Block

2

SUPPLY CHAIN PLANNING & DESIGN

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BLOCK 2: SUPPLY CHAIN PLANNING & DESIGN

The expanding scope of supply chain management has brought in the need for its seamless integration. A supply chain is a network of manufacturers, suppliers, distributors, transporters, providers of storage facilities, and retailers. Supply chain covers the entire gamut of lifecycle processes right from receipt of customer order, product development, engineering, manufacturing, testing, delivery, installation, customer support and retirement of the product. Thus supply chain integration becomes a challenging task seamlessly connecting all associated processes. This block addresses these important requirements of supply chain management in an integrated manner. This block has 4 units covering various related topics as detailed below.

Unit 2 is about nature of supply chain integration: supply chain management as practiced across the world embedded a number of new aspects, keeping in view its expanding scope. Superimposed on this is effective integration of the supply chain to ensure efficient supply chain operations to cater to the requirements of the internal and external customers. This calls for understanding methods of supply chain integration taking care of such performance aspects like productivity, customer satisfaction, etc. This unit covers cross functional process integration and external integration, factors driving supply chain integration: increasing customer satisfaction, concept of internal customer, improving supply chain productivity, changing competitive environment, role of organizational and channel support for supply chain integration, elements of supply chain strategy; framework for supply chain integration: understanding the supply chain, evaluating the organization's position in the supply chain, building the supply chain infrastructure for successful integration, create and communicate a common supply chain vision, develop integrative mechanisms, benefits of supply chain integration: increased customer responsiveness, increased supply chain productivity, barriers to supply chain integration: increase in product variety, shorter product life cycle, customer demands, increased outsourcing of the firm's activities and supply chain planning & design

Unit 3, demand forecasting in a supply chain is a very important aspect of supply chain management as it is the demand for a product or service that fuels the supply chain engine. Demand decides every aspect of supply chain to drive planning and execution processes suitably. Thus there is a need to understand the components, approaches, techniques and the factors influencing supply chain. this unit addresses such aspects as objectives & components and approaches of forecasting, demand forecasting process: integrated demand planning and forecasting, major factors that influence demand forecast, steps, customer segments; forecasting techniques: selection of appropriate forecasting technique - time series forecasting methods, static forecasting method, adaptive forecasting; measures of forecast error: mean absolute deviation, mean squared error, mean absolute percentage error; challenges in demand forecasting

Unit 4 is about managing demand and supply in a supply chain. Once reliable demand forecast data is available, operational management has to focus on managing its supply as per specific customer requirements. This necessitates knowledge of various planning methods, techniques and strategies. this unit discusses all these aspects in a cohesive way

covering aggregate planning and its role in a supply chain, process of aggregate planning: aggregate planning problem, aggregate planning strategies (chase strategy, stable workforce, level strategy), aggregate planning techniques (cut and try method, aggregate planning using linear programming); managing predictable variability in a supply chain' decision options in varying supply (managing capacity, managing inventory); decision options in varying demand (demand for the product, product margins, cost of holding inventory, cost of changing production capacity).

Unit 5 is about facility network design. Designing a facility network is one of the important aspects of the supply chain. Retail stores, finished goods warehouses, manufacturing plants and raw material storage warehouses constitute the facilities in a supply chain. Once a facility has been set up, it is difficult to shift to another location or shut down the facility, because of the huge amount of capital that would have been invested in setting it up. Thus, firms must choose locations that not only perform well in the current set of conditions but will also be able to adjust to changes that may take place in the future. Inappropriate facility decisions affect profitability and the very survival of firms. This unit discusses all these issues through the topics of factors influencing facility network design decisions, process of facility network design and models for facility network design and capacity allocation.

Unit 2
Supply Chain Integration

Structures

2.1 Introduction

2.2 Objectives

2.3 Nature of Supply Chain Integration

2.4 Factors Driving Supply Chain Integration

2.5 Role of Organizational and Channel Support for Supply Chain Integration

2.6 Elements of Supply Chain Strategy

2.7 Framework for Supply Chain Integration

2.8 Benefits of Supply Chain Integration

2.9 Barriers to Supply Chain Integration

2.10 Summary

2.11 Glossary

2.12 Self-Assessment Test

2.13 Suggested Readings / Reference Materials

2.14 Answers to Check Your Progress Questions

"Companies are urged to remember that no supply chain exists in isolation. Many supply chains are integrated and a disruption at one point could have knock-on effects for other companies."

- Evan Bloom

2.1 Introduction

The name supply chain itself indicates that, there are many intermediaries in this process having links to each other in sequential/parallel way. These are highly interdependent in delivering and fulfilling the necessary services. Integration of these is crucial for the success of the chain as a whole. The common saying is "The chain is as strong as the weakest link".

In the previous unit we explained the concept of supply chain and supply chain management.

A supply chain is a network of manufacturers, suppliers, distributors, transporters, providers of storage facilities, and retailers. The unit discussed various supply chain management processes carried out across the supply chain. This unit emphasizes the need for adopting the concepts of zero defect and zero effect as a corporate social responsibility to ensure sustainable supply chain management.

In this unit, we discuss the processes involved in achieving effective supply chain integration. We, first discuss the nature of supply chain integration. Next, we examine the factors that drive supply chain integration. Later, we look into the framework required to design and implement an integrated supply chain strategy. We will also examine the elements of an integrated supply chain strategy. Finally, we look into the benefits and barriers for achieving effective supply chain integration.

2.2 Objectives

After going through this unit, you will be able to:

- Explain the nature of supply chain integration
- Identify the factors driving supply chain integration
- Discuss the elements of supply chain strategy
- Examine the framework for supply chain integration

2.3 Nature of Supply Chain Integration

Integration of supply chain has become one of the key success factors for firms. Supply chain integration can be defined as a process of aligning the processes of suppliers, service providers, and customers, the main stakeholders. A well-integrated supply chain can increase efficiency, lead to faster new product development, and improved quality and productivity. For effective supply chain integration, a firm has to develop a framework that enables it to devise and execute an integrated supply chain strategy.

The success of a supply chain depends on the nature of integration that exists between the supply chain partners. There are two key types of supply chain integration- cross-functional process integration and external integration. Cross-functional process integration refers to the integration of the internal functions of the firm. External integration refers to the integration of a firm's operations with that of the supply chain members. This may include: backward integration with suppliers, forward integration with customers, and complete integration or supply chain-wide integration. Many firms start with internal integration and then gradually move towards external integration.

2.3.1 Cross-Functional Process Integration

Cross-functional process integration refers to the integration of the functional areas in the firm. In this form of integration, firms focus on seamless integration of the internal functions such as purchasing, transportation, and manufacturing to fulfill customer needs. Here, the firm aims at achieving a basic level of service standards at the lowest cost. Two techniques can be employed to achieve cross-functional process integration- simplification and consolidation.

Simplification of processes can reduce the time and effort in implementing the processes. One way to achieve simplification is to automate the processes with the help of information technology.

Consolidation is another technique to achieve internal integration. Some examples of consolidation are integration of warehousing facilities to reduce the costs of processing and integration of purchasing across the business units within the firm.

2.3.2 External Integration

External integration refers to linking firm's internal operations with that of the other supply chain members and customers. The focus of the firm is to develop a seamless and synchronized supply chain to effectively fulfill customers' needs. There are three approaches to achieve effective external integration- resource focus, outsourcing, and cooperative planning.

In the resource focus approach, firms have to identify key customer segments and supply chain partners, and focus on developing long-term relationships with them. By focusing resources and efforts on a particular customer segment, a firm can improve customer satisfaction. The firm can identify and design specific programs with the support of its supply chain partners to fulfill customers' orders faster.

A firm can identify its core competency and outsource other activities to supply chain partners, who can perform those activities better and more efficiently. This helps the firm in reducing costs and improving effectiveness in supply chain operations.

Co-ordinated planning aimed at alignment of facility networks, information sharing, joint new product development efforts, and joint promotional activities can increase supply chain efficiency and effectiveness.

Example: Supply Chain Approach at Amazon

Amazon introduced 'Prime service', and promised a guaranteed delivery of their products to the customers within two-days. This was purely based on the innovations in Amazon's supply chain management, which made the company leaders in the marketplace. Amazon supply chain model was built up on well planned integration of the supply chain members, quick and efficient logistics, advanced technology solutions, an extensive warehouse network, layered inventory management, and optimized transportation routing solutions. Amazon had various types of delivery models like: "Prime delivery, one-day delivery, first-class delivery, and free super-saver delivery, etc." Amazon's warehouses were placed so amicably close to the main logistically important areas.

Contd….

This helped Amazon to adopt push strategy and forecast demand for the products placed in Amazon warehouses. The company adopted pull strategy for the third-party seller products, using an order-by-order fulfillment model. The ship time was minimized, by optimizing last mile connectivity from local centers to customers. Amazon maintained huge warehouses, ensuring large inventories.

Amazon installed 45,000 warehouse robots, picking and packing deliveries fast, 24/7 automating the delivery process. Well adopted high-tech strategies, automation and robotization, helped transparent monitoring of inventory status at unit level. Amazon used their branded trailer trucks, for distribution to the warehouse sortation centers, from there items were distributed by most efficient transportation. Amazon used all transport media like: airplane fleet, fleet of trucks, vans, bikes, and even robots for last-mile delivery. Amazon had also implemented drone-based delivery system and planned to introduce self-driving cars. Amazon managed block chain which helped to meet the demands of thousands of customer applications running millions of transactions. Machine Learning approach produced forecasts and generated visualization dashboards, quick, easy, drag-and-drop interface, time-series input and forecasted output in their supply chain journey.

Source: https://sageseller.com/blog/how-amazon-is-changing-supply-chain-management/ September 2021, Accessed on 08th August, 2022

2.4 Factors Driving Supply Chain Integration

Various internal and external factors force firms to pursue supply chain integration. Some of the factors are:

2.4.1 Increasing Customer Satisfaction

One of the main reasons for organizations focusing on supply chain integration is to fulfill customers' needs, and thereby, increase customers' satisfaction. Due to changing customer preferences, firms that are focusing only on efficient and effective operations within the firm and neglecting supply chain integration are not able to satisfy customers' needs. Firms have realized that customers' needs can be fulfilled more effectively by collaborating with the supply chain partners.

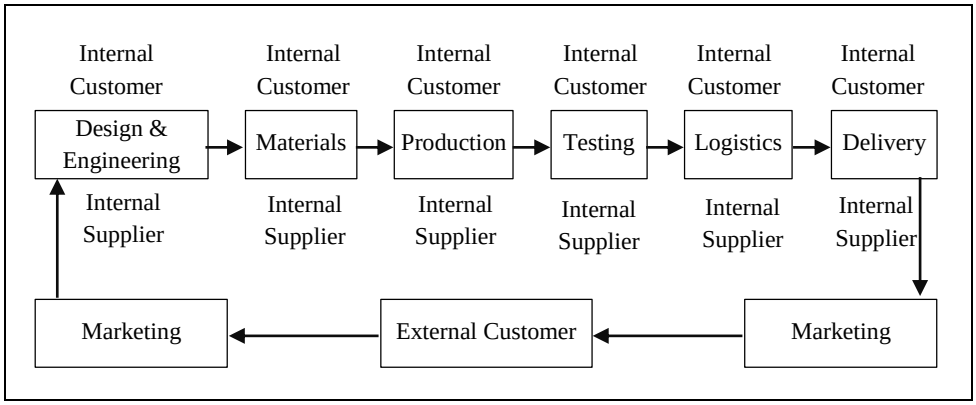
2.4.2 Concept of Internal Customer

A customer is an individual or an organization buying our products and services. The primary objective of any organization is to satisfy customers. However, in every organization, except the senior management, marketing staff concerned, and sometimes servicing personnel, no one else has the necessity or the opportunity to meet the customer. Explanation for the need and concept of internal customer are given below:

- It is not possible for others in the company to know personally and directly, whether the customer is satisfied with the products supplied and the services being provided, or not.

- To fill up this communication gap, the concept of internal customers has been evolved. It is a concept more popular in supply chain operations, as it involves many activities and processes, and, therefore, many actors and factors, as shown below in Figure 2.1.

Figure 2.1: Concept of Internal Customer



Source: ICFAI Research Center

- As is obvious, internal customer means the 'next stage' in the process.
- External customer places the order with the organization through marketing department.
- Marketing (internal supplier**)** sends inputs to Design & Engineering (internal customer).
- Design & Engineering (internal supplier) gives specifications to production (its internal customer).
- Materials (internal supplier) ensures procurement of right material at the right time and hands over to production (internal customer).
- Production (now the internal supplier), hands over the output to Testing (its internal customer).
- Testing (internal supplier) hands over the tested and approved products to logistics (the internal customer) for further processing.
- Logistics (the internal supplier) hands over the ready-for-dispatch product for delivery to marketing (internal customer).
- Marketing ensures the delivery of the product to the external customer.

Thus, the supply chain cycle in the organization starts and ends with marketing which is the interface point for the external customer.

- If each internal customer is satisfied with the inputs, he/ she receives from the previous stage- the internal supplier, and if this internal supplier-customer chain is efficiently managed, it is quite easy to satisfy the external customer.

- This is the best approach proved and practiced efficiently in Japan, since decades and proved to ensure effective internalization of customer requirements through the concept of Quality Function Deployment (QFD), about which you will know subsequently

This approach is expected to ensure:

- Effective internal communication and a 'preventive' approach to clearly understand all the customer requirements to ensure customer-focus in their respective activities.
- A team-based work culture to promote harmony and customer-oriented supply chain operations.
- On-line feedback on process performance so that problems, if any, can be solved immediately at the lowest possible level in the shop-floor itself.
- The concept of Quality Circles, a great success in Japanese industries, is based on this approach. It has helped not only in problem-solving but also in problem prevention and continuous improvement.

Thus, the concept of internal customer proved to be a highly effective approach with a positive impact on supply chain management and performance excellence.

2.4.3 Improving Supply Chain Productivity

Due to competition and globalization, profit margins of firms are under pressure, thereby forcing them to explore opportunities to reduce costs, and at the same time, to increase revenues. Firms have realized that if various processes across the supply chain are properly integrated, it cannot only reduce costs but also increase revenues.

Besides the above three factors, another factor that drives supply chain integration is the shift in competition from firm-level to supply chain-level. This is most evident in the automobile industry. The automobile manufacturers try to build networks of best supply-chain partners to maintain their position in the marketplace. The success of Toyota and Honda in global markets can be attributed to their long-term relationships with world-class suppliers.

2.4.4 Changing Competitive Environment

Another important factor driving supply chain integration is increased competition due to ever changing market conditions. Globalization, better technologies, and easy access to information have increased competition. Firms have realized that they cannot face competition without the support of supply chain partners. They are now focusing on effective supply chain integration, which enables faster customer order fulfillment, increased supply chain productivity, and faster new product development.

Example: Supply Chain at Small-Scale Manufacturing Company in Nigeria

Deets Company was a polypropylene (PP) woven sack manufacturing factory located in Lagos Nigeria. The supply chain of any manufacturing company had three classified units: 1) Supplier chain - raw material suppliers' network required manufacturing machinery, and all other daily operation's related equipment. The focus was on analysis of Deets suppliers' relationship management which was viewed from suppliers' viewpoint.

2) Internal chain - Internal organizational departmental or functional relationship interacting together, "production, finance, marketing, logistic and quality control". The focus was interaction levels of functional departments within Deets organization, and the manufacturing flow process' s effectiveness and efficiency. 3) Customer chain – necessary networks for products distribution to product distributors and retailers. Profits were made only when each supply chain member made. The focus was on the perspective of the customers and the other market forces on Deets customer's relationship management approaches.

The factors and five supply chain success drivers identified for Deets company: production, inventory, location, transportation, and information. It had been recognized that, continuous improvement in each of the drivers could enhance the supply chain capability. 1) Production - scope of decision making included the supply of raw materials, model and type of machinery, manpower training, deployment and CRM (Customer Relationship Management. 2) Inventory – maintain adequate inventory to ensure order fulfillment, by development of external and internal supply chains. 3) Location – locate manufacturing/ warehouses for quick supply of raw materials, storage of completed products. 4) Transportation – Focus high on movement of raw materials, from overseas to the factory, from factory to distribution centres. 5) Information - information systems connect all the stake holders and work better when integrated at all levels.

Source: https://www.scirp.org/journal/paperinformation.aspx?paperid=117729, July 2022, Accessed on 8th August, 2022

2.5 Role of Organizational and Channel Support for Supply Chain Integration

Organizational and supply chain partner support is essential for effective supply chain integration. The support has to first come from the top management of the firm. Top management support enables faster and smoother integration of various supply chain components.

The next level of support must come from the managers of various functional areas. The support of managers from different functions is essential, especially when there is a need for cross-functional collaboration. But, it is often difficult to get their support due to the conflicting objectives of each function.

The support from supply chain partners is critical for the success of supply chain integration. As supply chain integration is an inter-firm effort, support from within the firm is not sufficient and the cooperation of supply chain partners is necessary.

Example: Importance of Organizational Culture for Successful Supply Chain

Indonesia had a large market and was geared up to leverage the impact of Industry 4.0, by achieving the same by acceleration of the Supply Chains (SC) adoption. The supply chain adoption definitely could bring: ability for higher efficiency, reduction of production time and cost, minimization of human errors, and enhanced product quality and accuracy. The best results from supply chains were achieved by using block chain technology which helped storage of necessary data, and made more transparent, reliable, and secure transactions.

The aspect of culture had been identified as an important factor for Indonesian companies, as the movement was from an internal and rigid culture to a more external and flexible culture. The examination of supply chain ambidexterity and SC agility could determine the factor of enhancement of the relationship between "those determinants and the level of company maturity". Companies in Indonesia could understand that "increased agility, adaptability, and level of integration" along the supply chain was from 'the supplier, manufacturer, and retailer". Agile and ambidextrous capabilities were crucial for maturing the supply chain digitalization. Companies could realize that, being open to collaboration with their supply chain partners, engaging in joint innovation projects and building ambidexterity, were root causes for enhancing supply chain digitalization at Indonesia.

Source: https://www.researchgate.net/publication/360408577_Achieving_Supply_Chain_40_and_the_Importance_of_Agility_Ambidexterity_and_Organizational_Culture_A_Case_of_Indonesia, May 2022, Accessed on 8th August, 2022

2.6 Elements of Supply Chain Strategy

A supply chain strategy works best if it is designed to meet the needs and demands of the customers, besides creating value for the company and the supply chain partners. An effective supply chain strategy should include: demand flow strategy, customer service strategy, technology integration strategy, and collaboration strategy.

2.6.1 Demand Flow Strategy

Demand flow strategy concentrates on managing the uninterrupted flow of demand information across the supply chain. This strategy emphasizes integrating the supply chain to achieve the supply chain objective of fulfilling customer demand. The strategy is built around the need for sharing demand information like up-to-date forecasts, point-of-sales data, and any other decisions of the channel members that may affect demand. The firms adopting this strategy select a distribution channel that enables better flow of demand information from the retailer/ customer to the manufacturer. Advances in information technology have made it easier for firms to cater to the demand of customers faster by selling their products directly to the customer over the Internet. Channel structure plays an important role in how fast consumers' demand is fulfilled, as it is the conduit through which goods reach the end customer. Another important aspect of demand flow strategy is demand planning. When an organization takes up demand planning, it should not only involve different departments within the organization but also various partners in the supply chain. This way, the information projected will not be distorted and the bullwhip effect can be avoided. Another way to ensure that demand information is not distorted is to use a single, reliable, and steady source of data, all along the supply chain. Managing demand and supply in a supply chain is discussed in Unit 4.

To improve planning and demand processing, many firms are relying on vendor managed inventory (VMI). VMI helps in using shared sales and inventory data, among the supply chain partners.

2.6.2 Customer Service Strategy

Customer service differentiates a successful firm from an unsuccessful one. Effective service will retain customers by providing them with value-added products from time to time, according to the changing business trends. For a customer service strategy to be successful, there is a need for effective segmentation of the market, an analysis of a firm's customer-service delivery cost and revenue management. Segmentation is of prime importance as effective segmentation helps an organization to understand customers’ preferences better. Segments are formed after conducting surveys, focus group interviews, demographic analysis, and study of large-scale customer information databases. Apart from these, a host of techniques like the conjoint analysis, and hybrid modeling are used for identifying customer demand patterns. The next step is analyzing costs involved in meeting the service levels as per the newly identified perspective, for it to provide the required levels of service to the customer. The firm's supply chain should garner support from all the supply chain partners to provide effective customer service.

It is important for a firm to understand the needs of the customers, especially, it must understand what type of customer service will bring in maximum benefits for the firm. Hence, the firms need to consider various behavioral responses of customers to alternative levels of customer service. The techniques that are used to understand customers' behaviour are factor analysis, regression analysis, dynamic conjoint analysis, and other multivariate statistical techniques.

A firm adopting this strategy should concentrate on achieving supply chain integration that provides optimum customer service.

2.6.3 Collaboration Strategy

Collaboration is necessary for effective supply chain integration. More innovative products can be developed by collaborating with the partners in the supply chain. Collaboration helps in understanding future product demand, allows better forecasting, and reduces the time taken in fulfilling orders. Collaboration in a supply chain can take place at three levels: Collaboration between the manufacturer and the supplier, between the customer and the manufacturer, and between the third-party (3PL) and fourth-party logistics (4PL) providers. When a supplier and a manufacturer collaborate, they can derive benefits in terms of quicker order fulfillment and better capacity planning. This collaboration helps firms to develop products faster as both the partners' work together keeping in view each other's strategy. This way there is an efficient alignment of strategy. Further, manufacturers and suppliers can collaborate and build innovative products according to the requirements of customers.

When manufacturers collaborate with their immediate customers (wholesalers and retailers), they can understand customer requirements better and can manufacture goods that suit the demands of the end customers more effectively. This collaboration with customers (retailers and wholesalers) also provides better demand forecasts, thereby reducing obstacles in information processing.

2.6.4 Information Technology Strategy

Information technology (IT) is gaining prime importance in supply chain management. The application of information technology to the overall supply chain process is providing several benefits to firms. The various information processing tools used to increase the efficiency of a supply chain are transaction processing systems, operational planning tools, etc.

ERP systems are gaining importance as the supply chains are being built on IT infrastructure. ERP systems help firms to integrate various supply chain partners and present a common understanding of what the shared data represents.

All the above strategies when worked out effectively help in framing an effective supply chain strategy. For a supply chain to function efficiently, there is a need for synchronization between the people, process, and technology.

Example: Supply Chain Strategy at Dell Company

Dell had set a standard for effective Supply Chain Management. Dell's SCM strategy had three core aspects. It followed a 'built-to-order approach', thus proving customer centric product make and delivery and ready market production. Another aspect was the adoption of a 'just-in-time manufacturing system' which eliminated the need to hold unplanned amounts of inventory. Third was its direct-to-consumer selling strategy. Using these Dell could achieve: reduced manufacturing costs, enhanced customer satisfaction, strong collaborations with its suppliers, sharing of customer needs with their suppliers, influencing them to produce customer trended components, learning needs of customers in real-time without dependence on intermediaries in the distribution channel.

