decision variables. According to Simon (1960), these non-structured decisions are made through creativity, judgment of opinions, rules of thumb and holistic techniques, fall under management science domain.

While making warehousing decisions strategically, utmost attention is paid to consider the importance of warehouse and its role in overall supply chain. Warehouse design decisions could not be made alone as it affects the other supply chain drivers also. Warehouse might be considered as a logistic service provider (LSP) to the other stages of a supply chain. A strategic warehousing decision becomes the constraint factor even for its subsequent tactical and operation level decisions to follow. The supply chain variables as an indicators itself at various decision level hierarchy are also to be accounted while making warehousing decisions. For example, performance level of a warehouse also could be adjudged at floor/operational level and evaluate its efficiencies and effectiveness. Information of inefficiencies at the operational level could be the inputs while making decisions at the strategic level. Consequentially, a decision making process could be termed as two-way interaction (Nollet et al., 2005).
Decision support systems synchronize and integrate the supply chain drivers, warehousing decision variables and the levels of decision hierarchy. It points out the positive and negative aspect of the present supply chain, a gap analysis carried out for optimal decision making. This optimized warehouse decision design would effectively support the competitive strategy of the organization. Hence, DSS acts as a guide/road map in simplifying the decision making process and helps to build a benchmark strategy in improving customer satisfaction level thus sustain and augment its competitive advantages effectively.

1.8.12. Classical approach of developing a decision support framework (DSF)

The concept of decision support has evolved primarily from two main research areas: one related to the academic studies of organizational decision making during the late 1950s and early 1960s and another on the technical work on Technology in the 1960s. Decision support system (DSS) evolved during the 1980s, became a huge source as an aid to the supply chain managers to solve different decision problems. A participatory decision support framework integrates academicians, researchers, developers and local users perspectives enabled with information technologies to make right decision. The flow of information between decision processes must be analyzed to achieve accurate output and a decision support framework be modeled for implementation. A decision support framework (DSF) could be developed in a manner as described in sub-sections below.

1.8.12.1. Decision defined

According to R. Hoffman, the source of the word decision comes from the Sanskrit vocabulary khid’ati meaning to “tear”. The English dictionary gives the meaning as the passing a judgment to an issue under consideration. Decision is also the convolution of constraints and goals. Decision support is the means of assisting decision makers in making a decision.
1.8.12.2 Concept of decision support framework

According to Simon (1960), a decision support process could be broadly divided into intelligent phase, design phase, choice phase and review. For intelligent phase, a decision maker(s) need to follow efficient methods to identify the circumstance under which a decision is to be made. Decision makers need to pay utmost attention to visualize and define the surroundings effectively. In design phase, decision maker utilize the effective ways to establish, evaluate and analyze the possible courses of feasible alternatives. The choice phase also utilizes various means to assess the impact on the considered alternatives and select them in accordance with that degree of impact. In review phase, decision makers used to go for realistic assessment of the just concluded decision taken. Out of the four, design phase gives the most difficult time to the decision maker(s) as it evaluates and analyzes among a set of many possibilities. In all the phases, decision maker(s) need to follow effective methods to make the accurate decision.

DSS/DSF is a manager-computer interactive information system which is capable of making accurate and effective decisions within or outside the organization in a given situation. It utilizes relevant decision theories, optimization models, and appropriate database along with the decision maker’s own expertise, results in effective, accurate and implementable decisions. A decision support framework thus assists the organization management in making decisions and augmenting its effectiveness in a complex problem solving environment. Generally, a decision support framework is built keeping in view to users, their specific needs and requirements, the type of organization and its operating environment in making a rational decision. The goal of a DSS/DSF is to empower the decision makers with subjective and objective based tools to explore and augment the space of feasible alternatives for a set of accurate and realistic decisions. A decision support system can be classified as (a) a model-driven DSS (b) a communication-driven DSS, (c) a data-driven DSS, (d) a document-driven DSS and (e) a knowledge-driven DSS.
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1.8.12.3. Phase wise development of decision support framework

Based on the competitive strategy of an organization, its supply chain strategies are aligned. While developing a decision support framework for warehouse strategic decision, it is also essential to make it mandatory for its different consequential phases to be in response to the same. All the phases are supported with suitable and efficient decision making approaches in liaison with human expertise under a given set of environmental condition. Phase wise decision making approaches are described below.