Dell used information technology extensively, and ensured real-time communication with customers, and real-time information transmission among the components of the supply chain. Such IT integration, allowed real-time information transmission among the components, and strong integration of suppliers and enhanced value for the customer at Dell.

Source: https://studycorgi.com/dell-companys-supply-chain-management-strategy/ October 2020, Accessed on 8th August, 2022

Activity 2.1

Taking a clue from the Government of India's Make in India policy, an SME (Small and Medium Enterprise) ventured into manufacturing mobile phones in India. It has the necessary technological inputs.

- Draw a supply chain process to manufacture and market the mobile phones. Identify all internal suppliers and customers in the process.

Check Your Progress - 1

1. Which of the following is not a main element of supply chain integration?
   a. Suppliers
   b. Service providers
   c. Customers
   d. Employees
   e. Shareholders

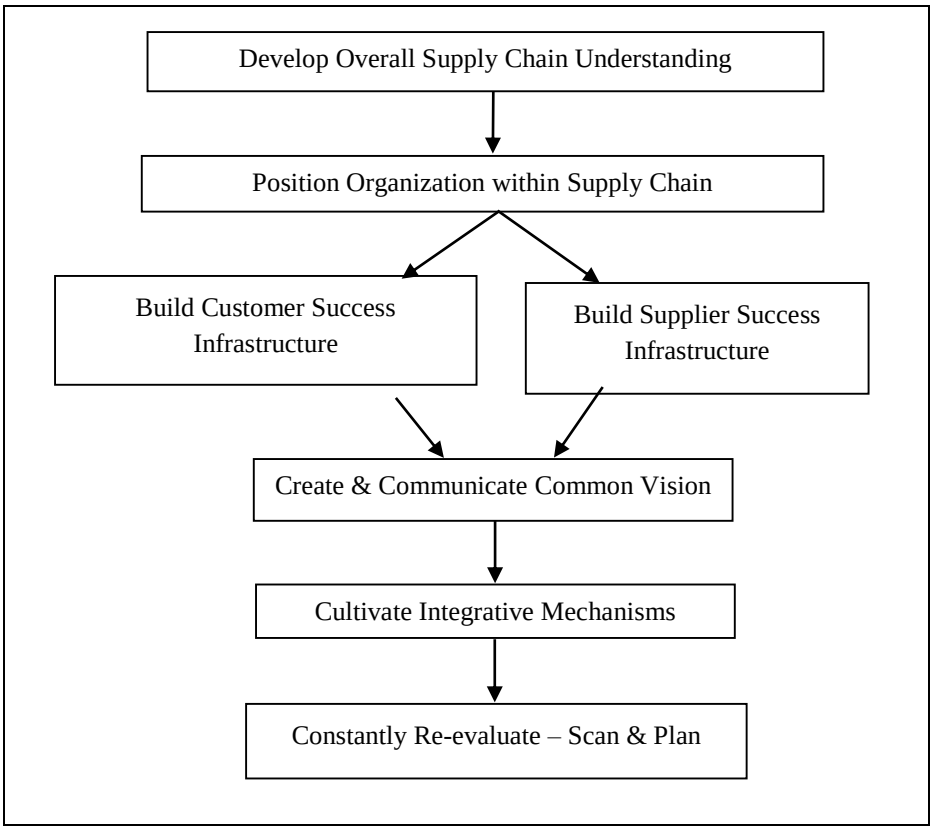
2. Which of the following is not a significant advantage of supply chain integration?
   a. Efficiency of operations
   b. Faster new product development
   c. Improved quality
   d. Organizational discipline
   e. Improved productivity
3. Which of the following is the most important driver of supply chain integration?
   a. Globalization
   b. Customer
   c. Shareholder
   d. Competitor
   e. Supplier
4. Identify from the following the 'odd man' in the approaches to supply chain integration.
   a. Financial support
   b. Resource focus
   c. Outsourcing
   d. Cooperative planning
   e. Logistics
5. Which of the following is not an element of supply chain strategy?
   a. Demand flow strategy
   b. Customer service strategy
   c. TQM strategy
   d. Collaboration strategy
   e. IT strategy

2.7 Framework for Supply Chain Integration

A firm has to follow a systematic approach to develop and implement a supply chain integration strategy. Fawcett and Magnan (2001) have proposed a six-stage framework for successful supply chain integration. The first stage involves understanding the supply chain, within which it is operating. In the second stage, the firm has to determine its position in the supply chain. In the third stage, it has to build the necessary supply chain infrastructure to suit its business strategy.

In the fourth stage, the firm has to develop its supply chain vision and procedures in line with its business strategy. The fifth stage involves developing integrated mechanisms for collaborating with the supply chain partners. The last stage in this framework concentrates on monitoring competitive conditions and implementing continuous improvement programs. Figure 2.2 depicts this framework for supply chain integration. Each stage is explained below:

Figure 2.2: Supply Chain Integration Framework



Source: ICFAI Research Center

2.7.1 Understanding the Supply Chain

To develop the supply chain strategy, a firm has to first understand the supply chain and its characteristics. The firm has to identify who are its customers, who are the partners in the supply chain and what are their roles, and what processes and systems exist in the supply chain. The process of understanding the supply chain is discussed below.

Market segmentation

A firm has to evaluate end-consumer preferences and needs, and their buying behavior to design a supply chain that provides maximum customer satisfaction. Then the firm has to cluster customers with similar features such as customers buying the same product, customers located in a region, customers having similar

buying patterns and requirements, etc. After forming the clusters, the next step is to form segments from these clusters. One or more clusters, which have common requirements or common features, can form a particular segment.

Describing the supply chains

The next stage is to identify the appropriate supply chain for each customer segment. All customer segments may have the same supply chain or each segment may be serviced by a different supply chain. For example, an FMCG company may have the same supply chain for all its customer segments while an automobile manufacturer may have a particular supply chain for new car sales and a different supply chain for its after-sale parts and services.

Once the supply chain is identified, the supply chain description is to be documented. The critical processes and levels of the supply chain and members involved in the supply chain have to be identified. As we know, there are three key flows in a supply chain - material or physical flow, information flow, and financial flow. These three flows and their characteristics have to be documented.

Physical flow: Physical flow is the primary and most important flow in the supply chain. The following areas have to be described:

- The levels of the supply chain through which the product flows
- The members of the supply chain such as suppliers, customers, and logistics providers, etc.
- The logistics options that are used in delivering the goods
- The lead times for each level of the supply chain
- The inventory levels at each level of the supply chain.

Information flow: Information is another flow which the firm has to evaluate. Effective information flow enables the firm to reduce inefficiencies and improves effectiveness in the supply chain, thus, providing a competitive edge. A clear description of the information flow helps the firm in identifying bottlenecks in the flow of information and opportunities where the flow can be further improved.

The following elements need to be described:

- The points of contact where the decisions are made have to be listed
- The information systems that manage the supply chain processes and their functionalities across the supply chain are to be compiled.
- The links and contracts between the members of the supply chain are to be depicted.

Financial flow: Financial flow deals with the financial aspects of the supply chain processes. The elements that need to be evaluated are the purchase-to-pay cycle and the order-to-cash cycle.

A purchase-to-pay cycle refers to the purchasing process of the firm. The cycle starts with a firm placing the order and ends with payment to the supplier. The financial flow during the process has to be described. Order-to-cash cycle refers to the customer order fulfillment process. The cycle starts with a customer placing the order, and ends with the payment by the customer to the firm.

Apart from understanding the above three flows in a supply chain, a firm should also learn about the nature of new product flow through the supply chain as this may alter the supply chain functioning. New products may impact the processes and members of the supply chain. So, a description relating to the new product flow process has to be prepared.

The following areas are to be covered under the description.

- The impact of new product development, on the supply chain processes.
- The impact of new product development on participant relationships and functioning.
- Any special requirements that are to be made for new product introductions.

After understanding the supply chain, the firm has to analyze various aspects, related to the supply chain. The firm has to first decide on what value the supply chain wants to provide to the customers. Clear knowledge about customer needs, the firm can decide upon the roles that each member of the supply chain needs to perform.

The firm has to evaluate each member's role in the supply chain, before it decides how each member of the supply chain can contribute to the supply chain, for effective fulfillment of customers' needs.

The firm should also evaluate the opportunities for profitability, as well as levers for improvement of operations in the supply chain.

2.7.2 Evaluating the Organization's Position in the Supply Chain

Once the firm has evaluated the supply chain, the next step is to identify its position in the supply chain. The firm has to evaluate, whether the objectives of the organization are in line with the supply chain's objectives. If there is a mismatch, the firm has to take appropriate measures, to reassess its role in the supply chain or synchronize the objectives. The firm can identify its strategic fit in a supply chain, by finding answers to the following questions:

- Is the firm participating in the wrong supply chain?
- Are there any other supply chains that the firm can consider?
- What steps can the firm take to integrate its activities, with that of the supply chains?

For achieving strategic fit in a supply chain, a firm has to first identify its core competencies and then develop specific processes that support those core

competencies. The activities, which do not match its core competencies, can be outsourced to other supply chain partners.

2.7.3 Building the Supply Chain Infrastructure Needed for Successful Integration

After evaluating the organization's position in the supply chain, the firm has to build the necessary infrastructure that caters to the needs of its customers and suppliers. The firm can classify the customers, depending upon their relationships with the firm. The firm can classify the customers, who have long term relationship with the firm and bring in significant business, as 'most-important'; those customers, who are not as big, can be classified as ‘important’ customers; other customers, who bring in insignificant business to the firm can be categorized as 'not-so-important' customers.

The firm should then establish relationships with the customers, based on this classification. It must establish long term partnerships with the 'most-important' customers, through collaborative initiatives like collaborative product forecasting and replenishment (CPFR), vendor managed inventory (VMI), collaborative product development and co-located manufacturing. Such high levels of collaborative initiatives are not required for the 'important' customers. The firm needs to be familiar with the needs of these customers and set processes and systems such that their most critical needs are met satisfactorily. The 'not-so-important' customers are usually not a profitable segment for the firm. This segment consists of small customers, but put together they may give considerable revenue to the firm. Establishing transactional relationships with such customers is desirable as some of these customers may later become major players in their business.

For building a successful supplier infrastructure, a firm has to classify its suppliers based on their contribution to the firm's success. A firm can build intensive relationships with critical suppliers such as first-tier suppliers. The relationship could involve information sharing, resource sharing, joint improvement efforts, etc. A firm needs to maintain a cordial relationship with the next level of suppliers such as second-tier suppliers. Proper and efficient systems and procedures need to be developed, for other small and transactional suppliers.

2.7.4 Create and Communicate a Common Supply Chain Vision

With a good understanding of the supply chain and with proper infrastructure in place, a firm can formulate its supply chain vision and procedures. The supply chain vision should guide the firm's supply chain initiatives, and should be aimed at achieving better integration. The top management can set up a committee for the creation and propagation of the vision within the firm. Managers and employees should be made aware of the supply chain vision so that they can contribute effectively to implement the firm's supply chain initiatives. The firm

has to then focus its efforts on promoting its supply chain vision with the supply chain partners. Customer service departments and supplier relationship departments can help in this regard. Sharing and promoting the supply chain vision can be done through periodic review meetings and frequent one-to-one interactions with customers and suppliers. Once the vision is communicated to the supply chain partners, the firm has to assess the degree of alignment achieved through continued relationships with the partners. The firm has to analyze how far the supply chain partners' expectations are matching with the firm's expectations. If there is a mismatch, appropriate steps should be taken to encourage all the partners to work towards fulfilling the common supply chain vision which is acceptable to all the members in the supply chain.

2.7.5 Develop Integrative Mechanisms

The next stage involves developing collaborative mechanisms with the supply chain partners. First, the firm has to identify the barriers to integration and try to reduce these barriers. Specific committees need to be established to identify the problems in supply chain integration and the committees should try to resolve those problems through consensus with the supply chain partners. Once the problems are resolved, the firm has to focus on specific collaborative programs with its supply chain partners. Initially, pilot projects may be implemented to gauge the results before implementing full-scale programs.

2.7.6 Constantly Re-evaluate and Continuously Improve

A firm has to make periodic reviews regarding the technologies, industry, and customers. It has to examine the changes taking place in the market, the impact of such changes on the supply chain, the alternative measures to tackle these changes, and the trade-offs that have to be made while implementing these measures. With continuous and ongoing re-evaluations of the situation, a firm can direct its supply chain integration initiatives with the objective of achieving both short-term and long-term objectives.

Example: Framework for Integration of Vertical Public Health Supply Chain at Nigeria

An expert view and qualitative thematic content analysis study among fifteen experts from the six geopolitical zones of Nigeria was conducted to build the framework for the public health supply chain framework. The experts had minimum of three years' experience in the management of pharmaceuticals and health products. They belonged to various public health intervention programs like: "HIV/AIDS, Reproductive Health and Family Planning, Vaccines and Immunization, Tuberculosis & Leprosy, Malaria, Neglected Tropical Diseases and Essential Medicines Programmes".

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In commercial sector supply chain, 'finances, products and services and information 'flew in both directions. In the public health supply chain, information on 'finances, products and services' was coming from Service Delivery Points (SDPs).

In public health sector, supply chain of a given country was government driven, and focus was on management of donated pharmaceutical and health products. The government or their partners took responsibility to deliver products till last mile. Consumer products were to a large extent substitutable. In public health supply chain, one cannot deliver Oral Polio Vaccine in place of Hepatitis-B vaccine. Products in public health were individual specific and were more expensive to afford and were needed by poor masses. They were to be subsidized or donated free and timely availability was crucial factor. In public health supply chains, the activities flew as part of collaboration and coordination of supply chains. These would be handled outside of the vertical supply chains systems like federal Ministry of health, its subsidiaries at the state Ministries of health. Public health supply chain systems in Nigeria was a mix of 'volatile and predictable supply and demand'. A clear assessment and understanding of all these issues, in the public health supply chain, would lead to framing modalities for seamless integration of vertical supply chain systems in the Nigerian public health sector.

Source: https://www.iprjb.org/journals/index.php/IJSCM/article/view/1483, 2022, Accessed on 8th August, 2022

Activity 2.2

An automobile multinational company with a view to expand its market shares in India, shortlisted a number of small companies for facilitating its sales and service operations. Your proposal is among those shortlisted. However, the company wants every prospect to prepare and submit a framework for supply chain integration as a precondition for your qualification.

- By taking guidance from Figure 2.2 and the subsequent explanation of each element covered in the integration framework, prepare a framework as required by the company, to ensure that you are qualified.

2.8 Benefits of Supply Chain Integration

By achieving successful supply chain integration, firms can obtain various benefits, ranging from customer satisfaction to improvement in supply chain productivity. Some of these benefits are:

2.8.1 Increased Customer Responsiveness

Enhanced customer responsiveness can have an impact on customer satisfaction levels. The attributes of customer responsiveness are faster delivery, providing quality, and innovative products. Faster delivery requires shorter lead times, high order-fill rates, and orders shipped completely. All these can be achieved, through supply chain integration. Another benefit of supply chain integration is the improvement in the quality of the products. With closer relationships and greater trust among the supply chain partners, quality can be enhanced. Faster new product development is another benefit of effective supply chain integration. With the involvement of supply chain partners in the new product development initiatives, a firm can bring the products into the market faster.

2.8.2 Increased Supply Chain Productivity

Reduction in costs is one of the important benefits of supply chain integration. Cost reduction is achieved through shorter lead times, faster product development, and efficient inventory management.

Due to consolidation of purchasing across the organizational units, a firm can gain substantial savings in purchasing. Closer relationships with supply chain partners increase information sharing, reduce communication problems, and provide opportunities to improve operations. Stock-out costs also reduce, as a result of faster information sharing, among the supply chain partners.

Other benefits of supply chain integration include increased forecast accuracy, increased flexibility, improved return on assets, and increase in sales and market share.

Example: Cost Reduction in Supply Chain

Deere & Company with brand name John Deere, was popular for diesel engines, lawn care equipment, and manufacture and supply of agriculture, construction, and forestry machinery. Deere and Company had diverse product range, with a mix of industrial equipment made to order and heavy machinery for the consumer market, retail being seasonal. The company was doing 'direct shipment and cross-docking operations' from their warehouses replenishing dealers' inventory weekly. This operation proved too slow and costly. The company had set a goal of achieving reduction of 10% in supply chain cost within four years.

Contd….

As a part of this, the company redesigned the supply chain network, which resulted in initialization of intermediate "merge centers" and locating of optimal cross-dock terminals. It started on consolidating shipments. During seasonal peak, it used break-bulk terminals. It increased the utilization of third-party logistics providers. It worked on methods for effective creation of a network which could be optimized tactically dynamically. Deere & Company's cost-management achievements realized a decrease of $1 billion at inventory, notable reduction in delivery times to customers, saving annual transportation by 5%.

Source: https://trans.info/en/alarming-shortage-truck-291261, 2020, Accessed in August 2022

2.9 Barriers to Supply Chain Integration

Certain barriers restrict firms from fully realizing the benefits of supply chain integration. A firm has to constantly evaluate these barriers and their impact on the supply chain. Four common barriers to supply chain integration are:

2.9.1 Increase in Product Variety

With increased competition, firms are forced to expand their product portfolios, to cater to wider segments of customers and to differentiate in the marketplace. With an increase in product variety, a firm may face demand volatility. Demand volatility may lead to an increase in production and inventory costs. This makes the supply chain inefficient, or reduces responsiveness in the supply chain.

2.9.2 Shorter Product Life Cycles

With changing market conditions and customer preferences, firms are forced to launch new products more frequently. Thus, the product life cycles are becoming shorter. High tech products such as electronic gadgets and computer software have short product life cycles. Even products such as automobiles are experiencing shorter product life cycles. The compulsion, to launch new products very frequently, puts pressure on the supply chain partners to redefine their roles and relations. Thus, these uncertainties on the product front and the demand side have an unsettling effect on integration initiatives, across the supply chain.

2.9.3 Customer Demands

Customer's preferences are changing fast. Customers are demanding better products, faster order processing, and timely delivery for the same price. This makes it necessary for the firm to maintain stable prices, in order to protect its market position. This increases the pressure on the profitability of the firm, which in turn puts pressure on the supply chain to reduce costs. The increasing number of customer demands force firms to forge relationships, with many supply chain partners, thereby making the process of supply chain integration more complex.

2.9.4 Increased Outsourcing of the Firm's Activities

Earlier, firms used to manage all the activities in their value chains. These days, most firms manage core functions and outsource non-core activities to third parties. This increases the number of participants in the supply chain and makes supply chain management a difficult task. As each participant works towards achieving his objectives, achieving coordination between them, or integrating the supply chain becomes difficult. This reduces the overall efficiency and effectiveness of the supply chain.

Example: Barriers in Sustainable Food Supply Chains

Rice was a strategic product in Iran and had a critical role in the economy of Iran. The analysis was an outcome of study, of literature survey and expert views from experts from the Ministry of Agriculture of Iran, JIHAD on supply chain related issue. The barriers identified were: B1) Lack of understanding and awareness of managers B2) Performance appraisal problems related to the performance of a sustainable food supply chain. B3) Lack of expert staff and lack of training in organizations on sustainability measures and the lack of workplace support. B4) High cost of deployment because of high initial investments, lack of sufficient financial resources, equipment, machinery, and integrated information systems. B5) Lack of government oversight and control in the areas of products that were not green and sustainable and lacking pressure leading to stagnancy in sustainable food supply chain implementation.

B6) Distrust of consumers due to eco-friendly labels, and difficulty for consumers to distinguish high-quality products. B7) More expensive products. B8) Development of laws and policies by the government leading to fear of food security and unsustainable natural resource decline. B9) Joint efforts and cooperation of suppliers, as supply chain partners needed to help each other for producing more and share. B10) Encourage and support nongovernmental and eco-friendly organizations as NGOs and international development organizations had key role in providing expertise to supply chain members for cooperation and implementing sustainability practices. B11) Entering the global market and exporting products as food security was crucial across the world, and became an issue for both developed and developing countries.

Source: https://www.hindawi.com/journals/mpe/2022/4486132/, 2022 Accessed on 8th August, 2022

Check Your Progress-2

6. Which of the following is not a part of the Supply Chain Integration Framework, suggested by Fawcett and Magnan?
   a. Supply chain vision
   b. Develop infrastructure
   c. Outsource totally

d. Mechanism for collaborating with partners
e. Monitoring the competitive environment and launching improvement programs

7. Identify the option that is not required for understanding the supply chain.
   a. Physical flow
   b. Financial flow
   c. Information flow
   d. Market segmentation
   e. Employee attrition
8. Which of the following is not a major aim of constantly monitoring and continuously improving supply chains?
   a. Technological improvement
   b. Achievement of short-term and long-term objectives
   c. Locating new customer segments.
   d. Fine-tuning supply chain strategy
   e. Evaluating the financial feasibility of proposed programs
9. Which option do you consider as a major barrier for supply chain integration in a retail chain operation, in India?
   a. Transportation
   b. Short product lifecycles
   c. Changing customer preferences
   d. Increasing outsourcing
   e. Increase in product variety
10. Why do you consider (most important) outsourcing is a major barrier, even though it is quite common?
    a. Reduces profitability
    b. Variety of products and suppliers complicate operations
    c. Management of rejections and returns
    d. Shortage of outsourcing professionals
    e. Lack of management support

2.10 Summary

- Effective supply chain integration enables firms to improve efficiency and effectiveness of their supply chain.
- An integrated supply chain can be defined as one, which has achieved alignment of the members of the supply chain with their processes.

- There are two types of supply chain integration- internal integration, which aims at achieving the integration between functional areas, and external integration, which aims at integrating the internal operations of the firm with that of its supply chain partners.
- The four elements of a supply chain strategy are demand flow strategy, customer service strategy, technology integration strategy, and collaboration strategy.
- The key factors that drive the supply chain integration are: increasing customer satisfaction, the need to improve supply chain productivity, and the changing competitive environment.
- The framework for developing and executing an integrated supply chain strategy consists of: understanding the supply chain, evaluating the organization's position in the supply chain, creating and communicating a common supply chain vision, cultivating integrative mechanisms, and constantly re-evaluating and improving.

2.11 Glossary

3PL: means 3rd Party Logistic service providers, mainly focusing on transportation, warehousing and cross-forwarding, and sometimes inventory management.

4PL: stands for 4th Party Logistics service providers, taking responsibility for managing the entire supply chain of a client.

Backward integration: refers to integrating with the suppliers of inputs.

Bullwhip effect: is a distribution channel phenomenon in which demand forecasts yield supply chain inefficiencies. It refers to increasing swings in inventory in response to shifts in consumer demand as one moves further up the supply chain.

CPFR: stands for Collaborative Product Forecasting and Replenishment.

Cross-functional process integration: refers to the integration of the functional areas in the firm.

Demand flow strategy: concentrates on managing the uninterrupted flow of demand information across the supply chain.

ERP: is an IT-based technique for Enterprise Resource Planning.

External integration: refers to linking of firm's internal operations with that of the supply chain members and customers.

Forward integration: means integrating with the processes of customers to ensure compliance to requirements.