- **Intelligent phase:** Problem arises due to instability around the surrounding. Major sources of the instability might be recognized as political pandemonium, environmental exigencies, social satisfaction entropy, and technological state of the art. The gap gradient between the ideal/equilibrium state and their practical counterpart is needed to be minimized which actually defines the problem in a given circumstances. This problem throws a challenge to all its inhabitants/denizens. Human beings being the prime constituent of this universe and socially active, take up that challenge. For example, a mismatch always exists between a sudden demand and its responsive supply which is one out of many real hindrances to achieve competitive strategy for any warehouse design. A firm forms a decision making committee comprises of experts from diverse domain, set a specified objective to solve that problem. These human experts by virtue of their superior cognitive thought process identify some suitable and feasible alternatives from infinite possibilities. They also recognize various requisite and relevant selection criteria. The decision makers carry out extensive studies from the available resources and prepare data pertaining to both the alternatives’ ratings as well as criteria weights. The rating of the alternatives are assessed by the expert’s opinion, Simple multi-attribute ranking technique (SMART) approaches etc. in a given situation. The weights of the criteria could be ascertained through expert’s opinion, entropy principle, pair wise comparisons among the criteria of analytical hierarchy process (AHP); analytical network process (ANP); statistical variance approach etc. Popular subjective weighting approaches are direct rating, point allocation, Delphi
method, Simple multi-attribute ranking technique (SMART) and SIMOS methods. Similarly different objective weighting approaches utilized are Principal component analysis method, Optimization methods, variation coefficient approaches etc.

- **Design phase**: Most difficult and decisive phase in a decision support framework is to evaluate and synthesize the feasible alternatives by different suitable decision making approaches under the given condition. Applied decision making approaches may be quantitative, qualitative or the combination of both. Decision making under both certainty and uncertainty might also be utilized for performance evaluation of the different alternatives. Some elementary approaches are based on the theory of dominance, Maximin, Maximax, Linear assignment, Additive weighted method and weighted product approaches etc. Other popular approaches e.g. AHP, ANP, MOORA, TOPSIS, ELECTRE, PROMETHEE, VIKOR etc. are frequently utilized in this phase to evaluate the alternatives.

- **Choice phase**: According to the resulting impact of the set of alternatives, the suitable selection is made. Ranking and selection is made on the basis of higher the better, lower the better or even nominal the better logic of the algorithm of the said approaches.

- **Review phase**: Developing decision support framework is a continuous process. It is paramount to assess the selection made. Even the pitfalls of this phase are considered as a valuable input in modifying the intelligent phase. Thus a decision support framework is aimed at simplifying the overall decision making process and increases its effectiveness.
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1.8.12.4. Decision making environment under certainty and uncertainty

Decision making is the process of recognizing the problems with opportunities and choosing the suitable option among the available feasible alternative actions to solve them successfully. Generally, decisions are made in three situations. These situations are described below:

**Decision making under certainty:** Decision maker has full and relevant information to make a decision with some quantitative approach. DM(s) have enough clarity regarding the circumstances, the nature of the problem and possible alternatives to get the solution. They exactly know about the outcome of the process. Break even analysis, benefit cost ratio, calculus or even mathematical programming techniques e.g. linear, Non-linear, integer, dynamic and goal approaches are utilized in making decisions. Reorder point in deterministic inventory control system is a suitable example for this situation.

**Decision making under risk:** Decision makers have some information, but it might not be enough to get the solution exactly and hence the chances exist regarding the expected outcome. DM could not assure fully how the suitable alternative would work in future. Terrorist encounter in a residential area could be an example of this type of situation. Statistical approach such as objective and subjective probabilities, analysis of variance, correlation and regression analysis; Simulation, Decision trees, heuristic approaches are utilized to make decision with risk involved.

**Decision making under uncertainty:** Decision makers have imprecise, partial or even no information to get the outcome. DMs could not provide even the subjective based outcome. Most of the input information is ambiguous, vague and ill defined. Leaving the house or not in a sudden flood situation might be a typical example for the same. Game theory, Coin flips, fuzzy set theory, genetic algorithm approaches are utilized for making decisions under uncertainty. The above mentioned three categories under which decisions are made is shown through Fig. 1.44.
1.8.12.5. Decision made: Application of human cognitive mind

A decision making approach takes the advantages of cognitive navigation of human mind. Environmental requirements are the source of a decision problem. Realizing the importance, human brain compares themselves to evaluate the degree of expertise in relation to other experts. Using the sense organs of the human body, the brain preliminarily identifies the feasible location alternatives as well as the tangible and intangible selection attribute/criteria. These human experts with higher level of domain knowledge assess the ratings of the alternatives. The cognitive brain also appropriately assesses the weights of the criteria for the better perception of evaluation procedure. Thereafter the brain, with the mental abilities of judgment, evaluation, reasoning, comprehension and computation, develops a new method or modifies an existing suitable methodology. Consequently, the cognitive process of the individual decision maker of the committee is navigated to the domain of real/environmental phenomenon in order to provide an appropriate solution to the decision problem. Cognitive navigation related to the decision problem, currently related to warehouse location selection in a supply chain, is pictorially depicted in Fig. 1.45. Many decisions making methods have been developed and illustrated by earlier
researchers related to various case studies in supply chain perspective as described in the next sub section.

Fig. 1.45. Cognitive navigation of an individual decision maker.
1.8.13. Fundamentals of fuzzy set theory utilized in decision making

While making decisions in a real life industrial scenario, decision maker(s) face paucity of information. Most of the time information is inaccurate, imprecise or even partial and subjective. Eventually, the decision making environment become fuzzy. Bellman and Zadeh (1970) were first to propose the decision making techniques in fuzzy environment. The fundamental concept of fuzzy set theory (Appendix A) when applied in multiple criteria decision making environment is called fuzzy multi criteria decision making (FMCDM) approach. The FMCDM approaches can assist decision makers in evaluating, ranking and selecting the best alternative in fuzzy environment. Human beings prefer subjective to objective assessment of vague, ambiguous and imprecise data and express it linguistically. Linguistic variables (LV) are words, phrases or sentences in a normal or simulated language (Chen, Lien, Tzeng and Yang, 2008). The words or phrases like good, very good, poor, medium, very poor etc. are called linguistic variables which are measured by human perception, feelings, experience etc. These are reasonably employed by researchers in the complex situations that are hard to define and calculate with conventional methods (Zadeh, 1975). Linguistic variables representing weights as well as ratings are converted into equivalent triangular fuzzy numbers (TFNs), Trapezoidal fuzzy number (Tr. FN), interval numbers or even range etc. (Zadeh, 1965; Zimmerman, 2001).

Researchers more often use TFN due to its simplicity, ease of use, capability of transforming linguistic variable into fuzzy number and its successful application in fuzzy environment by the past researchers. Fuzzy number could be defuzzified into a single/crisp value with some defuzzification method (Opricovic & Tzeng, 2007). Center of area (COA), Mean of maximal (MOM), and $\alpha$-cut methods are generally applied for defuzzification purpose. COA method of defuzzification is an easier and realistic approach without the need to bring in the preferences of any evaluators (Wu, Tzeng, & Chen, 2009). Application of fuzzy set theory helps the decision makers to formulate the real complex fuzzy environments, interpret and express it through fuzzy numbers and provides simplified way of solving the decision problems by defuzzification concept.
1.9. A typical decision framework for supply chain facility (warehouse) design

Theoretical aspect of decision support framework is studied in detail. The same concept is utilized while evaluating warehouse performances. Before illustration of the same numerically, it is essential to highlight the different phases of a typical framework for warehouse design decision. Schematic block diagram of a supply chain design decision framework comprises of four phases is shown in Fig. 1.46. They are described in detail below.

**Phase I: Supply chain strategy selection**

First of all a firm decides its well defined competitive strategy. To fulfill the set of customer’s need, the firm chooses the supply chain capabilities to be followed. Authority should chalk out whether the customers will be local or of global presence and the nature of competition. Firm should identify the nature of internal constraints to face; design of growth would be based on existing facilities, entirely new or partnership modification.

**Phase II: Define the regional facility design**

In this phase, a firm would identify the region for possible facility decisions based on the forecasting on economies of scale, homogeneous/scattered customer segments. For a homogeneous customer segment, number of facility location should be less with high capacity, would serve many markets. On the opposite side for scattered customer base, it would be useful to design for more number of facilities locations with smaller capacities. Authority should analyze the political risk, demand risk, exchange rate etc. before setting up facility locations. Decisions would be strategically important whether the facilities should be near/away to the customer base.

**Phase III: Sites selection**

The immediate objective of this phase would be to select the number of desirable sites in that region for its possible location. Site selection would be based on the type of infrastructure, availability of skilled/semiskilled work force and community culture etc.

**Phase IV: Selection of site location**

Selection of suitable site location from the available feasible alternatives is carried out to maximize the profitability of the firm.
An intensive study is put forward in this chapter by the author on various aspects of the decision support framework for warehouse performance evaluation in a supply chain. Now
at this juncture it is essential to declare the very need of carrying out this research work briefly under the present industrial background.