Integrative mechanism: means developing collaborative mechanisms with the supply chain partners.

Internal customer: refers to the next stage in the supply chain treated as an internal customer.

Product Lifecycle: is the cycle of all stages and activities involved in the evolution and exit of a product, starting from design to deployment and retirement.

QFD: stands for Quality Function Deployment, a technique used for internalization of customer requirements.

VMI: means Vendor Managed Inventory, aimed at ensuring efficient inventory management by sharing common data bases on sales and inventories.

2.12 Self-Assessment Test

1. Discuss the nature of supply chain integration.
2. Explain the major factors driving the supply chain integration.
3. Which are the major elements of supply chain strategy?
4. What are the basic aspects of creating a framework for supply chain integration?
5. Which are the major barriers to supply chain integration?

2.13 Suggested Readings / Reference Materials

1. Ashley McDonough, Operations and Supply Chain Management Essentials You Always Wanted to Know: 15 (Self Learning Management Series) Paperback – 1 January 2020
2. Russel and Taylor, Operations and Supply Chain Management, 10ed, ISV Paperback – October 2019
3. Chopra and Kalra, Supply Chain Management 6/e Paperback – 17 June 2016

2.14 Answers to Check Your Progress Questions

1. (e) Shareholders

Shareholders is not a main element of supply chain integration.

2. (d) Organizational discipline

Organizational discipline is not a significant advantage of supply chain integration.

3. (b) Customer

Customer is the most important driver of supply chain integration.

4. (a) Financial support

Financial support is the ‘odd man’ in the approaches to supply chain integration.

5. (c) TQM strategy

TQM strategy is not an element of supply chain strategy.

6. (c) Outsource totally

Outsourcing totally is not a part of the Supply Chain Integration Framework as suggested by Fawcett and Magnan.

7. (e) Employee attrition

Employee attrition is not required for understanding the supply chain.

8. (e) Evaluate the financial feasibility of proposed programs

This is not a major aim of constantly monitoring and continuously improving supply chains.

9. (a) Transportation

Transportation is considered as a major barrier for supply chain integration in a retail chain operation, in India.

10. (b) Variety of products and suppliers complicate operations

As variety of products and suppliers complicate operations, outsourcing is considered as a major barrier, though it is quite common.

Unit 3

Demand Forecasting in a Supply Chain

Structures

3.1 Introduction

3.2 Objectives

3.3 Objectives, Components, and Approaches of Forecasting

3.4 Demand Forecasting Process

3.5 Forecasting Techniques

3.6 Measures of Forecast Error

3.7 Challenges in Demand Forecasting

3.8 Summary

3.9 Glossary

3.10 Self-Assessment Test

3.11 Suggested Reading / Reference Material

3.12 Answers to Check Your Progress Questions

"To deal with the new era of trade, companies need systems that give them two essential ingredients – intelligence and visibility."

- Robert Kugel

3.1 Introduction

In the previous unit, we discussed effective supply chain integration. An integrated supply chain can be defined as one, which has achieved alignment of the members of the supply chain with their processes. We briefly discussed two types of supply chain integration- internal integration and external integration. The four elements of a supply chain strategy are demand flow strategy, customer service strategy, technology integration strategy, and collaboration strategy were discussed.

Forecasts are an integral part of any planning process. Accurate forecasts help firms effectively plan the production process so that inventory levels in the supply chain can be optimized and supply can be matched closely with demand. Demand forecasts can also help the marketing department of a firm, to decide upon the kind of promotional exercises required for a particular product. Further, forecasting accurately leads to better distribution planning, since firms can determine the exact level of inventory to be held, at each distribution center.

Forecasting needs to be paid a lot of attention, in the context of a supply chain. This is because the components of the supply chain (suppliers, distributors, retailers, etc.) are essentially interdependent. Inaccurate forecasts can either increase the inventory in the supply chain beyond the desired levels or decrease the chain's responsiveness. Forecasting is important, in both forms of the supply chain – built-to-order and built-to-stock. In the latter, popularly known as the push supply chain, a firm has to predict customer demand, before planning the production. FMCG firms would be the perfect example here since they typically decide their production schedules, based on customer demand forecasts. In a built-to-order supply chain (popularly known as the pull supply chain), a firm has to forecast the production capacity that can meet customer orders. For example, Dell Computers, whose supply chain is pull-based, forecasts the production capacity, to satisfy customer orders optimally.

Forecasts improve the supply chain's effectiveness, by enabling the firm to exchange and coordinate information among the chain's components. For example, companies like Walmart and Cisco share their demand forecasts with their trading partners. The logic behind doing so is that for proper supply chain integration, a common forecast needs to be followed by all the members of the supply chain. Consider the example of a manufacturer, who is equipped with a demand forecast for a particular product. He would know the exact quantity of components and raw material required to produce the planned quantity.

If suppliers from all the tiers of the supply chain share the above information, they would be able to develop their forecasts accordingly. This would ensure that the occurrence of events such as oversupply of inventory or stock outs would be minimized. Thus, for better synchronization and coordination of activities in the supply chain, an accurate demand forecast is necessary.

In this unit, we examine the concept and process of demand forecasting. We begin by examining the components of a forecast and then move on to various approaches followed in making forecasts. Then we understand the forecasting process and, look at various forecasting techniques that are used in forecasting. We also examine different time series forecasting techniques in detail. Finally, we talk about the concept of forecasting errors and learn how to measure the same.

3.2 Objectives

By the end of the unit, you will be able to

- Identify different approaches to forecasting
- Explain the demand forecasting process
- Examine forecasting techniques and selection of appropriate forecasting technique
- Define forecast error
- Identify the challenges in demand forecasting

3.3 Objectives, Components and Approaches of Forecasting

Objectives, components and approaches of forecasting are discussed below.

3.3.1 Objectives of Forecasting

Forecasting is estimating future demand, which is the basis for strategic planning. Forecasting is used to plan the level of production in push processes and it is anticipating customer demand. In pull processes, which is a response to customer needs, capacity needs to be planned.

Demand Forecasting is used in production, to plan the inventory levels, scheduling, and aggregate planning. Marketing uses the demand forecast to plan the sales team to be deployed for different areas/ product lines and promotion strategies. Finance needs this information for capital budgeting decisions and planning the finance and budget for the year. Demand forecasting is also an important factor, for hiring and firing people.

Forecasts are estimates of the future and, hence, should take into consideration estimation accuracy, i.e., factor the error in forecasting. Long-term forecasts are more prone to error, compared to short-term forecasts.

3.3.2 Forecasting Components

For forecasting purposes, firms need to take into consideration six major components: base demand, seasonal factors, trends, cyclical factors, promotions, and irregular components.

Not all the components need be included in each forecast. However, all of them have to be monitored and considered. Let us examine the characteristics of each of the six components.

Base demand: Base demand is the average of sales, over a given time period. This figure can be taken as the right forecast if the products' demand is not impacted by the seasonal, trend, cyclic, and promotional factors.

Seasonal component: This refers to the repeated pattern of increases and decreases in demand, over a period. For example, the demand for cool drinks and ice creams peaks during summer and remains low during the rest of the year. In this case, the demand pattern shows high seasonal variability during summer and low seasonal variability during the rest of the year.

Trend component: The trend component refers to the long-term pattern of movement of demand, over a period. The trend may be positive, negative, or neutral. In any given time period, a positive trend implies that the demand is increasing, while a negative trend indicates that the demand is decreasing. A neutral trend implies that changes in the demand are negligible, over a period. For example, the motorbikes sales in India have been showing a positive trend, since the late 1990s, due to changes in customer preferences. On the other hand, the trend in scooter sales in India has changed from positive to negative, during the same time.

Cyclic component: Cyclic component refers to changes in the demand patterns, which exist for more than one year. These changes could show either an upward or a downward movement. A good example of the cyclic component would be the business cycle, which changes every few years (from recession to boom and vice-versa). The demand for luxury products may be linked with the business cycle since sales usually increase during the boom phase and slow down during the recession.

Promotional component: The promotional component is one of the key factors that affect demand, especially for FMCG and consumer appliances companies, whose sales are more dependent on promotions. It refers to the changes in demand that occur due to promotional campaigns, undertaken by the firm. Promotions can be for the end customers and/ or for the distributors and retailers. Their impact on the forecast also depends on their regularity. A regular promotion is run at the same time every year. Discount sale by a refrigerator manufacturer, during the lean season, can be an example here. The regular promotion component can be termed as a seasonal component from the forecasting perspective. Irregular promotions are those promotions, which are run as per the market conditions and do not have a specific time frame. Such promotions need to be monitored carefully and considered separately. Unlike other forecasting components, the promotional component is controllable by the firm.

Irregular component: The irregular component refers to all those variations in demand that cannot be attributed to any of the above five factors. This factor is difficult to predict because of its random nature. Any forecasting exercise involves efforts to reduce the impact of this component, by accurately monitoring and predicting the other components.

Activity 3.1

Covid-19, while creating panic among all people across the world, has also generated a number of employment opportunities and demand for specific products. One such product is the facemask to be worn by the common public. It is expected to be made mandatory, thus assuring adequate demand in the years to come.

- You are required to identify basic components of demand forecasting and then forecast the demand for a product, initially in a major city like Hyderabad for 2023 and 2024.

3.3.3 Forecasting Approaches

There are two prominent approaches to forecasting: (i) Top-down and (ii) Bottom-up

Top-down approach: The top-down approach starts with forecasting the aggregate demand, narrowing down to the lower levels of demand. For example, the firm may first forecast the demand for the product, at the national level. The regional and local level demand can then be arrived at, based on the past sales history of these regions. Suppose a soap manufacturer arrived at a demand forecast, for the present year at 30,000 units. The regional sales percentage for last year for North, South, East and West are 10, 20, 40, 30 respectively. Thus, the demand forecasts for North, South, East, and West are 3,000, 6,000, 12,000, and 9,000 units, respectively. This centralized approach is more appropriate in cases where the product's demand is stable and uniform across the regions.

Bottom-up approach: In the bottom-up approach, a firm forecasts the demand separately for each of the markets it serves. By following this approach, the demand at each market can be forecasted more accurately. It also becomes easy to track and incorporate demand fluctuations occurring at the market level. However, this approach requires greater efforts, time, and resources. In addition, the firm may not be able to include certain systematic forecast factors (such as promotions that are run nationwide).

The above two approaches need not be considered in isolation by forecasters. Depending on the circumstances, both approaches can be integrated to achieve better results. As a thumb rule, the results arrived at using the top-down and bottom-up forecasts will be quite different. However, if the gap between the two results is too high, it could indicate the presence of some unwarranted discrepancies. In such cases, the firm can make further analysis to get the correct picture of the situation.

Example: Approach of Fine-Grained Demand Forecasting

The case was related to leveraging public trip history data from the New York City Bike Share program, also known as Citi Bike NYC. Citi Bike NYC had the slogan, “Unlock a Bike. Unlock New York.” They offer rental bikes, over 850 various rental locations throughout NYC. Citi Bike NYC’s challenge was as that of, retailers and consumer goods companies. How to best predict the dynamic demand helping them to allocate resources and deploy Bikes at right places at right times. If forecast of demand was low, it led to loss of revenue and customer confidence. Forecast of excess demand, led to unwanted inventory of bikes and escalated costs.

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The trip history was identifying the exact times of renting at a station and return at another station. This detailed transaction history was produced for forecasts and fine grained demand forecasting was used. Fine-grain demand forecasts could capture the patterns influencing demand very close to the demand to be met. Fine-grain demand forecasting had challenges. It moved away from aggregate forecasts. The level of processing required was not feasible with forecasting tools. Fine-grain demand forecasting helped forecasters in building localized models reflecting dynamics of a specific product, and in a given location.

Source: https://www.databricks.com/blog/2020/03/26/new-methods-for-improving-supply-chain-demand-forecasting.html , March 2020, Accessed on 11th August, 2022

3.4 Demand Forecasting Process

Following are the requirements of the demand forecasting process.

3.4.1 Understand the Objective of Forecasting

A firm needs to be clear about the objectives of the forecasting process. For every firm, the motive behind carrying out a forecasting exercise is to implement decisions, which are based on the forecast. Thus, first, the firm should identify the decisions that need to be implemented. It should also appraise all the concerned supply chain members, about these decisions. For example, if HP plans to run a discount sale, the dealers and logistics partners need to be aware of this plan, so that they can meet the demand effectively. All the participants should arrive at a consensus, about the forecast for the promotion period and decide upon a common action plan. If the members are not able to plan jointly, mismatches between the demand and supply would arise at various levels of the supply chain. This could also result in logistics problems, since transporters and warehouse operators would not have timely access to the promotion plan, resulting in a shortage of transportation vehicles and /or warehouse space, to meet the increasing customer demand.

3.4.2 Integrate Demand Planning and Forecasting

The forecast is the basis for most of the planning activities such as capacity planning, production planning, promotion planning, and various other functions like procurement and distribution. Hence, the firm has to integrate all these aspects right from the initial stages of working out the forecast. The above can be achieved, both at the information systems level and at the human resource management level. To facilitate the easy integration of different functional areas, the firm can form cross-functional teams representing all the departments.

3.4.3 Identify Major Factors that influence the Demand Forecast, Steps, and Customer Segments

The next step in the forecasting process is to determine the key factors that influence the demand forecast. These factors have already been discussed in the

section on forecasting considerations. The key task for the firm, here, would be to identify the major components that affect the forecast. For instance, if the firm is dealing with seasonal products, then seasonal factors would have a larger influence on the demand. Similarly, if the firm is dealing with FMCG products, then the promotional factor would play a greater role in influencing the demand.

3.4.4 Understand and Identify Customer Segments

The next step is identifying the customer segments. Under this, firms identify customers with similar service requirements, demand patterns, seasonality, etc., and cluster them into segments. For each such customer segment, the most appropriate forecasting method should be selected.

Example: Demand Forecasting in Retail industry

A leading retailer, with a multiple and diverse product portfolio, had presence globally through its stores. It realized that the demand forecasting models were not accurate which led to either overstocking or under stocking of its products as part of inventory, and led to diminished margins. The retailer especially could not predict high demand periods, which would have helped in business growth and increased margins. The retailer decided to use machine learning models to revamp its demand and supply forecasting strategy with the help of a company called Quantzig, who came up with an "Ensemble Machine Learning" solution. It had integrated predictions from multiple predictive models. This helped the retailer to forecast the demand for a substantial period like, next five years. The retailer also could benefit having 20% reduction of the lead time, 6% decrease in operating costs, 23% increase in profit margins, 25% reduction in unfulfilled orders and improved accuracy for sales demand by 8% on average of weekly and monthly.

The various variables included in demand forecasting for retail were: in-store displays, and external factors, seasonal demand, promotions, local competition, neighborhood changes, and climate. These variables were used in machine learning and the impact was studied on demand and, product inventory. This helped the retailer to address critical performance goals like: reliability of delivery time, optimized inventory, managing demand, higher order fulfillment, cycle time for fulfilling order, and inventory turnover.

Source: https://www.quantzig.com/case-studies/retail-demand-forecasting-optimized-supply-chain-operations/ June 2022, Accessed on 16/08/22

3.5 Forecasting Techniques

Selection of Appropriate Forecasting Technique: Forecasting techniques are statistical tools, which give the firm a clear picture of the future demand position. These techniques formulate 'models' about real-world situations. By manipulating

these models, firms can arrive at predictions for future status. Forecasting techniques are broadly classified into three categories – qualitative, time series, and causal techniques and are briefly described below.

Qualitative techniques: Qualitative techniques are those that depend primarily upon personal judgment - forecasts are made based on the ideas and experience of the persons involved in the forecasting process. These techniques are highly subjective in nature.

Time Series techniques: Time series techniques use historical data to make forecasts. The technique works on the premise that future demand can be determined by studying past demand patterns. Time series techniques provide firms with a proper approach for evaluating and understanding the past demand behavior pattern. This method is suitable, when the demand pattern is relatively stable and the market environment does not change, over a period. It is not suitable for new or innovative products (due to the lack of historical data).

Causal forecasting method: The causal forecasting method is used, when a variable that is to be forecasted depends on different environmental factors. Causal forecasting methods consider two types of variables: the dependent variable, on which forecast has to be made, and the independent variable, which is related to or influences the dependent variable. For example, the demand for FMCG products is dependent on pricing, promotion, and the demographic profile of the customers. This method establishes a statistical relationship between the dependent and independent variables. Regression analysis is a widely used causal forecasting method.

3.5.1 Time Series Forecasting Methods

Time series analysis is a widely used forecasting method, largely because it is simple and inexpensive to use. Forecasts obtained from this method can be a good basis for further analysis. The term 'time series' refers to a collection of well-defined data, which is obtained through repeated measurement, over a period. Weekly or monthly sales at each retail outlet of a company would qualify under this definition. The collected data is said to be well defined because it is collected at regular time intervals. Thus, data collected randomly or irregularly cannot be called a time series.

Time series analysis can be categorized into two broad categories, based on the complexity involved: static and adaptive.

3.5.2 Static Forecasting Methods

These methods are also known as basic time series forecasting techniques. Static forecasting methods assume that the estimates of trend and seasonal components do not vary from year to year. In this method, estimates of the trend and seasonal components are determined based on historical data, which is projected to obtain

future demand data. Static forecasting methods follow the procedure given below, to obtain forecasts:

- De-seasonalizing or decomposing the time series
- Identifying the trend and seasonal components
- Making the forecasts based on trend and seasonal components

Let us explore the static forecasting technique with the help of an example.

Consider a consumer appliances company, ABC Limited, that is planning to forecast future sales, based on the analysis of past demand data.

The firm has collected sales information for five years, on a quarterly basis, as given in Table 3.1.

Table 3.1: Quarterly Sales of ABC Limited in '000 units

Year	I	II	III	IV
2017	40	25	15	30
2018	38	26	13	28
2019	43	22	18	33
2020	45	29	14	30
2021	41	26	18	29

Source: ICFAI Research Center

As mentioned earlier, in order to forecast the future demand, the following steps need to be performed: Deseasonalizing the time series, estimating the trend and seasonal components, and making the forecast.

Deseasonalizing the time series: Deseasonalizing or decomposing the time series refers to identifying the seasonal variations in the time series and removing those effects. For this, first calculate the seasonal index. Later, using the seasonal indices, the effects of seasonality are removed from the time series.

Calculating seasonal index: Steps involved in calculating the seasonal index are as follows:

Step1: First, the 4-quarter moving total for the time series is calculated. The sum of sales for four quarters of the year 2017 i.e. 40+25+15+30 = 110 is calculated and placed at the mid data point of four values of the year 2017, between the II quarter and III quarter (See column four of Table 3.2). Then the moving total is calculated for the next set of four values, by dropping the first value i.e. the value of quarter-I of 2017 and adding the value of quarter-I of 2018. Therefore, the sum of the four values i.e. 25+15+30+38 is 108 and placed between the values of III and IV quarters of 2017. The next set of four values is III and IV quarters of 2017, and I and II quarters of 2018. The total i.e., 25 + 15 + 30 + 38 = 108, is placed between the IV quarter of 2017 and I quarter of 2018. Thus, this process of moving the four quarters and calculating the total is continued, until the last value of the time series is included in the calculation. The values of the four

quarters of 2021 are the last set of values. The total of these four quarters is placed between the II and III quarters of 2021.

The resultant values are shown in column four of Table 3.2.

Table 3.2: Calculation of 4-Quarter Center Moving Averages

Year (1)	Quarter (2)	Actual Sales (3)	4-quarter moving totals (4)	4-quarter moving averages (5) = (4)/4	4-quarter centered moving averages (6)	Percentage of actua to moving average values (7)
2017	I	40				
	II	25				
			110	27.5		
	III	15			27.25	55.05%
			108	27		
	IV	30			27.125	110.60%
2018			109	27.25		
	I	38			27	140.74%
			107	26.75		
	II	26			26.5	98.11%
			105	26.25		
	III	13			26.875	48.37%
			110	27.5		
	IV	28			27	103.70%
2019			106	26.5		
	I	43			27.125	158.53%
			111	27.75		
	II	22			28.375	77.53%
			116	29		
	III	18			29.25	61.54%
			118	29.5		
	IV	33			30.375	108.64%
2020			125	31.25		
	I	45			30.75	146.34%
			121	30.25		
	II	29			29.875	97.07%
			118	29.5		
	III	14			29	48.28%
			114	28.5		
	IV	30			28.125	106.67%
2021			111	27.75		
	I	41			28.25	145.13%
			115	28.75		
	II	26			28.625	90.83%
			114	28.5		
	III	18				
	IV	29				

Source: ICFAI Research Center

Step 2: Then, the 4-quarter moving average is calculated. This is obtained by dividing the values of 4-quarter moving totals (obtained in column four of Table 3.2) by four. Therefore, the moving average of the first set of values is 110/4 = 27.5. Similarly, moving averages are calculated for the rest of the values in column four of Table 3.2. These values are shown in column five of Table 3.2.

Step 3: Then, the moving averages are centered. The moving averages in column five fall halfway between the quarters of each year. Average of two four-quarter moving averages falling just above and below the quarter is calculated to center out the averages. For quarter-III of 2017, the resulting four-quarter centered moving average is 27.25. This was obtained by taking the average of two moving averages i.e. (27.5 + 27)/2 = 27.25. Similarly, the other values of column five of Table 3.2 are centered out. These are shown in column six of Table 3.2. (Step 3 is not required if the number of values is odd as the values will be centered out in step 2 itself.)

Step 4: For each quarter that is having a 4-quarter centered out moving average, the percentage of actual value to the moving average is calculated. The step is performed to regain the seasonal component of the quarters. The percentage is obtained by dividing the actual quarter value, with each associated 4-quarter centered moving average value. Then the resulting value is multiplied by 100.

Therefore, for quarter III of 2017, the value is (15/27.25) × 100 = 55.05%. Similarly, other values are calculated and shown in column seven of Table 3.2.

Step 5: The values obtained in column seven are arranged by quarter (as shown in Table 3.3), and the modified mean is calculated. The modified mean is obtained, by removing the highest and lowest values for each quarter and taking an average of the remaining values.

For example, for quarter I, the highest and lowest values are 158.53 and 140.74, respectively. By canceling these and totaling the remaining values, we get the modified sum as 291.47. Then, the modified mean of quarter I is 291.47/2 = 145.74

Similarly, for quarter II, the highest and lowest values are 98.11 and 77.53, respectively. By canceling and totaling the remaining values, we get the modified sum as 187.9. Thus, the modified mean of quarter II is 187.9/2 = 93.95 as given below in Table 3.3.

Table 3.3: Calculating Modified Mean

Year	Quarter I	Quarter II	Quarter III	Quarter IV
2017	--	--	55.05	--
2018	--	--	48.37	--
2019	--	--	--	108.64
2020	146.34	97.07	--	106.67
2021	145.13	90.83	--	--
Modified Sum	291.47	187.90	103.42	215.31
Modified Sum	145.74	93.95	51.71	107.65

Source: ICFAI Research Center

By removing the highest and lowest values for each quarter, the extreme irregular variations are removed. By averaging the rest of the values, the time series is further smoothed. Thus, the modified mean represents the seasonality component.

Step 6: In the final step, the modified mean is further adjusted to obtain the seasonal index.

From Table 3.3, the total of 4 indices = 145.74 + 93.95 + 51.71 + 107.65 = 399.

However, 100 is the base for the index. Hence, the total of four quarterly indices should be 400, and the mean of the indices needs to be 100. In order to rectify the error, the seasonal indices are adjusted by multiplying each index by an adjusting constant as shown below in Table 3.4.

Table 3.4: The Calculation of Seasonal Indices

Quarter (1)	Index (2)	Adjusting constant (3)	Seasonal Index (4) = (2) x (3)
I	145.74	1.0025	146.10
II	93.95	1.0025	94.18
III	51.71	1.0025	51.83
IV	107.65	1.0025	107.92

Source: ICFAI Research Center

The adjusting constant is obtained by dividing the desired index total, i.e. 400 by the actual total of 399. The value obtained is 400/399 = 1.0025.

The process of adjusting the modified mean and obtaining seasonal index is shown in Table 3.4.

Seasonal indices for different quarters are shown in column four of Table 3.4. The next step is calculating the Deseasonalized time series values. To obtain Deseasonalized time series values, the actual sales values are divided by the resultant value achieved by dividing corresponding seasonal indices with 100. Deseasonalized sales are calculated for various quarters in Table 3.5

Table 3.5: Calculating Deseasonalized Sales Values

Year (1)	Quarter (2)	Actual Sales (3)	Seasonal Index/100 (4)	Deseasonalized Sales (5) = (3)/(4)
2017	I	40	1.461	27.38
	II	25	0.942	26.54
	III	15	0.518	28.96
	IV	30	1.079	27.80
2018	I	38	1.461	26.01
	II	26	0.942	27.61
	III	13	0.518	25.10
	IV	28	1.079	25.95

Contd….

2019	I	43	1.461	29.43
	II	22	0.942	23.36
	III	18	0.518	34.76
	IV	33	1.079	30.58
2020	I	45	1.461	30.80
	II	29	0.942	30.79
	III	14	0.518	27.03
	IV	30	1.079	27.80
2021	I	41	1.461	28.06
	II	26	0.942	27.61
	III	18	0.518	34.76
	IV	29	1.079	26.87

Source: ICFAI Research Center

Developing trend component

After deseasonalizing the time series, a trend component of the time series is calculated. This can be done, using the least-squares method. The time variable (years 2018, 2019, etc. in this case) is converted into a form, which would simplify the calculation. This conversion of the time variable is accomplished using a technique called coding. In this technique, the mean of all the sample times is calculated, and then the resultant value is subtracted from each of the sample times. Table 3.6 provides the details.

Table 3.6: Calculations for Developing the Trend Equation

Year (1)	Quarter (2)	Y Deseason-alized Sales (Column 5 of Table 3.5) (3)	Translat-ing or Coding the Time Variable (4)	x Coded Time Variable (5) = (4)x2	Xy (6) = (5)x(3)	x^2 (7) = (5)2
2017	I	27.38	-9 ½	-19	-520.22	361
	II	26.54	-8 ½	-17	-451.18	289
	III	28.96	-7 ½	-15	-434.4	225
	IV	27.8	-6 ½	-13	-361.4	169
2018	I	26.01	-5 ½	-11	-286.11	121
	II	27.61	-4 ½	-9	-248.49	81
	III	25.1	-3 ½	-7	-175.7	49
	IV	25.95	-2 ½	-5	-129.75	25
2019	I	29.43	-1 ½	-3	-88.29	9
	II	23.36	- ½	-1	-23.36	1
Mean			0			
	III	34.76	½	1	34.76	1
	IV	30.58	1 ½	3	91.74	9

Contd….

2020	I	30.8	2 ½	5	154	25
	II	30.79	3 ½	7	215.53	49
	III	27.03	4 ½	9	243.27	81
	IV	27.8	5 ½	11	305.8	121
2021	I	28.06	6 ½	13	364.78	169
	II	27.61	7 ½	15	414.15	225
	III	34.76	8 ½	17	590.92	289
	IV	26.87	9 ½	19	510.53	361
		$\sum y$ = 567.2			$\sum xy$ = 206.58	$\sum x^2$ = 2,660

Source: ICFAI Research Center

The idea behind this exercise is to eliminate the need for squaring large numbers like years 2019, 2020. By setting the mean as zero, the calculations are simplified to a great extent. Suppose we are dealing with three time points - years 2019, 2020 and 2021. We assign the codes -1, 0, 1 to the respective years, where zero represents the mean (year 2020), -1 represents the last or previous year (2019), and 1 represents the next year (2021). This translation process will differ, depending upon the number of time periods. If the problem consists of an odd number of time periods, the mean can be easily found out. For instance, if there were 7 time points, then the mean would be the middle of the time points i.e. 4. However, if the time points are even in number, then the mean would contain a '½ fraction', which if subtracted from each time point, would make the calculations cumbersome. To overcome this problem, each time variable is multiplied by 2. The coded variable is denoted by x. In this problem, the time points are 20, the mean is 9½, which falls between the II quarter and III quarter of 2020. The first value i.e., Quarter I of 2017 is assigned as -9½ and the last value i.e. quarter IV of 2021 is assigned as 9½. The translating time variable is shown in column four of Table 3.6, and the coded time points, which are obtained by multiplying the translating variables with two, are shown, in column five of Table 3.6. Now using the least squares method, the trend component is developed. The trend component is obtained using the equation:

$$\hat{y} = a + bx$$ ----------Equ. 3.1

Where $\hat{y}$ = estimated value of the dependent variable

x = independent variable (time in trend analysis)

a = y-intercept (the value of y when x = 0) = $\bar{y}$ = y/n

b = slope of the trend line = $\frac{\sum xy}{\sum x^2}$

By substituting the values of xy, x^2, y, and n, the values of a and b are 28.36 and 0.08, respectively.

Therefore, $\hat{y}$ = 28.36 + 0.08x ----------Equ. 3.2

Now, various values of x can be substituted in Equ. 3.1 and the estimated values of $\hat{y}$ for each value of x can be calculated. The calculation is shown in Table 3.7.

Making the forecast

The final step in the static forecasting method is to forecast the demand for future periods. The following steps are followed, in forecasting the demand.

Step 1: Calculate the trend level for the periods, for which forecast needs to be made, using the trend equation.

Step 2: Next step is to multiply the trend level from Step 1, with the period seasonal index to include seasonal effects.

Step 3: Then multiply the result of Step 2, by the projected cyclic index to include cyclic effects and get the final forecast result.

Suppose the firm wants to forecast, for all the four quarters of the year 2020.

First, all four quarters of the year 2022 need to be coded. The coded value after multiplying by two for the last quarter (IV) of 2021 is 19. Looking at the trend in Table 3.6, it can be easily estimated that the coded time variable, for the four quarters of 2022 will be 21, 23, 25 and 27, respectively.

Substituting these values in Equ. 3.2, we get $\hat{y}$ for I, II, III, and IV quarter of 2022 as 30.04, 30.2, 30.36 and 30.52, respectively.

Next step is to calculate the seasonalized estimates, by multiplying the deseasonalized sales estimates, with the respective seasonal indices and expressing them as a fraction of 100. Seasonal indices for the four quarters are shown in Table 3.4.

Seasonalized estimates for quarter I of 2022: 30.04 × (146.1/100) = 43.89

Seasonalized estimates for quarter II of 2022: 30.2 × (94.18/100) = 28.44

Seasonalized estimates for quarter III of 2022: 30.36 × (51.83/100) = 15.72

Seasonalized estimates for quarter IV of 2022: 30.52 × (107.92/100) = 32.94

Table 3.7 shows the trend components calculations.

Table 3.7: Trend Component Calculations

x (From column 5 of Table 3.6)	$\hat{y}$ = a +bx = 28.36 + 0.08x
-19	28.36+0.08(-19) =26.84
-17	28.36+0.08(-17) = 27
-15	28.36+0.08 (-15) = 27.16
-13	28.36+0.08 (-13) = 27.32

Contd….

-11	28.36+0.08 (-11) = 27.48
-9	28.36+0.08 (-9) = 27.64
-7	28.36+0.08 (-7) = 27.8
-5	28.36+0.08 (-5) = 27.96
-3	28.36+0.08 (-3) = 28.12
-1	28.36+0.08 (-1) = 28.28
1	28.36+0.08 (1) = 28.44
3	28.36+0.08 (3) = 28.6
5	28.36+0.08(5) = 28.76
7	28.36+0.08(7) = 28.92
9	28.36+0.08(9) = 29.08
11	28.36+0.08(11) = 29.24
13	28.36+0.08(13) = 29.4
15	28.36+0.08(15) = 29.56
17	28.36+0.08(17) = 29.72
19	28.36+0.08(19) = 29.88

Source: ICFAI Research Center

Check Your Progress - 1

1. Which is the most important benefit of Demand Forecasting?
   a. Strategic Planning
   b. Day to day planning
   c. Capacity additions
   d. Reducing inventories
   e. Manpower reduction
2. In the case of the Fast-Moving Consumer Goods industry, which is the most applicable forecasting component?
   a. Base Demand
   b. Seasonal demand
   c. Trends
   d. Promotional strategies
   e. Yclical factors
3. Which forecasting approach is best suitable, for a capital goods manufacturer?
   a. Top-down approach with a global perspective
   b. Bottom-up approach with a local perspective
   c. Top-down approach with a national perspective

d. Bottom-up approach with a national perspective
e. Combination of both top-down and bottom-up approaches

4. Which of the following is not a part of developing a forecasting process?
   a. Understanding the objective
   b. Integrating demand planning and forecasting
   c. Analysis of the existing infrastructure
   d. Identify and understand the customer segments
   e. Determine the appropriate forecasting technique
5. Which of the following is not an appropriate forecasting technique for new and innovative products?
   a. Time-séries technique
   b. Qualitative technique
   c. Causal technique
   d. Combination of a and b
   e. Combination of b and c

3.5.3 Adaptive Forecasting

Adaptive forecasting is an advanced form of time series analysis, where the trend and seasonal components are adjusted, after each demand observation.

There are three widely used adaptive forecasting methods. They are moving average, simple exponential smoothing, and trend adjusted exponential smoothing.

Moving average

Moving average is the simplest method in adaptive forecasting techniques. In this method, the first step is the selection of time period for which moving averages of demand are calculated. In calculating moving averages, recent figures are considered, and old figures are omitted. For example, you have the sales data, for the last six months i.e. from January to June and you want to calculate three-month moving averages. The first moving average will consider the data from January to March, in the second moving average, January data will be dropped, and April data will be added. Moving average method is useful when the demand does not show any trend and seasonal variation.

So, in order to make the forecast for the time period t+1, the average of demand for previous time periods until t is calculated. The formula for moving averages is given by

$F_{t+1} = [Y_t + Y_{t-1} + ... + Y_{t-n+1}] / n$----------Equ. 3.3

The successive values are forecasted, by dropping the older values and adding new values.

Let us use this method to make forecasts for S.G Refrigerators Limited. Table 3.8 shows monthly demand for S.G Refrigerators for the year 2022 (From January 2022 to April 2022).

Table 3.8: Monthly Demand for S.G Refrigerators

Period	Demand	Moving Average (4 Months)
January	330	
February	315	
March	302	
April	308	
May		313.75(F_5)
June		317(F_6)
July		326.25 (F_7)

Source: ICFAI Research Center

To forecast the demand for May, the demands during Jan, Feb, Mar, and Apr are considered.

$F_5 = F_{4+1} = [Y_4 + Y_3 + Y_2 + Y_1]/4$

$= [308+302+315+330]/4$

$= 313.75$

If the actual values in May were 343 units, the forecast for June will be:

$F_6 = F_{5+1} = [Y_5 + Y_4 + Y_3 + Y_2]/4$

$= [343+308+302+315]/4$

$= 317$

If the June sales were 352, the July forecast would be:

$F_7 = F_{6+1} = [Y_6 + Y_5 + Y_4 + Y_3]/4$

$= [352 + 343 + 308 + 302]/4$

$= 326.25$

Simple exponential smoothing

One of the widely used and successful forecasting methods is the exponential smoothing technique. In this technique, the forecast, for the future periods, is calculated, by taking the weighted average of all the previous values. The method assumes that the most recent value is the most important for forecasting future values. The weightage declines progressively, for the earlier time periods.

$F_{t+1} = \alpha Y_t + \alpha (1- \alpha)Y_{t-1} + \alpha (1- \alpha)^2 Y_{t-2} + \alpha (1- \alpha)^3 Y_{t-3} + \alpha (1- \alpha)^4 Y_{t-4}$ +--Equ 3.4

Where:

F_{t+1} is the forecast for the next period.

Y_t is the actual value of the current period

Y_{t-1}, Y_{t-2}, Y_{t-3}.....are values of previous time periods.

α is called the smoothing constant, which is a fractional value. Its value lies between zero and one.

From the above equation, we can observe two points.

Since α <1, the weightage becomes smaller as we move back in time, to earlier time periods. This is evident from Equation 3.4, where each weight is obtained by multiplying (1- α) with the previous weight. Going further, we can see that, if we want to give more weightage to recent data in comparison to older data, we must use a large value of α.

The sum of the weights assigned to various values is equal to unity.

The simplified form of Equation 3.4 is

$F_{t+1} = \alpha Y_t + (1- \alpha_t) F_t$

$= F_t + \alpha (Y_t – F_t)$ ----------Equ. 3.5

Using the same data given in Table 3.8, we can forecast the demand for S.G. Refrigerators, using the simple exponential smoothing method.

Exponential forecasting method is a recursive process, where the current forecast is based on the previous forecast values. This method requires an initial forecast value, to start the forecasting process (If this is not available, we start with the actual value of January as the forecast value for February). Therefore, we forecast from January itself and assume the initial forecast for January as 317.

Initial forecast $F_1 = 317$ and $\alpha = 0.1$

By substituting values in Equ. 3.5, we can forecast in the following manner.

For the month of February (t = 1), forecast value is

$F_{1+1} = F_2 = F_1 + 0.1(Y_1 – F_1)$

$= 317 + 0.1(330 – 317) = 318.3$

If the actual demand in February was 315, for the month of March (t = 2), the forecast value is

$F_{2+1} = F_3 = F_2 + 0.1(Y_2 – F_2)$

$= 318.3 + 0.1(315 - 318.3) = 317.97$

Similarly, if the actual demand in March was 302, for the month of April (t=3), forecast value is

$F_{3+1} = F_4 = F_3 + 0.1(Y_3 – F_3)$

$= 317.97 + 0.1(302 – 317.97) = 316.37$

Similarly, for the rest of the time periods, forecasted values can be calculated. The calculated forecasted values are shown in Table 3.9.

Table 3.9: Calculation of Forecasted Values

Period	Demand Y_t	Forecast F_t
Jan	330	317
Feb	315	318.3
Mar	302	317.97
Apr	308	316.37
May	343	315.54
Jun	352	318.28
Jul		321.65

Source: ICFAI Research Center

Trend-adjusted exponential smoothing (Holt's model)

The moving averages method and simple exponential smoothing model assume that the demand variable does not show any trend. Thus, two models cannot provide accurate forecasts, if the demand shows a continuing trend. Holt's model overcomes the inherent defects of these models, by adjusting the forecast for the trend component. This model first forecasts using simple exponential smoothing and then adjusts the forecast for a positive or negative trend.

If Y_t is the actual demand, then we need to first obtain smoothed level S_t by using the following equations:

$S_t = \alpha Y_t + (1- \alpha) (S_{t-1} + B_{t-1})$ ----------Equ. 3.6

$B_t = \beta (S_t – S_{t-1}) + (1- \beta) B_{t-1}$ ----------Equ. 3.7

Where:

S_t = smoothed level at time t

A = smoothing constant, as defined earlier in the simple exponential smoothing technique

B_t = trend level at time t

β=smoothing constant for the trend similar to α, with the value ranging between 0 and1

After obtaining the S_t and B_t, the forecasted values can be calculated using the following equation

$F_{t+m} = S_t + mB_t$ ----------Equ. 3.8

The value of m is dependent on the period, from which reference values (actual and forecasted demand) are taken. For example, to forecast for July using the actual and forecasted figures of June, the value of m will be one. Similarly, to forecast for August using the actual and forecasted figures of June, the value of m will be two.

If the values of β are higher, the model is more sensitive to the recent changes in the trend, and if its values are lower, the model is slow to react to the recent trend changes.

Let us make forecasts for S.G. Refrigerators, using Holt's model.

We assume $S_0 = 317$, $B_0 = 0$, $\alpha = 0.1$, and $\beta = 0.2$. As we are using the immediately preceding values (actual and forecasted) to forecast demand values, the value of m is taken as one. Substituting these values in Equ. 3.6 and Equ. 3.7, we get

$S_1 = \alpha Y_1 + (1- \alpha) (S_0 + B_0)$

$= 0.1 (330) + (1 – 0.1) (317+0)$

$= 33 + 285.3$

$= 318.3$

$B_1 = \beta (S_1 – S_0) + (1 – \beta) B_0$

$= 0.2 (318.3 – 317) + (1 – 0.2) \times 0 = 0.26$

By substituting the values of S_1 and B_1 in the Equ. 3.8, we get

Forecast value for the month of February, $F_{1+1} = 318.3 + 1\times 0.26 = 318.56$

Similarly,

$S_2 = \alpha Y_2 + (1 – \alpha) (S_1 + B_1)$

$= 0.1(315) + (1 – 0.1) (318.3 + 0.26)$

$= 31.5 + 286.7$

$= 318.2$

$B_2 = \beta (S_2 – S_1) + (1- \beta) B_1$

$= 0.2 (318.2 – 318.3) + (1 – 0.2) \times 0.26$

$= 0.189$

By substituting the values of S_2 and B_2 in the Equ. 3.8, we get

Forecast value for the month of March, $F_{2+1} = 318.2 + 1\times (0.189)$

$= 318.39$

Similarly, we can calculate for the rest of the periods. The calculated forecast values are shown in Table 3.10.

Table 3.10: Calculating Forecasts for S. G. Refrigerators Using Trend-Adjusted Exponential Smoothing

Period (1)	Demand Y_t (2)	Smoothed level S_t (3)	Trend B_t (4)	Forecast F_t (5)
Jan	330	318.3	0.26	317
Feb	315	318.2	0.189	318.56
Mar	302	316.75	-0.139	318.39
Apr	308	315.75	-0.311	316.61
May	343	318.20	0.240	315.44
Jun	352	321.79	0.911	318.44
Jul				322.70
Aug				323.61

Source: ICFAI Research Center

Forecasts for July and August months, for which historical values are not available, can be calculated in the following manner:

$F_{6+1} = S_6 + 1 \times B_6$ (m = 1 as we are forecasting for July based on June figures)

$= 321.79 + 1 \times 0.911$

$= 322.70.$

$F_{6+2} = S_6 + 2 \times B_6$ (m = 2 as we are forecasting for August and using the figures of June)

$= 321.79 + 2 \times 0.911$

$= 323.61$

3.5.4 Selection of Appropriate Forecasting Technique

Selecting an appropriate forecasting technique is a crucial step, in the demand.

Forecasting process, where the firm needs to analyze various issues. These may include the stage of the product life cycle, the geographical region, the customer group, etc. If the product is in the early stages of its life cycle (i.e., when the product has been launched recently), then it would have little or no sales history. In such cases, judgmental techniques would be more appropriate. However, if the product is in the maturity stage, time series techniques can be used, since a lot of data would be easily available. When detailed sales-related data is available for a product, causal techniques can be the right option.

Example: Forecasting Techniques at Bike Rentals

Citi Bike NYC was a company with a slogan "Unlock a Bike. Unlock New York." Their service helps people to rent and leave a bike among 850 various rental locations throughout the NYC area. Citi Bike NYC's challenge was similar to a retailers and consumer goods companies, predicting demand for allocating resources at right time and place. Underestimating demand led to effect on revenue opportunities, and loss of customer base. Overestimating demand led to excess inventory of bikes. The trip history data which identified the time and rental station where a bike was hired, and the time and rental station where bike was returned. These rental transaction history was used to produce forecasts.

One approach of forecast used, to leverage Poisson regression capabilities which were adopted in traditional time series model. Second potential solution was to model the scale of non-zero values - the frequency of the occurrence of the zero-valued periods, and combine output of each model for forecast. Decision trees, in general, did not impos0065 the same constraints as general statistical methods on data distribution. They transformed rentals using a square root transformation before training the model. To leverage this model, they needed few additional features. There were strong seasonal patterns in the data, on daily, weekly and annual levels. That helped to extract year, month, day of week day as features.

Source: https://www.databricks.com/blog/2020/03/26/new-methods-for-improving-supply-chain-demand-forecasting.html March 2020, Accessed on 11th August, 2022

3.6 Measures of Forecast Error

The accuracy of the forecasts can be determined by comparing the forecasted values with actual sales figures. The difference between the actual value and the forecasted value is referred to as the forecast error. Table 3.11 shows the forecast errors.

Table 3.11: Calculating Measures of Forecast Error for S.G. Refrigerators
(For forecasts made using Simple Exponential Smoothing Technique)

Period (1)	Demand Y_t (2)	Forecast F_t (3)	Forecast error E_t (Y_t-F_t) (4)	Squared error E_t^2 (5)	Absolute Error A_t $(\|E_t\|)$ (6)	Absolute Percentage error $(\|A_t/Y_t\| \times 100)$ (7)
Jan	330	317	13	169	13	3.94
Feb	315	318.3	-3.3	10.89	3.3	1.04
Mar	302	317.97	-15.97	255.04	15.97	5.29
Apr	308	316.37	-8.37	70.06	8.37	2.72
May	343	315.54	27.46	754.05	27.46	8.01
Jun	352	318.28	33.72	1137.04	33.72	9.58
Sum				2396.07	101.82	30.53

Source: ICFAI Research Center

Table 3.12: Calculating Measures of Forecast Error for S. G. Refrigerators
(For forecasts made using Trend-adjusted Exponential Smoothing)

Period (1)	Demand Y_t (2)	Smoothed level S_t (3)	Trend B_t (4)	Forecast F_t (5)	Forecast error $E_t = (Y_t-F_t)$ (6)	Squared Errors E_t^2 (7)	Absolute Error $A_t = (\|E_t\|)$ (8)	Absolute Percentage error $(\|A_t/Y_t\| \times 100)$ (9)
Jan	330	318.3	0.26	317	13	169	13	3.93
Feb	315	318.2	0.189	318.56	-3.56	12.67	3.56	1.130
Mar	302	316.75	-0.139	318.39	-16.39	268.63	16.39	5.42
Apr	308	315.75	-0.311	316.61	-8.61	74.13	8.61	2.79
May	343	318.20	0.240	315.44	27.56	759.55	27.56	8.034
Jun	352	321.79	0.911	318.44	33.56	1126.27	33.56	9.53
Sum						2410.26	102.68	30.86

Source: ICFAI Research Center

The forecast error indicates the level of over and under estimation as compared to the actual values. If the forecast error is positive, it indicates that the forecast value has underestimated the sales figures and if the forecast error is negative, it indicates that the forecast value has overestimated the sales figures.