1.10. Need analysis of the current research work

In recent years, the business fraternity faces growing complexity due to its fast and rising competitive environment in the global arena. Their supply chain function becomes increasingly important and integrated worldwide. The attainment of sustainability, stability, and survival in that global competition draw constant attention by the business leaders. Under the above mentioned circumstances, unstructured conventional approaches with inherent inflexible attitude and the lack of adaptability of the management can’t solve those issues. The top level decision makers are searching for new key trends driven strategy in a supply chain which has the potential to affect the overall performance of the organization.

Facility location decisions are very crucial and have a strategic impact on the performance of the organization. Once a long term decision is taken and implemented, it is very expensive to simply close that facility or relocate to other place. The location of the facility would make the supply chain strategy either responsive or efficient one. The design of a supply chain network has a strong impact on the overall profitability and success of an organization. To achieve optimized supply chain network, facilities such as manufacturing plants, warehousing, wholesale distribution centers (DCs) and local retail outlets should be strategically located (Coyle et al., 2003; Simchi-Levi et al., 2003). Appropriate warehouse location assists the management to respond quickly to the demand of the end users. It reduces the supply chain risk and uncertainty, lowers the prices of a better product and improves the customer service. All these strengths and weakness indicate the strategic significance of warehouse location selection that deserve the attention and interest of the academic fraternity.

Global competition in the market place has posed a significant challenge to the very survival of the companies. Requirement of technological push in production, enormous pressure to meet the customer’s ever changing demand, continuous flow production, operator’s safety and increased environmental awareness, warehouse operations have been
constantly being upgraded and revolutionized. A global supply chain with shorter delivery lead time to meet the demand makes it imperative for the business community to opt for continuous business solution by strategically positioning warehouses at the right place ensuring its maximum utilization.

While making warehousing decisions strategically, utmost attention is paid to consider the importance of warehouse and its role in overall supply chain. Warehouse design decisions could not be made alone as it affects the other supply chain drivers also. Decision support frameworks synchronize and integrate the supply chain drivers, warehousing decision variables and the levels of decision hierarchy. Hence, DSS acts as a guide/road map in simplifying the decision making process and helps to build a benchmark strategy in improving customer satisfaction level thus sustain and augment its competitive advantages effectively. In view of that, one of the keys is to apply appropriate decision making approaches with relevant information, so that supply chain managers can plan for a tailor made business structure in the future to sustain that global edge. The stability, success and sustainability of any business entity only can be ensured if they follow a constant endeavor

- To attain competitive advantages over the competitors,
- To increase reputation of the organization,
- To attain higher profit and lower cost,
- To keep the desired quality,
- To attain sustainable global leadership,
- To make continuous upgrade of business organization in terms of growth / expansion.

Now, resources like raw materials are always scarce and have the inherent tendency of rapid cost increment, production cost becomes high. Other inputs in the transformation process are also equally costly. The finished product as the output also faces a tough challenge for the increased customer satisfaction. Under the stiff business competition profit tends to be shrunken. In these circumstances, the decision makers in any supply chain are constantly investigating every feasible chance, at upstream, midstream or even at the downstream in all possible ways for better warehouse design decision opportunities.
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Supply chain professionals apply accurate and appropriate decision support aids as a strategic decision making tool to make right warehouse design decisions avoiding risk hazards, promising a lot of saving potential and increased profitability. But the savings cannot be recognized if the random traditional techniques of the past are allowed to prolong. The above mentioned reasons that provide the utmost thrust, current exposure of the purpose and its significance to a novel and tailor made approach for decision making aids for the supply chain managers.

1.11 Outline of the present Research Work

Fulfillment of the above mentioned need necessitates the continuance of research work in development of state-of-the-art warehousing DSFs under supply chain perspective. The outline of the complete research work is graphically represented through a research flow diagram as shown in Fig. 1.47. The complete research work is divided into eleven chapters. Chapter 2 describes the comprehensive literatures survey carried out on past works by different renowned researchers on different aspect of decision support framework for warehouse performance evaluation in a supply chain. A gap analysis is also carried out on the limitations of the works by past researchers that act as the motivation factor of conducting this current research work. Chapter 3 puts forward some relevant research questions, and later clearly states the aims, scopes and objectives of the considered research work. Chapter 4, 5, 6 & 7 include the actual research work done enlisting the different innovative development of decision support frameworks on warehouse performance evaluation by the author. Case studies are conducted to different industrial scenarios in order to revalidate the developed DSFs are placed in Chapter 8. Overall discussion on the research work is mentioned in Chapter 9. Conclusions and future scopes of the research work are presented in the Chapters 10 & 11 respectively. Appendices and references are placed after Chapter 11.
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Fig. 1.47 Proposed research methodology flow diagram.