Forecast error is denoted by E_t and it is obtained by

$E_t = Y_t - F_t$

Where Y_t is the actual sales value and F_t is the forecasted value.

There are three key measures of forecast error- Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE).

3.6.1 Mean Absolute Deviation (MAD)

Mean Absolute Deviation is a simple method that measures the dispersion (or variation) of observed values, around the expected values.

MAD is the mean of the errors made by the forecast over a period of time, without considering the direction of error i.e. method does not determine, whether the forecast was an overestimate or underestimate. MAD is calculated by adding up the differences between the forecast value and the actual demand, for each period of time and dividing the sum by the number of periods. Therefore, MAD is described as the sum of the absolute deviations divided by the number of data points. It can be expressed in the form of an equation as:

$$MAD = \frac{1}{n}\sum_{t=1}^{n} A_t$$

Where,

$A_t = |Y_t - F_t|$ = Indicates the absolute value of deviation

Y_t = Actual demand in the period t

F_t = Forecasted demand for the period t

n = Number of periods considered

Let us now find out the MAD for the forecasts made for S.G. Refrigerators, using the exponential smoothing technique and trend-adjusted exponential smoothing method.

Simple exponential smoothing technique

From column 6 of Table 3.11, we get $\sum_{t=1}^{6} A_t$ = 101.82

In addition, there are six forecasts.

Therefore, MAD = 101.82/6

= 16.97

Trend adjusted exponential smoothing method

From column 8 of Table 3.12, we get $\sum_{t=1}^{6} A_t$ = 102.68

In addition, there are six forecasts.

Thus MAD = 102.68/6

= 17.11

3.6.2 Mean Squared Error (MSE)

Mean Square Error is a measure of forecast accuracy, in which the mean of the squares of deviations of forecast values from the actual result is calculated. It is expressed as:

$$\text{MSE} = \frac{1}{n}\sum_{t=1}^{n} E_t^2$$

where $E_t = Y_t - F_t$

As can be seen from the above equation, large errors are penalized more than the small ones because of squaring. Let us now find out the MSE for the forecasts made, using exponential smoothing technique and trend-adjusted exponential smoothing method.

Simple exponential smoothing technique

From column 5 of Table 3.11, we get $\sum_{t=1}^{6} E_t^2$ = 2396.07

Therefore MSE = 2396.07/6

= 399.34

Trend adjusted exponential smoothing method

From column 7 of Table 3.12, we get $\sum_{t=1}^{6} E_t^2$ = 2410.26

Therefore MSE = 2410.26/6

= 401.71

3.6.3 Mean Absolute Percentage Error (MAPE)

Though MAD and MSE provide information on the extent of error in the forecast model, they do not indicate the relative errors. MAPE, however, indicates a relative error. MAPE is calculated using the following equation:

$$\text{MAPE} = \frac{\sum_{t=1}^{n} \frac{|Y_t - F_t|}{Y_t} \times 100}{n}$$

Simple exponential smoothing technique

From column 7 of Table 3.11, we get $\sum_{t=1}^{6} \frac{|Y_t - F_t|}{Y_t} \times 100$ = 30.53

Therefore, MAPE = 30.53/6 = 5.08%

Trend adjusted exponential smoothing method

From column 9 of Table 3.12, we get $\sum_{t=1}^{6} \frac{|Y_t - F_t|}{Y_t} \times 100 = 30.86$

Therefore, MAPE = 30.86/6 = 5.14%

Using these measures of forecasting errors, the firm can evaluate the utility of the forecasting methods, in obtaining accurate forecasts. Table 3.13 summarizes the forecasting error measures of three forecasting techniques, for the above two examples.

Table 3.13: Comparison of Forecasting Error Measures

Forecasting method	MAD	MSE	MAPE
Exponential smoothing	16.97	399.34	5.08%
Trend adjusted exponential smoothing	17.11	401.71	5.14%

Source: ICFAI Research Center

Example: Accuracy Identification of Forecast Demand made at OEM Company at Europe

The future demand forecasting estimating techniques (baseline, statistical, and Machine Learning -ML algorithms) of an automotive OEM company located in Europe were studied by three researchers from Slovenia. Multiple metrics and criteria were adopted to assess forecasting models' performance using 'R^2 adj (corrected goodness-of-fit model accuracy measure for linear models), MASE-Mean absolute scale error (mean absolute error of the forecast values, divided by the mean absolute error of the in-sample one-step naive forecast), the ratio of forecasts with less than 30% error, and the ratio of forecasts with under-estimates, which were all magnitude-agnostic. This helped to assess the statistical significance of results. The best MASE performance was observed on models created: same demand type group of products. ML batch models displayed a more robust performance. Building a single demand forecasting model for multiple products drove better performance and more engineering implications.

Source: https://www.mdpi.com/2076-3417/11/15/6787/html 2021, Accessed on 12th August, 2022

Check Your Progress - 2

6. What is Adaptive forecasting?
   a. It is a form of Time Series Analysis
   b. It just employs Moving Average Method only
   c. It employs Simple Exponential Smoothing Method only
   d. It employs Adjusted Exponential Smoothing only
   e. Is a qualitative technique

7. Which is the adaptive forecasting method to be followed, when the demand does not show any trend and seasonal variation?
   a. Moving Average
   b. Exponential Smoothing
   c. Trend Adjusted Exponential Smoothing
   d. Casual technique
   e. Non-time series method
8. Which of the following methods is called "Holt's Model"?
   a. Moving Average
   b. Exponential Smoothing
   c. Trend Adjusted Exponential Smoothing
   d. Qualitative techniques
   e. Casual technique
9. Which of the following statements is not true, for describing the Forecasting Error?
   a. It is the difference between forecasted demand and actual demand.
   b. It indicates the level of over and under estimation, as compared to the actual value.
   c. Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Mean Absolute Percentage Error (MAPE) are key measures of Forecast Error.
   d. Forecast error is obtained by the formula $E_{t=} Y_{t -} F_{t,}$ where E is the error, where Y is demand forecasted and F is the actual demand.
   e. It is an error representing the difference between forecasts made, by the internal marketing department and external consultants.
10. Which of the following is the most widely used and successful forecasting methods?
    a. Moving Average
    b. Simple exponential smoothing
    c. Trend adjusted Exponential Smoothing
    d. Qualitative techniques
    e. Casual technique

3.7 Challenges in Demand Forecasting

Forecasting is a major challenge in a volatile business environment. Many retailers find forecasting challenging but they prioritize it because it is generally

accepted that better demand forecasting helps improve cost-effectiveness and availability in the supply chain.

However, what is it that retailers find especially difficult when it comes to forecasting? Martec International (a leading provider of industry training, knowledge, and insight on retailers, consumer goods companies, and suppliers to retail) found that retailers listed the hardest challenges as follows:

- Forecasting new product introductions
- Coping with challenges related to sales volumes
- Forecasting promotions and promotional lift

Promotions play a significant role in sales promotion, especially in retail and emerging B2C business operations. Initiatives taken provide the necessary upward swing to the sales activity.

3.7.1 The Challenge of New Products

Forecasting new product introductions are becoming increasingly important, as the product life cycle shortens and assortment turnover increases. It poses a particular challenge in speciality retail sectors such as electronics, fashion, books, and gardening, where new product introductions and heavily refreshed seasonal assortments account for the bulk of sales. One of the extreme cases is the book industry, where, as a rule, more than 90% of items sold are new that year. Therefore, if you do not get the forecasting of product introductions right, you can forecast only a small fraction of your business.

Good examples of customers, who have cracked the new product forecasting conundrum, are some European book retail chains, both market leaders in their respective countries. They have implemented a process, where forecasting, for new items, is also carried out automatically- it is done by searching the historical assortment, for items with similarities to those being introduced, and building a forecast from that. The results, in this high assortment turnover and highly seasonal business, have been great - availability has increased several percentage points to the near-perfect level and, simultaneously inventory values and markdowns have reduced considerably. Additionally, the whole business of managing introductions is far simpler, as staff does not have to spend huge amounts of time, hunting down reference products. With a large assortment, this process is, in practice, almost always very inaccurate, as there are simply too many new products to map them correctly.

3.7.2 How to Tackle Variance in Sales Volume?

Coping with changes in sales volumes is pretty much inevitable, in modern retail environments. This should be a standard feature of most retail forecasting processes. The key, to tackling these change situations effectively, is to bring together statistical forecasting with human insight. Typically, humans react too

quickly to changes and give too much weight to recent events, even though they are probably well within the bounds of normal statistical distribution and best interpreted as such. However, sometimes a change can indeed be traced to wider market conditions and that is where our ability, to infer a causal link from events, serves us well. This is where humans still outperform computers.

Having a solution that can map these exceptional situations and present data for effective manual checking and commenting, enables supply chain teams to react far more quickly. A good system gives a dispassionate overview of the situation, directly comparing recent and historical changes, and this context means that managers can quickly make a judgement whether a change is 'just one of those things' or linked to specific external or internal factors.

Example: Demand forecasting and Navigating the Supply Chain during Holiday Season

Port delays, enhancing consumer demand and need for holiday season forecasting, impacted demand forecasting especially the holiday preparations for retail industry like Walmart. Walmart had been doing holiday forecast and customer services for last 50 years and wanted to improve every year to help ensure product orders reached the customers on right time. First challenge was to work with suppliers to source holiday merchandise earlier than usual. Second challenge was on inventory levels. Walmart aimed at chartered ships and diverted shipments through less congested ports. Next challenge focus was on land transportation to avoid rail delays. Getting ready with additional drivers was added challenge. Adding new employees and training them on their processes was crucial. Focus on storage capacity, which would be a challenge with sudden spurt of demand was next challenge. Enhance delivery capabilities and plan optimum routing was one of the required challenge to address.

Source: https://corporate.walmart.com/newsroom/2021/10/08/how-walmart-is-navigating-the-supply-chain-to-deliver-this-holiday-season October 2021, Accessed on 12th August, 2022

Activity 3.2

One industry that benefits immensely by adopting innovative forecasting techniques to face market challenges is the automobile industry. For a significant period, all major players in the industry enjoyed reasonable market share and profitability. The industry became very competitive, with the deployment of technologies in products and processes to make their supply chain agile and efficient.

However, even before the advent of Covid-19, the industry started witnessing a slump and entered the recession. A new dimension has been added to the competition, by the entry of electric vehicles.

Taking petrol and diesel automobiles into consideration, analyze the challenges being faced by the industry, especially regarding demand forecasting.

3.8 Summary

- Demand forecasting is critical to the efficient functioning of the supply chain process, as it forms the basis for the planning activities in the supply chain.
- An accurate forecast optimizes the inventory level and improves the supply chain's responsiveness.
- Key components in a forecast: base demand, seasonal factors, trends, cyclical factors, promotions, and irregular quantities.
- Two types of forecasting approaches are top-down and bottom-up.
- The three types of forecasting methods examined are Qualitative, Time series and Causal techniques.
- The two-time series forecasting techniques discussed are the static and adaptive techniques.
- The three key adaptive forecasting techniques are, moving averages, simple exponential smoothing technique, and trend-adjusted exponential smoothing.
- The forecasting errors that are used to measure the effectiveness of forecasting methods are Mean Squared Error (MSE), Mean Absolute Deviation (MAD), and Mean Absolute Percentage Error (MAPE).

3.9 Glossary

Adaptive Forecasting: It is an advanced form of time series analysis, where the trend and seasonal components are adjusted, after each demand observation.

Base demand: Average of sales over a given time period.

Cyclic component: Changes in the demand patterns, which exist for more than one year.

Exponential Smoothing: It is a rule of thumb technique, for smoothing time series data, using the exponential window function.

Holt's model: It is a two-parameter model, also known as linear exponential smoothing, and is a popular smoothing model, for forecasting data with trend.

Irregular component: All those variations in demand that cannot be attributed to any of the five factors.

MAD stands for Mean Absolution Deviation: It is a simple method that measures the dispersion (or variation) of observed values, around the expected values.

Moving Average: A moving average is a technique to get an overall idea of the trends in a data set; it is an average of any subset of numbers. The moving average is extremely useful for forecasting long-term trends.

MSE is Mean Squared Error: It is a measure of forecast accuracy, in which the mean, of the squares of deviations of forecast values from the actual result, is calculated.

Seasonal component: The repeated pattern of increase and decrease in demand, over a period of time.

Seasonal Index: It is a numerical value, used to evaluate seasonal trends in the demand for a product or service.

Static forecasting: It is a method of forecasting which assumes that the estimates of trend and seasonal components do not vary from year to year and are determined based on historical data, which is projected to obtain future demand data.

Time Series techniques: They use historical data to make forecasts. The technique works on the premise that future demand can be determined, by studying past demand patterns.

Trend component: The long-term pattern of movement of demand over a period.

3.10 Self-Assessment Test

1. List the objectives, components, and approaches of forecasting.
2. Explain the demand forecasting process.
3. What are all the available forecasting techniques? Which is the most popular and successful method and why?
4. Which are all the measures of forecast error and how is it measured?
5. What are the challenges in demand forecasting?

3.11 Suggested Readings / Reference Material

1. Ashley McDonough, Operations and Supply Chain Management Essentials You Always Wanted to Know: 15 (Self Learning Management Series) Paperback – 1 January 2020
2. Russel and Taylor, Operations and Supply Chain Management, 10ed, ISV Paperback – October 2019
3. Chopra and Kalra, Supply Chain Management 6/e Paperback – 17 June 2016

3.12 Answers to Check Your Progress Questions

1. (a) Strategic Planning

Strategic planning is the most important benefit of demand forecasting.

2. (d) Promotional strategies

Promotional strategy is the most applicable forecasting component in the Fast-Moving Consumer Goods industry.

3. (a) Top-down approach with a global perspective

Top-down approach with a global perspective forecasting approach is best suitable for a capital goods manufacturer.

4. (c) Analysis of the existing infrastructure

Analysis of the existing infrastructure is not a part of developing a forecasting process.

5. (a) Time-series technique

Time-series technique is not an appropriate forecasting technique for new and innovative products.

6. (a) Adaptive forecasting

Adaptive forecasting is a form of time-series analysis.

7. (b) Exponential Smoothing

Exponential Smoothing is the adaptive forecasting method to be followed, when the demand does not show any trend and seasonal variation.

8. (c) Trend Adjusted Exponential Smoothing

Trend Adjusted Exponential Smoothing method is called "Holt's Model".

9. (e) It is an error, representing the difference between forecasts made by the internal marketing department and external consultants.

10. (b) Simple Exponential Smoothing

Simple Exponential Smoothing is the most widely used and successful forecasting methods.

Unit 4

Managing Demand and Supply in a Supply Chain

Structure

4.1 Introduction

4.2 Objectives

4.3 Aggregate Planning and its Role in a Supply Chain

4.4 Process of Aggregate Planning

4.5 Managing Predictable Variability in a Supply Chain

4.6 Decision Options in Varying Supply

4.7 Decision Options in Varying Demand

4.8 Summary

4.9 Glossary

4.10 Self-Assessment Test

4.11 Suggested Reading / Reference Material

4.12 Answers to Check Your Progress Questions

"Make inventory a common enemy for your company."

- Dave Waters, self-motivated supply chain professional

4.1 Introduction

A major activity in all supply chain is managing intermittent inventory related storage between movement of goods or services among intermediaries. Planning well about this activity leads to saving, timely dispatch as well as cost reduction. Thus, assessing and managing demand in supply chain is strongly linked to inventory.

In the previous unit, we discussed the concept and process of demand forecasting. This covered the concepts of components of a forecast, various approaches followed in making forecasts, forecasting process, techniques and forecasting errors. The success of any firm depends on how well it matches supply with demand by managing internal variables like capacity, production, and inventory. To effectively synchronize supply with the forecasted demand, firms design aggregate plans that help them to make sound decisions, regarding capacity utilization, production schedules, and inventory levels. Designing an aggregate plan is a complex job, as the firm must make various trade-offs, to maximize the effectiveness of the supply chain. Apart from managing these internal variables, a firm also must manage variability in demand. This can be achieved by managing

both supply and demand. In this unit, we discuss the process of managing demand and supply. First, we examine the use of aggregate planning and its role in the supply chain. Then we discuss different aggregate planning strategies and techniques in formulating an optimal aggregate plan. Finally, we examine methods for effectively managing predictable variability, to maximize profits.

4.2 Objectives

By the end of this unit, you will be able to:

- Discuss aggregate planning and its role in a supply chain
- Explain aggregate planning process
- Examine predictable variability in a supply chain
- Identify decision options in varying supply
- Establish options in varying demand

4.3 Aggregate Planning and its Role in a Supply Chain

Proper planning is necessary to manage production and inventory, to match supply closely with demand. The primary objective of firms is not simply satisfying demand, but deriving maximum profit from it. To achieve this objective, firms must deal with capacity, workforce, and inventory constraints.

Aggregate planning refers to intermediate-range (3-18 months) capacity planning. It is used to establish workforce levels, production rates, inventory levels, subcontracting, and backorders for broad categories of products, rather than for individual products. This plan is developed, based on estimates of customer demand and capacity limitations. Aggregate planning is thus a macro-planning tool, which focuses on the optimal utilization of the existing resources, in the medium term. It specifies the optimal combination of the following factors for a given period:

- Production rate - The production rate is the number of units completed per unit time (per hour or per day).
- Workforce level - The number of workers needed for production.
- Inventory on hand - Unused inventory that is carried over from the previous period.
- Overtime - The level of overtime production
- Subcontracting - The quantity of production through subcontracting

Within the constraints of the aggregate plan, short-term production plans, for each product, are made. To achieve optimal supply chain performance, all the members of the supply chain must collaborate and devise a broad aggregate plan. For example, if a manufacturer formulates an aggregate production plan for one year,

then the suppliers, the upstream members of the supply chain, must make plans to suit the aggregate plan of the manufacturer. The downstream members like transport operators and warehousing operators, must also make plans, based on the requirements of the manufacturer. If each member makes one's own plans, without considering the requirements of other members then, a mismatch between supply and demand, would occur leading to an increase in cost and a decrease in the responsiveness of the supply chain.

Example: Aggregate Production Planning in an Indonesian Cement Company

Aggregate production model integrating multi product-stage-period was built for a cement company at Indonesia for demand uncertainty. This model helped in determining the optimized production figures, inventory levels of clinker/cement, which led to fulfilling demand at least cost within the scope of the defined planning.

A mathematical optimization approach using 'linear programming involving scenario based approach' was built to satisfy the demand at optimal (minimum) cost. The aggregate production-planning model had accommodated demand uncertainty in the Indonesian Cement Company, taking care of balancing material at all process stages, equipment and inventory capacities covering the full planning cycle.

Source: https://iopscience.iop.org/article/10.1088/1757-899X/1072/1/012033/pdf, 2021, Accessed on 17/08/22

4.4 Process of Aggregate Planning

To develop an optimal aggregate plan, a firm must formulate an aggregate planning problem that specifies the production requirements. It should also specify the costs and constraints involved in satisfying the production requirement. Then the firm must identify the trade-offs that it has to make, for developing an optimal aggregate plan. Next, by using an appropriate aggregate planning technique, it can develop an optimal aggregate plan that satisfies customer demand at the lowest cost possible. Let us examine the aggregate planning process in detail.

4.4.1 Aggregate Planning Problem

The aggregate planning problem identifies the production requirements, and the costs and constraints involved in satisfying those requirements. Based on the information provided by the aggregate planning problem, an optimal production plan is developed. First, the aggregate plan must provide the timeframe, for which the plan has to be formulated (generally 3-18 months). Then, the firm must provide time intervals, within the specified timeframe like months, days, and

weeks. Further, the firm must provide information on various factors. The information requirements for the aggregate planning problem are:

- The demand forecast for a given timeframe and its break up for each time interval are specified. For example, total demand for a timeframe of, say, 18 months, and the breakup of the forecast for each month are specified.
- The production costs involved in meeting the demand are:
  - Labor costs (regular time and overtime labor costs)
  - Material costs
  - Subcontracting costs
  - Changing capacity costs. These include the cost of the varying workforce (hiring and firing costs) and cost of varying machine capacity (cost of adding and reducing machine capacity).
- The number of hours required to produce a unit
- Cost of backordering
- Cost of stockouts
- Constraints in producing the required output:
  - Workforce constraints (number of workers a company can hire and the number of workers it can layoff).
  - Working hour constraints (regular time hours and overtime hours - specifications).
  - Stock out and backordering constraints (the level of stockouts and backordering that a company can bear).

Based on the information, the firm develops an optimal production plan, which provides the level of each of the following decision variables, which maximize the profitability of the firm given below.

- Production rate in regular time, overtime, and subcontracting
- This determines the level of workforce required and the level of production to be sub-contracted.
- Inventory levels
- Determining inventory levels can help the firm plan warehouse space and the investment needed to manage the inventory.
- The level of stockouts and backordering
- The level of stockouts and backordering helps the firm decide on the level of customer service to be offered.

4.4.2 Aggregate Planning Strategies

When developing an aggregate plan, a firm must make many trade-offs regarding inventory, production capacity, and stockout costs. For example, if the firm tries to decrease capacity costs by decreasing production, then stockout costs may increase, due to shortage of the product. If the firm decides to reduce stockout costs by increasing product availability, then capacity costs and inventory carrying costs increase. Hence, depending on the volatility in demand, the firm must make a trade-off between these three costs and develop an aggregate plan, which can maximize profits. If the capacity varying costs are low, then building the inventory in the off-season, to manage demand during the peak season is not necessary. However, if the capacity varying costs are high, then the firm will have to build the inventory, during the off-season, to reduce the total costs, during the peak season. Different strategies are adopted by firms, to make a proper trade-off between these three costs. Prominent among them are the chase strategy, the stable workforce strategy, and the level strategy. If only one of these strategies is adopted, the strategy is referred to as a pure strategy, and if a combination of two or more of the above strategies is adopted, then the strategy is referred to as a mixed strategy. In practice, most firms adopt a mixed strategy.

Chase strategy

In this strategy, the firm matches the production rate with the demand/ order rate. The number of units produced is changed, by hiring and firing workers or by changing production capacity levels. This strategy helps reduce inventory but increases volatility in production capacity and workforce. This strategy can be successful, only when the firm has ready access to a pool of skilled workers and has the ability to vary machine capacity, at short notice. The varying workforce strategy may also have a negative impact on the morale of the workforce. This strategy is suitable for firms, which have high inventory carrying costs, low capacity varying costs, and low personnel costs. Food processing firms, for example, have high inventory costs. Moreover, they require a large workforce, only during harvesting and processing of food.

Stable workforce strategy

In this strategy, the workforce is kept stable, and the output is varied by varying work hours. The work hours are varied to match production with customer demand. This is achieved through flexible work schedules or the use of overtime. This strategy ensures that the workforce is always busy. It also improves the productivity of the firm and reduces its hiring and firing costs. By providing continuity in work, this strategy improves the morale of the employees. This strategy is useful when inventory costs are high, and capacity varying costs are low.

Level strategy

In this strategy, the workforce and the production rate are kept stable. Fluctuations in demand are managed, either by maintaining a high inventory level or through order backlogs. This strategy helps firms in reducing capacity varying costs. Since the production is kept stable, employees benefit from a stable production schedule. However, this strategy will lead to a reduction in customer service levels and an increase in inventory levels.

Activity 4.1

Daily Needs is a supermarket, planning to expand its operations in the twin cities of Hyderabad and Secunderabad. Capacity planning and inventory levels vary for each branch, depending upon the demand pattern. The local branch manager must prepare an aggregate planning strategy.

- Identify the strategies available and the trade-offs required while preparing a strategy.

4.4.3 Aggregate Planning Techniques

Firms use various techniques to formulate aggregate plans. These techniques range from simple methods like cut and try methods to more advanced methods like linear programing. In this section, we first discuss the cut and try method, and then go on to examine the use of linear programming, in the formulation of aggregate plans.

Cut and try method

In this approach, a firm examines various production plans and the costs involved in each plan. Then the firm chooses the best plan, which has the lowest cost structure. Let us understand this technique, with an example. ABC limited, a product manufacturer, experiences seasonal demand for its products (i.e. demand peaks in a particular season and falls thereafter). Therefore, the firm has to determine the production plan for the entire year, to optimally utilize the resources, during the peak demand season and slack season. Let us assume a plan period of six months. Table 4.1 provides the demand forecast and the number of working days for each month.

Table 4.1: Demand Forecast at ABC Limited

	March	April	May	June	July	August
Demand Forecast	300	500	400	100	200	300
Number of working days	22	19	21	21	22	20

Source: ICFAI Research Center

The workers work for 8 hours per day. They are paid ₹ 4 per/hr during regular time and ₹ 6 per/hr during overtime. There are no restrictions on subcontracting, inventory, and overtime. If the customer orders are not filled in the current month, they can be backlogged and filled in the subsequent months. An inventory carrying cost of ₹ 1.5 is incurred for each unit held per month. The inventory costs are calculated on the ending inventory of each month. The marginal cost of subcontracting is ₹ 26. The stockout cost is ₹ 10 per unit. Material costs are not considered while identifying costs for each alternative plan, as they remain the same for all plans. For this problem, let us assume an initial inventory of 50 units. To counter demand fluctuations, the firm decides to hold safety stock, worth 20% of the demand forecast, for each month. The firm's aim is to choose the best plan, which has the lowest total cost. The cost information is summarized in Table 4.2.

Table 4.2: Cost Information for ABC limited

Item	Costs
Materials cost	₹ 100
Inventory holding costs	₹ 1.5 per unit/period
Marginal cost of subcontracting	₹ 26
Marginal cost of stockouts	₹ 10
Hiring and training costs	₹ 300
Layoff costs	₹ 400
Labor hours required	8 hrs/unit
Regular time costs	₹ 4/unit
Overtime costs	₹ 6/unit

Source: ICFAI Research Center

Before examining various plans, let us determine the production requirements, based on the demand forecasting and the safety stock that is to be held. The production requirement is determined by summing up the forecasted demand for that month with the safety stock that is to be held. The ending inventory of each month will be the beginning inventory for the following month. Table 4.3 provides the production requirements for the given period.

Table 4.3: Aggregate Production Requirements

	March	April	May	June	July	August
Beginning Inventory	50	60	100	80	20	40
Demand Forecast	300	500	400	100	200	300
Safety stock (0.2×demand forecast)	60	100	80	20	40	60
Production requirement (demand forecast + safety stock-beginning inventory)	310	540	380	40	220	320
Ending Inventory (Beginning Inventory + production requirement - Demand forecast)	60	100	80	20	40	60

Source: ICFAI Research Center

Now, let us examine the four different plans. The four plans under consideration are:

Production Plan I: Exact production; Vary workforce

Production Plan II: Maintain a constant level of the workforce; Vary inventory

Production Plan III: Maintain a low level of the workforce; Use overtime

Production Plan IV: Maintain a constant level of the workforce; Use subcontracting

Production plan 1: Exact production; Vary workforce

In this approach, the firm's production matches exactly with the demand, by varying the workforce level (i.e., the firm adopts a chase strategy). This is achieved through hiring additional workers when the demand increases and laying off the workers when the demand decreases. Table 4.4 shows the details of the plan.

Table 4.4: Production Plan I- Exact Production: Vary Workforce

	March	April	May	June	July	August	Total
Production requirement	310	540	380	40	220	320	
Production hours required (Production requirement × 8 hr/unit)	2480	4320	3040	320	1760	2560	
Working days per month	22	19	21	21	22	20	

Contd….

Hours per month per worker (Working days × 8 hrs/day)	176	152	168	168	176	160	
No of workers required (production hours/ hours per month per worker)	14	28	18	2	10	16	....
No. of new workers hired (assuming initial work force as 14)	0	14	0	0	8	6	
Hiring costs (no. of new workers hired × ₹ 300)	0	4200	0	0	2400	1800	8400
Workers laid off	0	0	10	16	0	0	
Layoff costs (no of workers laid off × ₹ 400)	0	0	4000	6400	0	0	10400
Regular working time costs (production hours required × ₹ 4)	9920	17280	12160	1280	7040	10240	57920
Total costs							**76720**

Source: ICFAI Research Center

Production Plan II: Maintain a constant level of the workforce; Vary inventory

In this plan, the firm maintains a constant monthly rate of production, by keeping the workforce constant at 15. Demand is managed through the unused inventory of the previous period. (i.e., firm is adopting the level strategy). The number of workers is determined, by identifying the average number of workers required for each period. To do so, the firm must calculate the total production hours required, for a given period, by multiplying the total production requirement with the number of hours required for manufacturing each unit. Then the figure obtained is divided by the total number of hours a person works, for a given period (6 months). i.e.

$$\frac{(1810 \text{ units} \times 8\text{hr per unit})}{(125 \text{ days} \times 8\text{hrs per day})} = 15 \text{ workers (rounded off)}$$

The demand fluctuations are managed by building up the inventory in the slack periods and using that inventory during the peak season. Table 4.5 provides the details of the plan.

Table 4.5: Production Plan II- Maintain a Constant Level of the Workforce; Vary Inventory

	March	April	May	June	July	August	Total
Beginning inventory	50	80	0	0	215	345	
Working days per month	22	19	21	21	22	20	
Production hours available (working days per month × 8hrs/day ×15 workers)	2640	2280	2520	2520	2640	2400	
Actual production (production hours available/8hr per unit	330	285	315	315	330	300	
Demand Forecast	300	500	400	100	200	300	
Ending Inventory (beginning inventory + actual production -demand forecast)	80	-135	-85	215	345	345	
Shortage costs (shortage units ×10)	0	1350	850	0	0	0	2200
Safety stock (0.20 × demand forecast)	60	100	80	20	40	60	
Excess units (ending inventory -safety stock)	20	0	0	195	305	285	
Inventory carrying costs (Excess units × ₹ 1.5)	30	0	0	292.5	458	428	1208.5
Regular working time costs (production hours available × ₹ 4)	10560	9120	10080	10080	10560	9600	60000
Total costs							**63408.5**

Source: ICFAI Research Center

Production plan III: Maintain a low level of the workforce; Use overtime

In this plan, production is managed using a constant workforce of 15 workers. Additional demand is met by making the workforce work overtime. Table 4.6 provides the details of the plan.

Table 4.6: Production Plan III- Maintain a Low Level of the Workforce; Use Overtime

	March	April	May	June	July	August	Total
Beginning inventory	50	80	0	0	215	345	
Working days per month	22	19	21	21	22	20	
Production hours available (working days per month × 8 hrs/day × 15 workers)	2640	2280	2520	2520	2640	2400	
Regular production	330	285	315	315	330	300	
Demand Forecast	300	500	400	100	200	300	
Units available before overtime (beginning inventory + regular production - demand forecast)	80	-135	-85	215	345	345	
Units overtime	0	135	85	0	0	0	
Overtime costs (units overtime × 8hr × ₹ 6/hr)	0	6480	4080	0	0	0	10560
Safety stock (0.20 × demand forecast)	60	100	80	20	40	60	
Excess units (units available before over time-safety stock)	20	0	0	195	305	285	
Inventory carrying costs (excess units × ₹ 1.5)	30	0	0	292.5	457.5	427.5	1207.5
Regular working time costs (production hours available × ₹ 4)	10560	9120	10080	10080	10560	9600	60000
Total costs							**71767.5**

Source: ICFAI Research Center

Production Plan IV: Maintain a constant level of the workforce; Use subcontracting

In this plan, production is managed using a constant workforce of 12 workers, working during regular time. Additional demand is met through subcontracting. The subcontracting quantity is arrived at by calculating the difference between the production requirement and the actual production. Table 4.7 provides the details of the plan.

Table 4.7: Production Plan IV- Maintain a Constant Level of the Workforce; Use Subcontracting

	March	April	May	June	July	August	Total
Production requirement	310	540	380	40	220	320	
Working days per month	22	19	21	21	22	20	
Production hours available (working days per month × 8 hrs/day × 12 workers)	2112	1824	2016	2016	2112	1920	
Actual production (production hours available/8hr per unit)	264	228	252	252	264	240	
Units subcontracted (production requirement-actual production)	46	312	128	0	0	80	
Subcontracting costs (units subcontracted × 26)	1196	8112	3328	0	0	2080	14716
Regular working time costs (production hours available × ₹ 4)	8448	7296	8064	8064	8448	7680	48000
Total costs							**62716**

Source: ICFAI Research Center

After examining all the four plans, the firm should select the plan, which has the least total cost. Production plan IV, which uses subcontracting, has the lowest total cost. The firm can minimize total costs, by subcontracting a part of the total requirement, thus meeting demand in the most profitable manner. Table 4.8 compares all the four plans.

Table 4.8: Comparison of all Four Plans

Cost	Production Plan I	Production Plan II	Production Plan III	Production Plan IV
Regular time costs	57920	60000	60000	48000
Overtime costs	0	0	10560	0
Hiring costs	8400	0	0	0
Layoff costs	10400	0	0	0
Stockout costs	0	2200	0	0
Subcontracting	0	0	0	14716
Inventory carrying costs	0	1208	1207	
Total costs	**76720**	**63408**	**71767**	**62716**

Source: ICFAI Research Center

Activity 4.2

A manufacturer of Air Coolers wants to prepare a workable production plan, to ensure smooth production and timely deliveries. However, the uncertainty, caused by the Covid-19 environment, is not giving confidence in preparing an effective plan, considering the capital investment, and working capital requirements for capacity expansion, labor availability, inventories, etc.

Identify various techniques available under the Cut and Try method of aggregate planning to help the company to arrive at a meaningful approach.

Check Your Progress - 1

1. What is the main purpose of planning in Supply Chain Management?
   a. To manage production and inventory
   b. To match supply and demand
   c. To get maximum profit by serving demand
   d. To increase/utilize capacity
   e. To utilize manpower

2. Which of the following statements is not true about Aggregate Planning?
   a. Intermediate range (3-18 months) capacity planning
   b. Used to establish employment levels
   c. Used to establish inventory levels
   d. Used to formulate outsourcing strategy
   e. It is a plan derived by aggregating different plans
3. Identify the factor that does not contribute to the formulation of the Aggregate Plan.
   a. Production rate
   b. Workforce level
   c. Inventories
   d. Overtime
   e. Quality level
4. Which of the following is not a stage in Aggregate Planning Process?
   a. Estimate production requirements
   b. Specify costs and constraints involved in meeting production requirements
   c. Identify the trade-offs
   d. Identify the machinery required to increase capacity
   e. Formulate a plan that satisfies customer`s demand at a minimal cost.
5. Which Aggregate Planning Strategy is the best for the food processing industry where the demand is seasonal?
   a. Chase strategy
   b. Stable workforce strategy
   c. Level strategy
   d. Long-term strategy
   e. Outsourcing strategy

Aggregate planning using linear programing

Aggregate planning problems can also be solved using linear programing. Linear programing models can be used to refine Cut and Try approaches, only if the variables have a linear relationship and the demand is assumed to be deterministic. Two linear programing models that are often used to solve aggregate planning problems are the simplex method and the transportation method. Let us examine the transportation method.

The transportation method solves aggregate planning problems, by optimally allocating the supply to meet the demand. Demand is met through inventory on hand, and by producing units using regular time, overtime, and subcontracting. In this method, the workforce is considered constant (i.e., hiring and layoff costs are not the considerations). Let us understand the transportation method with an example. Table 4.9 provides the demand forecast of S.B Electronics. The timeframe of the aggregate plan is 4 months.

Table 4.9: Demand Forecast at S.B Electronics

Period	Demand forecast
Period 1	600
Period 2	700
Period 3	900
Period 4	800

Source: ICFAI Research Center

Table 4.10 provides the costs that are involved in meeting the demand.

Table 4.10: Cost Information

Item	Costs
Regular time costs	₹ 30/unit
Overtime costs	₹ 40/unit
Subcontracting costs	₹ 50/unit
Inventory carrying costs	₹ 2 per unit per period

Source: ICFAI Research Center

Production capacity

The regular production capacity is 600 units for each month.

The overtime production capacity is 200 units for each month.

However, there is no limit for subcontracting, let us set a figure of 1000 units.

Backordering is not allowed, i.e. the demand for each month should be fulfilled in the same month.

Initial inventory: The initial inventory is 50 units. Inventory carrying costs are not charged for the initial inventory if they are used in period 1. Carrying costs are ₹ 2 per unit per period if they are carried over to period 2, ₹ 4 if they are carried over to period 3, and ₹ 6 if they are carried over to period 4. At the end of the fourth period, if the units are unused, an additional charge of ₹ 2 is added, to carry it forward to the next period.

Regular time costs. Regular time costs of ₹ 30 per unit are incurred, if the units produced are used in the same period. If inventory is carried over to the next period, an additional charge of ₹ 2 is levied.

Overtime costs. Overtime costs of ₹ 40 per unit are incurred, if the units produced are used in the same period. If inventory is carried over to the next period, an additional charge of ₹ 2 is levied.

Subcontracting: Subcontracting costs of ₹ 50 are incurred per unit if the units are used in the same period. If the units are carried forward to the next period, an additional charge of ₹ 2 is levied. Generally, production is subcontracted only for additional units, which the firm cannot produce during regular time and overtime. Therefore, it is unlikely that the units subcontracted will be carried over to the next period.

Final inventory: The final inventory should be 400 units at the end of the fourth period, which is added to the demand requirement of period 4.

The initial linear programming matrix, in terms of capacity, is shown in Figure 4.1. The bottom row shows the demand forecast for the given period. The last column shows the production capacity for the given period. The costs are shown in small boxes in each cell. Since the total capacity is more than the demand, a slack demand or unused capacity is added to match demand with supply. Since backordering is not allowed, the demand in the previous month is not met by production in the current month (i.e., production in period 2 is not used to meet the demand in period 1). As mentioned earlier, subcontracted units are generally not carried forward. Therefore, the cells associated with backordering and the cells associated with the carrying forward of subcontracted units are shaded out in the figure. The sum of all the cells in each period equals to the respective demand requirements and each row needs to be equal to the respective production capacity.

Figure 4.1 gives the initial transportation matrix.

Figure 4.1: Initial Transportation Matrix

Period		Period				Unused Capacity	Total Capacity
		1	2	3	4		
	Beginning Inventory	0	2	4	6		50
1	Regular Time	30	32	34	36		600
	Overtime	40	42	44	46		200
	Subcontract	50	52	54	56		1000
	Regular Time		30	32	34		600

Contd….

2	**Overtime**		40	42	44		200
	Subcontract		50	54	56		1000
3	**Regular Time**			30	32		600
	Overtime			40	42		200
	Subcontract			50	52		1000
4	**Regular Time**				30		600
	Overtime				40		200
	Subcontract				50		1000
Requirements		600	700	900	1200*	3850**	Σ=7250

Source: ICFAI Research Center

* Demand in period 4 + 400 = 800 + 400 = 1200

**7250− (600 + 700 + 900 + 1200) = 3850

The aggregate planning problem is solved, using the least cost method. In this method, capacity allocation follows the least cost method. That is, production is first allocated to the cell, which has the least cost, and the remaining to the next lowest cost cell, and so on. The optimal plan is shown in Figure 4.2.

Figure 4.2: Final Allocation Matrix

Period		**Period**				**Unused Capacity**	**Total Capacity**
		1	**2**	**3**	**4**		
	Beginning Inventory	0 **50**	2	4	6	0	50
1	**Regular Time**	30 **550**	32	34	36 **50**		600
	Overtime	40	42	44	46 **200**		200
	Subcontract	50	52	54	56	1,000	1000
	Regular Time		30 **600**	32	34		600

Contd….

2	**Overtime**		40 **100**	42	44 **100**		200
	Subcontract		50	54	56	1,000	1000
3	**Regular Time**			30 **600**	32		600
	Overtime			40 **200**	42		200
	Subcontract			50 **100**	52	900	1000
4	**Regular Time**				30 **600**		600
	Overtime				40 **200**		200
	Subcontract				50 **50**	950	1000
Requirements		600	700	900	1200	3850	7250

Source: ICFAI Research Center

Period 1

In period 1, the demand requirement is 600 units. First, the initial inventory of 50 units is used, as it has no inventory carrying cost. The remaining 550 units are obtained from regular time production of 600 units. Here, overtime production and subcontracting are not used.

Period 2

In this period, the demand requirement is 700 units. 600 units are obtained through regular time production and the remaining 100 units are obtained through overtime production. In this period, no unit is subcontracted.

Period 3

In this period, the demand requirement is 900 units. The first 600 units are produced using regular time production and the next 200 units using overtime production. The remaining 100 units are subcontracted.

Period 4

The demand requirement for this period is 1200 units, which includes the 400 units of ending inventory. The first 600 units are obtained through regular time production. The next least cost option is an unused capacity of 50 units of regular production from period 1. The next 200 units are obtained through overtime production in period 4. The next least cost option is the unused capacity of 100 units of overtime production from period 2. The next least cost option is an unused capacity of 200 units of overtime production from period 1. The last 50 units are subcontracted.

Thus, using the transportation method, the optimal production plan is obtained.

Example: Aggregate Planning for Minimizing Cost in Production

Perum Bulog; Indonesia was a state-owned, food logistics public corporation. Bulog's wheat flour with the trademark “Terigu Keluarga Indonesia" "Terigu Kita" was produced and distributed by Perum BULOG. Production planning was a very important activity of all production activities of a company. Data used in aggregate planning computation were: 3 years product demand data, available resources in complete aggregate production planning period, labor regulations, various costs like recruitment, firing, overtime, unemployment, inventory storage, subcontracting, part-time labor, inventory costs or re-ordering. The aggregate planning helped in planning, production, inventory, and resources against fluctuating demand, minimize the total production costs, aggregate planning process. The different steps were, calculation of chase strategy, level strategy and flexible strategy, analyse all strategies, and pick the best strategy. Earlier aggregate planning at PT. Bulog guided them to use the chase strategy method (increase or reduce the number of workers based on the consumer demand).

Source: https://www.researchgate.net/publication/346616903_Aggregate_Planning_Method_as_Production_Quantity_Planning_and_Control_to_Minimizing_Cost November 2020, Accessed on 03/09/22

4.5 Managing Predictable Variability in a Supply Chain

As discussed earlier, developing an aggregate plan is easier for products, which have a stable demand. However, many products show demand variability over a period, due to various predictable seasonal and non-seasonal factors.

Predictable variability in demand refers to the variability in demand patterns that can be predicted. To tackle demand variability, firms can use one of the following options:

- Managing supply, i.e., managing production capacity, managing inventory, subcontracting, and backordering
- Managing demand, i.e. making pricing and promotion decisions

Generally, supply management decisions and demand management decisions are taken in isolation. Demand management decisions (like offering price discounts and making trade promotions) are taken by the marketing department. Supply management decisions (making changes in inventory levels and production capacity) are taken by the manufacturing department. This approach of tackling demand variability leads to improper coordination, among the supply chain members and a reduction in profits across the supply chain. If the manufacturing and marketing departments coordinate their activities, i.e. integrating promotion

with production activities, they could increase the effectiveness of supply chain operations. This would also help the members of the supply chain maximize their profits. In the following section, we will examine the process of managing demand and supply effectively.

Example: Supply Chain Management Experience at DSM Food Specialties

Royal DSM; Netherlands had € 9 billion net sales, 22000 global employees, with prime business areas spanning, nutrition, health, materials and sustainable living. DSM delivered innovative solutions for nutrition, aroma and personal hygiene, medical equipment. and innovative new mobility and connectivity. The Supply Chain Management department was covering 'Supply Chain (network) Planning and Scheduling' (supply network planner), services to customers, Logistics related functions and Warehousing activities. Supply Chain Management was taking total responsibility for the international Sales, related operational planning and allied variability. In this process, it used to interact very closely with functional groups within like: Sales and Manufacturing, Business Management, Finances. The supply chain group optimized supply and inventory plans, provided global supply network and ensured agreed service levels, addressed strategies for supply of end products. The Supply Network Planner (SNP) managed the supply and capacity performance, in both manufacturing and tolling network. It built and was responsible for continued improvement agenda of the operations discipline. SNP enhanced supply planning processes and ensured global consistency.

Source: https://nl.karier.co/job/Supply-Network-Planner-DSM-Td5 October 2021, Accessed on 17/08/22

4.6 Decision Options in Varying Supply

Firms should ensure that there is an optimal supply of their product in the marketplace. Excess supply results in a drain on company resources and high levels of inventory. Inadequate supply, however, leads to a loss of customers and limits the growth of firms. Therefore, firms must vary the supply of their products, according to market conditions. The supply of a product can be controlled effectively by managing these two variables.

- Production capacity
- Inventory

Firms should manage their supply in such a way that their profits are maximized. In other words, the revenue received from sales should be more than the cost incurred for managing inventory and capacity. By using a combination

of inventory and capacity management options, firms can manage supply cost-effectively and maximize profits. Some of the popular approaches for managing capacity and inventory are discussed below.

Managing Capacity

Managing capacity to suit predictable variability is a challenging task for manufacturing firms. Let us examine some of the commonly used approaches for managing capacity.

Time flexibility

Some companies match supply with demand, by varying the work hours of their employees. Many manufacturers work only for two shifts, instead of three during the normal demand period, thereby leaving some operational capacity of the plant idle. During the peak demand period, they can make use of these idle work hours and idle capacity to increase production, to match the increase in demand. They can run a third shift and pay workers overtime for working during the third shift. This arrangement will help them match supply with customer demand.

Use of seasonal workforce

One of the popular approaches for managing capacity is the use of a seasonal workforce. Firms employ a seasonal workforce during peak demand periods, to increase production to match the increase in customer demand. In this approach, a fixed number of full-time employees work for the company throughout the year, while some employees work part-time, during the peak season. Firms use the seasonal workforce mostly for routine jobs. Such jobs can be done by semi-skilled or unskilled workers, who are available in large numbers. This approach is widely practiced in the agriculture industry, where temporary workers are hired during the harvesting and processing seasons. This strategy may not work for jobs that require skilled or specialized workers, since such workers are not available at short notice.

Use of sub-contracting

Many firms subcontract some of the production during the peak season, to match supply with demand. In this approach, the internal production rate is kept constant and the extra demand is subcontracted to a third party so that costs can be kept low. These subcontractors have flexible plant capacity and low cost of production since they undertake subcontracting work for many manufacturers. This strategy can be adopted, only when the sub-contractor can meet the quality and quantity requirements of the firm in a cost-effective manner and supplies on time. Sub-contracting requires the firm to maintain strong ties with the suppliers and have a thorough knowledge of the subcontractor's operations. The use of subcontracting has its disadvantages. The firm may not have control over its production schedule and may become unable to monitor the quality of the product.

Designing product flexibility into the production processes

Firms adopting this approach set up different production lines for different products. The facility is designed in such a way that the rate of production can be changed, by varying the number of workers on a particular production line. This type of approach is effective when the demand for different products is complementary. That is, when the demand for one product increases and demand for the other product decreases. In such a situation, workers can be shifted from a low demand production line to a high demand production line, to optimally utilize the existing capacity as well as manage the demand for the products. The workers need to be multi-skilled so that they can work on different production lines.

Flexibility in production can also be achieved, by employing production machinery, which manufactures different products. This approach is used by firms, which offer a wide variety of products. Using this approach, firms can vary the production of each product, according to demand. For example, a manufacturer of cosmetic products can increase the production for winter care products, in the winter season and shift the production to summer care products, as the summer season arrives.

Managing Inventory

Predictable variability in supply can also be managed by controlling the level of inventory. Let us examine two popular approaches for managing inventory.

Using common components across multiple products

In this approach, the firm determines the common components that are required for multiple products and the production of these components is kept constant. For example, for a computer manufacturer, the desktop PCs and servers may have variable demand. However, combined demand for keyboard and mouse components for these two ranges (i.e., desktops and servers) may be relatively constant. Therefore, the production of these components can be easily matched with the demand, and the level of inventory of these components can be kept low.

Build an inventory of high demand or predictable demand products

If a firm's products experience peak demand, then the firm must build the inventory of these products during the off-peak period. The inventory of products with predictable demand can be built up, as their demand during the peak season will be more or less the same every year. For example, an apparel manufacturer can build up the inventory of fabric for suits during the off-season, for consumption during the festival period, as these products have predictable demand. However, in the case of products, whose demand cannot be known beforehand, they should be produced, only when information regarding the demand becomes available. For example, readymade garments can be produced as per demand because fashion keeps on changing frequently.

Example: Supply chain scenario at Zara

Zara was a clothing retailer with global presence across 80+ countries, and also had notable online presence. Zara was known for 'Fast Fashion'. In the process of 'Fast fashion', three elements called 'design, manufacturing, and marketing' were aligned in optimum way, and equal emphasis was on rapid production as well distribution of high volumes of material. The method leveraged quick replication of trends, paved way to intelligent supply chain models, and easily-sourced materials helping to send cheaper styles as fast as possible to the end consumer.

At the center of their activities and their supply chain was a huge distribution hub, named as "*The Cube".* Situated in Europe was 'The Cube'; a 5 million sq. ft. distribution center, connected to around ten Zara-owned factories within a 15 km, which helped as a hub between all their factories, suppliers, designers, and stores. The entire process of planning supply was done every 2-3 weeks. If the products were not sold fully, either they were reused or discarded, leading to sustainability issues. Zara sold 85% of their inventory at MRP compared to the industry avg. of only 60%, but left with just 10% unsold annual inventory. Zara planned the demand to a large extent perfectly. Data and AI usage was done to predict about the fade out of a trend. Zara manufactured only 50-60% in advance, as they were capable of ramping up or reducing production speed. Because of the capability of managing with small inventory and well established internal processes, Zara ensured a Supply Chain that could very quickly change, iterate or follow trends.

Source: https://insideiim.com/supply-chain-case-study July 2022, Accessed on 17/08/22

4.7 Decision Options in Varying Demand

Variation in demand will have an impact on the revenue and costs of a company. Generally, demand can be influenced by various pricing and promotional strategies. For example, a price cut coupled with a promotion during the off-season can boost sales. Promotions and price cuts also can be used during the peak season, to achieve maximum sales. Though an increase in promotion, during the peak demand season, will bring in additional revenues, it will also increase the costs of the company. Hence, the timing of price cuts and promotions should be determined, after analyzing their effect on sales and costs, at different periods. The marketing departments of firms usually push for promotions, during the peak season to get maximum market share, but the manufacturing departments prefer promotions during the off-season, as it helps them decrease the variability of demand over the year. Therefore, demand in a supply chain can be managed in a cost-effective manner, if pricing and promotional strategies are prepared by the

marketing department, in coordination with the manufacturing department. The timing of promotional activities would depend on their effect on:

- Demand for the product
- Product margins
- Cost of holding inventory

4.7.1 Demand for the product

Demand for products and services forms the basis for any organization to take up their development, production and delivery. Demand may be an intrinsic or essential need or created by the organization to sell their goods and services.

Effect of promotions on demand

Promotions generally increase the demand for a firm's product. The increase in demand results in increase in the market share, an increase in the number of customers switching from the competitors, and forward buying.

Market growth

Market growth refers to the increase in sales for a product, due to an increase in the number of new customers or an increase in repeat purchases by existing customers. For example, if Hero Honda cuts the price of one of its popular motorbike models and brings it closer to the price of scooters, customers who planned to buy a scooter may buy the bike. Such a price cut will increase the sale of Hero Honda's motorbikes as well as increase the size of the market for motorbikes.

Stealing market share

Promotions encourage customers to purchase a particular firm's product, instead of its competitor's products. Thus, by using promotions, the firm is 'stealing' its competitor's market share. For example, if AMD (a leading computer chip maker) offers a price cut on its latest microprocessor, then the people who are planning to buy Intel processors may be inclined to buy AMD processors. Thus, AMD gains market share at the cost of Intel, even though the overall size of the processor market remains constant.

Forward buying

Forward buying refers to the purchase of goods in advance by customers. Forward buying does not increase the sales of a firm in the long-term, but it can help the firm spread the demand evenly throughout the year. Take the case of a woolen garment manufacturer, who has excess demand - more than it can handle - in winter and low demand in summer. The manufacturer must either under-produce or carry huge inventories (which will increase his costs). In such a situation, the manufacturer can promote his products in the summer, which will encourage

forward buying by customers, thereby moving some of the excess demand from the coming winter season to the present summer season. Thus, promotions help the firm manage predictable seasonal variability in a supply chain.

The market growth and stealing of market share effects of promotions, increase overall demand for the company's products. However, forward buying does not increase the overall demand, since in this type of buying the purchase decision is simply advanced by the customer. Thus, the firm must analyze the impact of these three factors on demand, to determine the right timing for promotions. If demand increases due to forward buying, then promotions during the peak season are not appropriate. Offering a promotion like price cuts during the peak demand period, when demand is influenced more by forward buying, may result in increased volatility in demand. As a result, the demand that exists during the lean season may shift to the peak demand period, resulting in an uneven demand pattern, which increases costs.

Offering promotions during the peak season is advisable, only when the demand caused by forward buying constitutes a small portion of the overall increase in demand.

4.7.2 Product margins

Product margins can also influence promotion timing decisions. If product margins are increasing with increasing volumes, offering promotions during the peak demand season can increase profitability. However, if product margins are decreasing with increasing volumes, then promotions during the peak season are not appropriate since the overall profit decreases with the increase in sales. When product margins are on the decline, firms should offer promotions during the low-demand period to increase profits.

4.7.3 Cost of holding inventory

Inventory holding costs can also influence promotion timing decisions. If inventory holding costs are high, then offering promotions during the off-season can reduce inventory holding costs and improve profitability. Consider the PC industry, which experiences short product life cycles. A PC manufacturer has high inventory holding costs due to the high risk of product obsolescence. The firm can offer discounts to dispose of products that were unsold during the peak demand season.

Example: Supply & demand at Amazon

Amazon had made a change in the way of communicating inventory demand to vendors. **Probability Level Demand Forecast:** Vendors were made to take critical decisions that would directly impact their stock levels for Amazon, leading to impact on their business success.

Contd….

Three new probability forecasts were defined for vendors covering history of sales, demand projection for promotion. **P70** – indicated a chance of **70%**, that Amazon would purchase the demand level indicated or less, a **30%** chance to purchase more. **P80** – indicated a chance of **80%**, that Amazon would purchase the demand level indicated or less, a **20%** chance to purchase more. **P90** – indicated a chance of **90%**, that Amazon would purchase the demand as indicated or less. It also said that there was a chance to purchase 10% more.

Amazon had optimized the supply chain puzzle – including warehousing, inventory management, delivery times and prices. Sellers who sold Amazon Marketplace had fulfillment options to choose from: either they could choose if they wanted to handle fulfillment or let Amazon sort, package and ship products through their own fulfillment centers.

Source: https://tinuiti.com/blog/amazon/amazon-supply-chain/ February 2020, Accessed on 17/08/22

Check Your Progress - 2

6. For solving aggregate planning problems, Transportation method of Linear Programming is used. Which is the single most important assumption in this method?
   a. Stable inventory
   b. Producing during regular time
   c. Producing using overtime and subcontracting
   d. Constant workforce
   e. Total outsourcing
2. Which, of the following, is not an effect, due to predictable variability in demand?
   a. Stockouts
   b. High inventory
   c. Low customer service
   d. Quality problems
   e. Demand-supply mismatch
3. Managing Supply is one way of tackling demand variability. Which, of the following, is not an option in this strategy?
   a. Production capacity
   b. Inventory
   c. Subcontracting
   d. Backordering
   e. Rejecting orders

4. Managing the capacity to handle demand variability has some options. Which is the best one, for a full capacity running manufacturing unit?
   a. Time flexibility
   b. Use of seasonal workforce
   c. Use of subcontracting
   d. Designing product flexibility into production processes
   e. Increasing capacity
5. Timing of Promotional activities depends upon which of the following?
   a. Demand for the product
   b. Sales maximization motto
   c. Profit maximization motto
   d. Cost of holding inventory
   e. Market growth motto

4.8 Summary

- Studied the aggregate planning process and its importance in the supply chain
- Discussed various aggregate planning strategies followed by businesses such as the chase strategy, the stable workforce strategy, and the level strategy, which were examined in detail.
- Also studied the techniques used for solving aggregate planning problems.
- Understood, using examples, the Cut and Try method and transportation methods.
- Examined the process of managing predictable variability, using various strategies for managing both supply and demand

4.9 Glossary

Aggregate Planning is an intermediate range (3-18 months) capacity planning

Chase Strategy- Matching production rate with demand rate

Cut and Try method of aggregate planning technique is used, when a firm chooses the least cost option from different production plans

Forward buying: Forward buying refers to the purchase of goods in advance by customers.

Level strategy- Workforce and production rate are kept stable and fluctuations are managed through high inventory or order backlogs

Market growth: Market growth refers to the increase in sales for a product, due to an increase in the number of new customers or an increase in repeat purchases by existing customers.

Stable workforce strategy- Keeping workforce stable, the output is varied by varying working hours

4.10 Self-Assessment Test

1. What is Aggregate Planning? Explain its Role in a Supply Chain.
2. Describe the Aggregate Planning Process.
3. How will you Manage Predictable Variability in a Supply Chain?
4. What are the Decision Options in Varying Supply?
5. What are the Decision Options in Varying Demand?

4.11 Suggested Reading / Reference Material

1. Ashley McDonough, Operations and Supply Chain Management Essentials You Always Wanted to Know: 15 (Self Learning Management Series) Paperback – 1 January 2020
2. Russel and Taylor, Operations and Supply Chain Management, 10 ed, ISV Paperback – October 2019
3. Chopra and Kalra, Supply Chain Management 6/e Paperback – 17 June 2016

4.12 Answers to Check Your Progress Questions

1. (b) To match supply and demand.

To match supply and demand is the main purpose of Supply Chain Management

2. (e) It is a plan derived by aggregating different plans.

It is not true that a plan derived by aggregating different plans is aggregate planning.

3. (e) Quality level

Quality level is the factor that does not contribute to the formulation of aggregate plans.

4. (d) Estimate production requirements

Identifying the machinery required, to increase capacity is not a stage in the aggregate planning process.

5. (a) Chase Strategy

Chase strategy is the best aggregate planning strategy, for the food Sales maximization motto. Sales maximization decides the timing of promotional activities.

6. (d) Constant workforce

It is the single most important assumption for solving aggregate planning problems using transportation method of Linear Programming.

7. (d) Quality problems

It is not an effect due to predictable vulnerability in demand.

8. (e) Rejecting orders

Rejecting orders is not an option in managing supply to tackle demand variability.

9. (d) Designing product flexibility into production processes

It is the best method for a full capacity running manufacturing unit.

10. (b) Sales maximization motto

Timing of promotional activities depends upon sales maximization motto.

Unit 5

Facility Network Design

Structures

5.1 Introduction

5.2 Objectives

5.3 Factors Influencing Facility Network Design Decisions

5.4 Process of Facility Network Design

5.5 Models for Facility Network Design and Capacity Allocation

5.6 Summary

5.7 Glossary

5.8 Self-Assessment Test

5.9 Suggested Reading / Reference Material

5.10 Answers to Check Your Progress Questions

"Networking is an investment in your business. It takes time and when done correctly can yield great results for years to come."

- Diane Helbig, (Diane Helbig is an internationally recognized business and leadership development advisor, award-winning speaker, author, and workshop facilitator.

5.1 Introduction

Designing a facility network is one of the important aspects of the supply chain and when such network is designed with right investment of time, money, strategy and business goals, is bound to support the supply chain and business operations towards growth for longer times.

In the previous unit, we discussed the process of managing demand and supply. The concepts covered included the use of aggregate planning and its role in the supply chain, aggregate planning strategies and techniques and the methods for effectively managing predictable variability.

Designing a facility network is one of the important aspects of the supply chain. Retail stores, finished goods warehouses, manufacturing plants, and raw material storage warehouses constitute the facilities in a supply chain. Firms take facility decisions at three levels: strategic, tactical, and operational. At the strategic level, firms determine the set of facilities that are to be located, the role of the facilities, the capacity at each facility, etc. At the tactical level, firms determine the allocation of demand for each facility, the level of inventory that needs to be held at each facility, etc. At the operational level, firms make decisions regarding the

coordination of the activities carried out by the facilities to serve customer needs in an efficient and effective manner. Once a facility has been set up, it is difficult to shift to another location or shut down the facility, because of the huge amount of capital that would have been invested in setting it up. Thus, firms must choose locations that not only perform well in the current set of conditions but will also be able to adjust to changes that may take place, in the future. Inappropriate facility decisions affect profitability and the very survival of firms. Webvan, a high-profile online grocery store (now closed), had made huge investments in facilities, without understanding market conditions. This was one of the reasons for the failure of the company. Huge capital was locked in these facilities, resulting in a liquidity crunch. Facility decisions have a profound impact on the business operations of firms. Facility decisions determine the network design and the limitations, within which a company can move inventory, transport goods, and exchange information successfully, to cater to the needs of customers at minimum costs.

In this unit, we first examine the factors that influence facility decisions. The framework for designing facility networks is examined next, followed by the models that are used for designing these networks.

5.2 Objectives

By the end of the unit, you will be able to

- Identify the factors influencing facility network design decisions
- Explain the process of facility network design
- Discuss models for facility network design and capacity allocation

5.3 Factors Influencing Facility Network Design Decisions

There are many factors that influence facility network design decisions. These factors may be strategic, technological, political, economic, or competitive in nature. While some factors are financial in nature and are easily quantifiable, others are non-financial and, hence, not easily quantifiable. Some of the factors that influence a firm’s facility network design decisions are discussed below.

5.3.1 Strategic Factors

The firm chooses the facilities as per its core competency or based upon its organizational objectives. If the firm is following the strategy of providing goods to customers at low prices, then it looks for a facility that is cost-effective. On the other hand, if the firm's strategy is to provide a high level of customer service, then it focuses on facilities, which are responsive so that the firm can react quickly to the market conditions. Departmental stores like Shopper's Stop and Lifestyle try to provide better customer service by locating their outlets close to the target customer, even if the location is highly expensive. On the contrary, hypermarkets like Giant look for locations, where the fixed and operating costs are lower so that

they can cut costs and provide goods to the customers at a lower price. Facilities of multinational companies located in various countries play different roles, to achieve the strategic objectives of the firm. For example, Microsoft's development center in India was set up to provide services to its global clients, whereas its development center in China caters to the needs of the growing domestic (Chinese) market.

While deciding to set up facilities on a global scale, the firm must determine the role each facility has to play within the supply chain and the purpose or objective for which it is set up. The roles that different facilities located in a global network perform are discussed below.

Offshore facility: Facilities that are set up outside the country are known as offshore facilities. These facilities are set up to exploit the advantage of low-cost resources of that location so that the total costs in the supply chain can be reduced. For example, many multinationals have set up manufacturing facilities in China, where the production and operating costs are low, resulting in a reduction in total manufacturing costs.

Source facility: The purpose of the source facility is not only providing goods to the firm at a lower cost but also acting as a key provider of the product, for total global operations. Source facilities are set up, where a favorable environment for quality production at low cost exists, i.e. low production costs, cheap and skilled labor and good infrastructure are available. Offshore facilities that satisfy the above conditions have the potential to become source facilities.

Server facility: The role of the server facility is to act as a supply source for the market, where it is set up. The factors that prompt firms to set up server facilities are import barriers for the company to enter the market, requirements like a high level of local components in the product framed by the local government, and high costs in servicing the local market by sourcing from facilities located in other countries.

Contributor facility: The contributor facility performs a dual role, where it not only serves the local market but also helps the parent company, in other value-added activities like new product development initiatives, process enhancements, product customization, overseas marketing, etc. For example, Ford's plant in India manufactures the Ford Ikon car, which is customized for the Indian environment. This model is now being sourced by the parent company to sell it in other markets with a similar environment. The server facilities that are set up by the firm slowly develop into contributor facilities. Many automobile companies that have set up manufacturing plants in India to cater to the needs of the domestic market are now becoming contributor facilities for the parent company.

Outpost facility: The outpost facility is set up primarily to benefit from the local knowledge and skills that are unique to that particular region. These facilities may

also act as server facilities. For example, Huawei Technologies, a Chinese telecom company, has set up its largest R&D center outside China in Bangalore, India, in order to gain access to the software development skills, which are inadequate in their country.

Lead facility: The lead facility provides the entire gamut of activities, which add value to the product, for its parent company. The lead facility develops new products, improves processes and products, and creates new technologies for the firm's entire global network.

5.3.2 Location Strategies in Supply Chains

In the Post-globalization era, any organization can start operations anywhere in the world. The factors like competitive pressures, availability of skilled workforce, managerial talent, resources, local industrial laws and regulations, etc., decide the country and locations. Deciding locations, to create physical infrastructure for conducting an organization's operations, has assumed significance in view of the operations being established there. But with increasing salaries and strengthening currencies, countries like China are no longer cost-effective and companies are searching for locations elsewhere. Automobile companies are locating their manufacturing plants in countries of consumption. Once the locations are fixed, layouts are designed depending upon the complexity and nature of the products and processes.

Key imperatives for business leaders, to reengineer their location strategies are:

- Business leaders need to understand how the customer's preferences and competition are evolving and watch for new sources of innovation and potentially disruptive changes.
- Companies, in the emerging world, set their sights on international expansion and, therefore need to compete, for acquiring global customers, talent, capital, and resources.
- They must revisit headquarters configuration, structure, and location of senior management.
- After understanding the new ecosystem, companies must think about the structure and location of senior management.
- Business leaders must understand how companies make location choices and where they face challenges. They must improve company reputation nationally and internationally.

This calls for reviewing traditional organizational structures and drafting new operations strategies while deciding locations. CEOs must prepare for the new wave of competitors, by understanding who they are and what their strategy is. Accordingly, they need to make changes in their organizations.

5.3.3 Technological Factors

The available technologies also play an influential role in deciding the design of the facility network. If economies of scale can be achieved by using technology, then the firm may set up a few large facilities to serve its entire global network. But if fixed costs are low for the facilities, when using a particular technology, then several facilities can be set up catering to each market. For example, the investment involved in oil refineries is huge, and hence, many oil companies set up only a few facilities, with large capacities to serve their entire global network. Facilities that manufacture FMCG products like soaps and detergents can be set up at low fixed costs, hence many firms set up (stand-alone) plants for each market.

5.3.4 Tariffs and Tax Incentives

Tariffs refer to duties imposed by the local government, for importing goods from another state or country. These tariffs are imposed to protect the domestic industry. Tariffs also influence facility network design decisions. Companies choose locations, where the tariffs are low. As tariffs are imposed on the goods imported, the firm either does not market the product or it sets up more facilities to manufacture and distribute the products within the country to avoid the tariffs.

To encourage industrial growth, many governments provide various incentives to firms that want to set up facilities in their countries. The Indian government has set up Export Processing Zones (EPZs) and Special Economic Zones (SEZs), to augment industrial growth. In these zones, companies are provided with various incentives and amenities. Taxes are low or nil if the products are manufactured for export. Individual state governments also provide such incentives to attract companies to set up facilities in their states.

Special Economic Zones in India

India was one of the first, in Asia, to recognize the effectiveness of the Export Processing Zone (EPZ) model in promoting exports, by setting up Asia's first EPZ in Kandla in 1965. EPZ gave rise to the concept of Special Economic Processing Zone (SEZ) in India. The SEZ policy was announced in April 2000, in its Export & Import Policy, with a view to provide an internationally competitive and hassle-free environment for export production and to attract larger foreign investments in India.

Under this scheme, units may be set up in SEZ for manufacture, trading, re-conditioning, repair, or service activity. The policy provided for setting up of SEZs in the public, private, joint sectors, or by State Governments. It was also envisaged that some of the existing Export Processing Zones would be converted into Special Economic Zones. The Government has also approved SEZs, across the country.

Some of the incentives provided for the firms located in these zones are:

- Import/ Procurement of goods without payment of customs/ excise duty.
- Income Tax exemption for the first 10 years.
- Facility to develop a township within the SEZ with residential areas, markets, playgrounds, clubs, and recreation centers, etc.
- Exemption of Central Sales Tax on domestic purchases.
- 100% Foreign Direct Investment in the manufacturing sector, allowed through the automatic route, barring a few sectors.
- Facility to retain 100% foreign exchange receipts in Exchange Earners Foreign Currency (EEFC) Account.
- Overseas investment by SEZ units from the EEFC account, through the automatic route.
- Facility to set up overseas banking units.
- No cap on foreign investments for SSI reserved items.
- Exemption from industrial licensing requirement for items reserved for the SSI sector.
- Profits allowed to be repatriated freely, without any dividend balancing requirement.
- Support services like banking, post office, clearing agents, etc., provided in the Economic Zone Complex.
- Developed plots and ready to use built-up space.

5.3.5 Political Stability

Political climate is another important factor that a company looks at while planning to set up a facility in a country. Companies prefer a stable political climate so that business operations run smoothly. India has been able to provide a stable political climate for the past several years, which had a positive effect on the industrial front. Companies also look for a fair and transparent legal system, so that their legal problems are easily redressed.

5.3.6 Infrastructure

Infrastructure can be a major factor in facility location decisions for many companies. Infrastructure refers to the adequacy of roadways, railways, airways, seaports, power supply, and telecommunication networks. Companies prefer locations, where the infrastructure is reasonably good for a better flow of goods and information.

5.3.7 Proximity to Suppliers, Resources, and Markets

Another factor, which needs to be examined, while taking facility network decisions, is the proximity to suppliers and resources. If the plant is close to suppliers, then lead time and transportation costs can be reduced. This is important for companies adopting Just-in-Time (JIT) strategies. Many manufacturing firms locate their plants near the source of raw material. Many automobile manufacturers select Chennai, a south Indian city, to set up their facilities, as it gives them access to a qualified pool of suppliers. Locating nearer to suppliers enables the manufacturers to reduce inventory costs, by arranging for JIT supplies.

Supplier Parks - A New Facility Network Design

The increasing acceptance, of Just-In-Time delivery and lean manufacturing practices, has made proximity of suppliers and customers an important consideration for plant and distribution set up decisions. Now companies are trying to develop new facility network designs so that the resources can be optimally utilized. One such design is supplier parks. A cluster of suppliers is located within the vicinity of a large customer in supplier parks. In this setup, suppliers are not only clustering near big customers but also are collaborating and sharing their resources and providing components to customers in a shorter time. The supplier park concept is still in its nascent stages. It gained prominence among automotive manufacturers. In co-located sites, suppliers can coordinate and send pre-assembled modules to the customer. For example, if one supplier produces nuts and another bolts for the same customer, then both can collaborate to assemble and send them as a single module to the customer. This reduces time and cost for the customer because the module is pre-assembled. Generally, clustering of suppliers takes place, due to the presence of large customers in that area. This clustering may also provide more opportunities to the suppliers, to cater to a wider range of customers. Clustering of suppliers can lead to a chain reaction, where the location attracts more suppliers. If the first-tier suppliers are co-located, then the second-tier and third-tier suppliers will also find an advantage in shifting to the location.

The advantages to customers from supplier parks are reduced delivery time, assembled components, reduced transportation costs, and inventory costs. The advantages to suppliers are a reduction in transportation costs and increased productivity due to the sharing of resources among the suppliers. It also provides a steady demand from the customer. These parks may also provide opportunities to serve other customers.

Volkswagen is a pioneer in this concept, which it successfully implemented in its plant in Martorell, Spain, in collaboration with the British supply chain

management solution provider, Exel. After the Sept 11th attacks, this type of set-up began gaining recognition.

Co-located sites can minimize disruptions in the supply of raw material, as the suppliers are located close by. These setups make for more efficiency and responsiveness in the supply chain.

To be successful, firms must provide good customer service and be very customer responsive. This requires them to be in touch with their customers, by locating their facilities near them. This is more important for service firms like retailers.

5.3.8 Facility Costs

Costs involved in setting up the facility and maintaining it must also be considered while taking any facility network design decisions. There are two types of costs involved in setting up a facility: fixed costs and variable costs. Costs for leasing or construction, cost of acquiring land for the site, etc., are treated as fixed costs. Variable costs include energy costs, personnel costs, and other maintenance costs. Facility costs are higher in cities, as compared to locations in rural areas, where land and construction costs are substantially lower.

5.3.9 Other Factors

There are other factors, though not as important as those discussed above, that the firm should also take into consideration while making any facility network design decisions. Some of them are discussed below.

Labor climate: The labor environment is also a factor for consideration. The status of labor unions in the region, the labor laws existing in the region, and the traditions and attitudes of the labor are few factors that affect the operation of the facility.

Proximity to the company's other facilities: Proximity to the company's other facilities is another factor, which a firm must consider. This is more important for firms that require a high degree of coordination, between various units.

Quality of life: The quality of life is important from the employee's point of view. An employee will shift to a location only if the quality of life at the location meets his expectations. The local climate, crime rate, living expenses, and traffic congestion are some of the considerations. The firm must think not only about the employee's needs but also those of his family. The employee also looks out for better schools, recreational and other facilities, which he can provide for the family. The quality of life may affect both the turnover of the company and the productivity of employees.

Environmental factors: Environmental factors are becoming increasingly important for a company while setting up facilities. These aspects include environmental regulations, proximity to waste disposal plants, and environment-related taxes, if any.

Room for expansion: The Company should take a long-term perspective while selecting a location and evaluate the prospects for expansion in that area.

Example: Collaborative Hospital Supply Chain Networks

Territorial Hospital Groups (THGs) was a group of hospitals in France, which had joined together to modernize the health care system. The basic challenge laid in building an efficient logistics organization structure to facilitate a collaborative supply chain model. They adopted a concept of logistics pooling for collaboration between hospitals in THGs. The objective was to pool the stored products in warehouses to optimize their distribution to reduce various logistics costs, like: goods transportation, intermittent storage, required workforce, etc. The healthcare supply chains were likely imprecise or uncertain, due to the unavailability and incompleteness of data in real-world situations. A Fuzzy chance-constrained programming approach was built in a 'multi-supplier, multi-warehouse, and multi-commodity supply chain', using possibility theory, for solution of a network design problem. Using the fuzzy demand, a linear programming optimization model was built and solved.

The analysis helped in meeting the customers' demand, and also that of optimum allocation at warehouses. Multiple instances were generated based on available territorial hospital group, and various combinations of tests were developed to study the advantages from collaboration and uncertainty handling. The efficiency of the proposed model was tested by comparing the fuzzy chance-constrained programming with the weighted average method, and the proposed approach was proved to be robust.

Source: https://link.springer.com/article/10.1007/s12351-022-00724-, July 2022, Accessed on 20/08/22

Activity 5.1

Designing a facility network is an important aspect of strategic planning, in supply chain management. Facilities in SCM generally cover retail stores, finished goods warehouses, manufacturing plants, and raw material storage facilities. Facility decisions are taken at strategic, tactical, and operational levels.

Strategic level- firms determine the set of facilities that are to be located, the role of the facilities, the production capacity at each facility, etc.

Tactical level- firms determine the allocation of demand for each facility, the level of inventory that needs to be held at each facility, etc.

Operational level- firms make decisions regarding coordination of the activities carried out by the facilities, to serve customer needs in an efficient and effective manner.

Amazon, the global retailer, during September 2020, opened its largest Fulfillment Center in India, at Hyderabad. Analyze the reasons for choosing to locate the facility at Hyderabad from strategic, tactical, and operations point of view.

Check Your Progress - 1

1. If an Indian company wants to start manufacturing in an African country, which, of the following, is an appropriate term to describe the location decision?
   a. Strategic
   b. Political
   c. Technological
   d. Economic
   e. Competitive
2. Name the location decision, if Microsoft decided to establish its development center in India.
   a. Strategic
   b. Political
   c. Technological
   d. Economic
   e. Competitive
3. What do you call the Suzuki's decision to expand India operations by establishing more units?
   a. Strategic
   b. Political
   c. Technological
   d. Competitive
   e. Business growth

4. In which of the following, a company's 'Contributor Facility' does not engage in?
   a. Serving only local market
   b. Helping the parent company in New Product Development
   c. Improving processes
   d. Locating better suppliers
   e. Product customization
5. How do you classify an automobile manufacturing unit established by multinational corporations in India?
   a. Offshore facility
   b. Source facility
   c. Server facility
   d. Contributor facility
   e. Outpost facility

5.4 Process of Facility Network Design Decision

The process of facility network design decision involves the following steps:

- Developing a supply chain strategy
- Studying the regional market configuration
- Identifying a set of potential sites
- Selecting the location

5.4.1 Developing a Supply Chain Strategy

The supply chain strategy plays a major role, in a facility network design decision. The firm's supply chain strategy can be built around its core competencies like customer service, product quality, technology leadership, product attributes, process attributes, etc. For example, Walmart's core competency is offering products to customers at a low price. Therefore, its facility network design needs to be in line with the low pricing strategy. For this, Walmart must set up cost-effective facilities so that costs can be kept minimal and it can offer products to customers at low prices. The departmental store chain Nordstrom's core competency is maintaining a high level of customer service, i.e., availability of a wide range of products and satisfying every customer need. For this, facilities need to improve the supply chain's responsiveness rather than cost-effectiveness. Thus, based upon the core competency and the supply chain strategy, the firm needs to design its facility network.

5.4.2 Studying the Regional Market Configuration

The firm then needs to study the regions where the facilities can be set up, their scope of operation and capacity allocation.

First, the managers need to make a forecast of the demand of each region. The forecast must include the size of demand and determine whether the demand is similar in all the regions or variable across different regions. If the demand is large and homogenous then the firm can set up large consolidated facilities, at fewer locations. If the demand is variable, then the company can set up smaller facilities at each location. For example, the consumption of coffee is high and more homogeneous in the southern part of India, as compared to the northern part of India. Therefore, a coffee production firm can set up large, consolidated facilities in a few locations in south India to cater to the needs of that market. In northern India, where the consumption pattern is varied and less, the firm can set up small, localized facilities at different locations.

Later the managers need to see, whether economies of scale can reduce the facility costs. If economies of scale reduce the costs significantly, then it would be better for the firm to set up a few facilities for serving many markets. If the costs are not affected by economies of scale, then the firm can set up a facility in each region. For example, Samsonite, the leading player in the luggage product market has very few production facilities serving its markets worldwide, which gives economies of scale advantages to the company. On the other hand, the FMCG major Unilever has many production facilities in the markets it serves. This is because the products differ in each of the markets and do not allow the company to take advantage of economies of scale.

Next, the managers have to evaluate the risks, in setting up a plant in a particular region. These include demand risk, exchange rate risk, and political risk. The company should also analyze the tariff structure, tax incentives, and import-export restrictions in each market. The company must also study its competitors' strategies and decide, whether the facilities should be located near or away from the competitors.

After evaluating all these factors, the company needs to identify the regional facility configuration, for the supply chain. The regional facility configuration describes the regions, where the facilities need to be set up, the products that need to be manufactured, and the markets that the facilities need to serve.

5.4.3 Identifying a Set of Potential Sites

After studying the characteristics of different regions, the firm has to identify potential sites, in each of the regions. The sites need to be identified, based on the firm's production and infrastructure requirements and also based on the company's policies. Infrastructure requirements include the suppliers,

transportation services, sources of raw material, utilities, etc. The company should also evaluate qualitative factors like labor climate, availability of workforce, community attitude towards the industry, etc.

5.4.4 Selecting the Location

Finally, the firm has to select the exact location, where the facility will be set-up. The site needs to be selected from among the potential sites. The aim of the selection is to maximize profits and minimize costs.

Example: Product-Service System case on Logistics Network Design

HAL- France was a multi-disciplinary, open access repository for the dissemination of published and unpublished scientific research documents, coming from teaching and research institutions in 'France or abroad public or private research centers'. A two-year-old start-up company; at Grenoble metropolitan area, which adopted the Product-Service System (PSS) business model, was analyzed for optimizing tools, to build a logistics and transport network. The approach adopted was a logistics network design, using the configuration of a multi-level logistics network, based on Location-Inventory; modeled with a Mixed Integer Linear Program (MILP). As the company was relatively young, available data related to maintenance, installation and refurbishing demand was small.

A logistics network design dedicated to a PSS business model was developed. It was built based on a data model covering the proposed product life cycle and the strategic growth plan of over 5 years. The Uncapacitated Facility Location, based Integer Linear Programming helped to design optimized logistics networks facilitating the computation of overall system costs. The model was vibrated over various strategies likely to be adopted by the company. The study of the comparison of various strategies paved way for recommendations for outsourcing possibilities. As time progressed, and more data would be available with the company, finer refinements could be done for the model.

Source: https://hal.archives-ouvertes.fr/hal-03271991/document May 2021, Accessed on 20/8/22

5.5 Models for Facility Network Design and Capacity Allocation

Facility network design decisions are complex and data-intense. The complexity arises from the number of facilities and their associated capacity allocation strategies. Data intensity is due to the requirement of comprehensive data on demand, time, distance, transportation routes and schedules, cost components, etc. There are several sophisticated models that aid in the decision-making of facility network design. Broadly, they are classified into gravity location models, optimization or linear programming models, heuristic models, and simulation techniques.

5.5.1 Gravity Location Models

Gravity location models are calculus-based models that find the location, with the minimum cost of transportation, between suppliers and markets. The model assumes that the sources of supply and the customer markets can be plotted on a plane linearly. It also assumes that the transportation costs are linearly proportional to the quantity shipped between two points. The model is based on Cartesian coordinates, where the horizontal or east-west axis is labeled as x-axis and the north-south axis is labeled as y-axis. Any given point in a quadrant can be identified with reference to the x and y axis coordinates.

The distance between the two centers can be calculated as follows

$d_k = \sqrt{(x - x_k)^2 + (y - y_k)^2}$ ---- Equ. (5.1)

d_k = distance between the destination and warehouse

x_k , y_k= coordinate location of either a market or supply source k

x, y = Facility at the location (x, y).

The total transportation cost, TC, is given by the following formula

$TC = \sum_{k=1}^{n} (d_k Q_k C_k)$ ---- Equ. (5.2)

Where Q_k = quantity to be shipped between the facility and the market or source of supply k

d_k = distance between the facility, and the market or source of supply k

C_k = Cost of transportation for delivering the goods between the facility and the market or source of supply k

The location that minimizes the total transportation cost is the ideal location for setting up a new facility.

The algebraic formulae for gravity location computation are given below:

$$x' = \frac{\sum_{k=1}^{n} [(Q_k C_k x_k) \div d_k]}{\sum_{k=1}^{n} [(Q_k C_k) \div d_k]}$$ ------- Equ. (5.3)

$$y' = \frac{\sum_{k=1}^{n} [(Q_k C_k y_k) \div d_k]}{\sum_{k=1}^{n} [(Q_k C_k) \div d_k]}$$ ------ Equ. (5.4)

(x', y') = unknown coordinates of the new facility

The procedure for identifying an optimal location is as follows:

1. For each market or source, the distance is calculated using equation 5.1.
2. The new facility location (x', y') is obtained by equations 5.3 and 5.4. The initial x and y coordinates are taken (0, 0).

3. If the new location obtained is equal to previous location coordinates, then the obtained location is the optimal location, which minimizes the total cost TC.
4. Otherwise, the values for (x, y) are set to the newly obtained (x', y') and the procedure from step 1 to 3 is followed till the values obtained for (x', y') are equal to the values obtained in the previous iteration.

For example, if the initial values of x and y are (0, 0), then the distance between the proposed facility and the destination is calculated from equation 5.1.

Next, the values of x' and y' are calculated. Let us say, values obtained are (234, 567). The new coordinates indicate a substantial shift from previous values (0, 0). Therefore, the procedure is not complete and additional iterations are required. For the next iteration values (x = 234, y = 567) are used. These iterations should be carried out until (x, y) = (x', y'). Suppose the immediate results of (x', y') are equal to x = 234, y = 567, this implies that the adjustment is minimal or zero. Hence the optimal location is obtained that minimizes the total transportation cost TC.

5.5.2 Linear Programming Models

Linear programming is a widely used tool in strategic and tactical planning. Linear programming, which is used to solve managerial problems, consists of allocating scarce resources among various activities to meet certain demands optimally.

The optimization model assumes the following conditions:

- Two or more facilities or plants are vying for limited resources
- The relationships between the variables in the problem are deterministic and linear.

There are two types of linear programming models, which are widely used in facility network design decision-making: the network optimization model and the transportation model.

Transportation linear programming models aim at identifying a distribution network, which minimizes transportation costs while satisfying overall supply and demand requirements. This model is based on the following assumptions:

- Transportation costs are a linear function of the number of units shipped.
- The transportation cost per unit is fixed, irrespective of the quantity shipped.
- Total supply matches total demand.

A model transportation matrix is shown in Figure 5.1. The demand from each market is denoted by D_i, placed in the bottom row of the matrix. The supply from each warehouse or production plant is denoted by S_j, which is shown in the last column of the matrix. The transportation costs between the supply points and

demand destinations are indicated by C_{ij}, which are placed in the upper corner of each cell. The optimal quantities that are allocated to satisfy the demand are expressed, as the number of units shipped from a supply point to the demand destination. They are indicated by X_{ij} and are placed in the appropriate cells. There are several methods for obtaining initial and optimal solutions for solving transportation problems.

There are three methods for arriving at an initial solution: least cost, Northwest corner, and Vogel's Approximation Method (VAM). The initial solution is improved upon, using the Steppingstone and Modified Distribution (MODI) methods, to arrive at an optimal solution. Let us understand this method using an example.

Figure 5.1: Transportation Matrix

				Supply
	C_{11} X_{11}	C_{11} X_{11}	C_{11} X_{11}	**S_1**
	C_{12} X_{12}	C_{12} X_{12}	C_{12} X_{12}	**S_2**
	C_{13} $X_{13.}$	C_{13} X_{13}	C_{13} X_{13}	**S_3**
Demand	**D_1**	**D_2**	**D_3**	

S.B Pharmaceuticals has manufacturing plants Dhanvantari-I, Dhanvantari-II, and Dhanvantari-III. The products from these three plants are distributed to its outlets, in Mumbai and Delhi. The firm has decided to set up a new outlet in Calcutta, due to an increase in demand from that market.

The transportation costs per unit for shipping the load from each supply point to the demand destination are shown in Table 5.1.

Table 5.1: Transportation Costs per Unit

	Markets		
Plants	**Mumbai**	**Delhi**	**Calcutta**
Dhanvantari-I	6	4	1
Dhanvantari-II	3	8	7
Dhanvantari-III	4	4	2

Source: ICFAI Research Center

The Dhanvantari-I, Dhanvantari-II, and Dhanvantari-III facilities can produce 50-unit loads, 40 unit loads, and 60 unit loads per week, respectively. The demand requirements at Mumbai and Delhi markets are 20 and 95 unit loads per week, respectively. The demand requirements for the Calcutta market are estimated to be 35 unit loads per week.

S.B Pharmaceuticals has to determine the optimal allocation of demand to minimize transportation costs if the Calcutta market is selected.

Let us use the least cost method for obtaining the initial solution.

The allocation of the supply to meet the demand using the least cost method is as follows:

- Assign as many units as possible, where the transportation cost is the least. The lowest cost in the matrix is ₹ 1 for the Dhanvantari-I - Calcutta cell. Supply and demand for that cell are 50 and 35, respectively. Thus, the cell is assigned 35 units to satisfy the demand of that column.
- The next least cost is ₹ 2 for the Dhanvantari-III - Calcutta cell. But the demand for that column has already been met.
- The next least cost is ₹ 3 for the Dhanvantari-II - Mumbai cell. Supply and demand for that cell are 20 and 20, respectively. Thus, 20 units from Dhanvantari-II plant are allocated for meeting the demand for the Delhi market.
- The demand for the Mumbai and Calcutta markets has been met, the demand for the Delhi market can be met, by allocating the units from the available supply sources. 60 units are allocated to Dhanvantari-III plant, 15 units are allocated to the Dhanvantari-I plant, and the remaining 20 units are allocated to the Dhanvantari-II plant.

35 units Dhanvantari-I to Calcutta @ ₹ 1 per unit	₹ 35
15 units Dhanvantari-I to Delhi @ ₹ 4 per unit	₹ 60
20 units Dhanvantari-II to Mumbai @ ₹ 3 per unit	₹ 60
20 units Dhanvantari-II to Calcutta @ ₹ 8 per unit	₹ 160
60 units Dhanvantari-III to Delhi @ ₹ 4 per unit	₹ 240
Total	**₹ 555**

The transportation cost for the distribution arrangement is shown in Figure 5.2.

Figure 5.2: Initial Solution using Least Cost Method

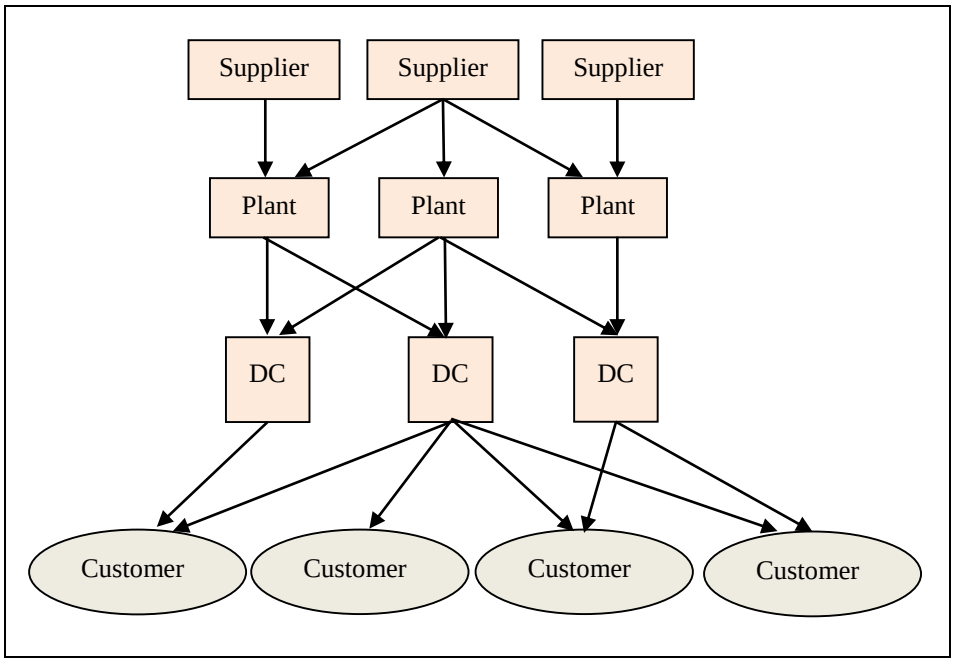
	Mumbai	**Delhi**	**Calcutta**	**Supply**
Dhanvantari - I	6	4 15	1 35	**50**
Dhanvantari - II	3 20	8 20	7	**40**
Dhanvantari - III	4	4 60	2	**60**
Demand	**20**	**95**	**35**	**150**

Source: ICFAI Research Center

This solution can be improved using either the MODI method or the Steppingstone approach.

There are certain disadvantages associated with the transportation method. If the number of variables or the size of the problem increases, the optimality of the solution tends to decrease. In a multi-system, there are several stages including suppliers, manufacturing plants, finished goods warehouses, and markets. The needs and constraints of each of these supply chain members are to be considered while solving a transportation problem (See Figure 5.3). With the advent of new and powerful technologies, as well as new algorithms, problem size is not an issue. Another disadvantage is the incorporation of fixed as well as variable costs in the problem.

Figure 5.3: Multi Echelon System



Source: ICFAI Research Center

C- Distribution Center

The shortcomings of problem size constraints and the inability to include fixed and variable costs in the problem can be overcome using the mixed integer programming model. This model is capable of incorporating fixed and variable costs in the problem.

There are two types of costs associated with a facility, fixed costs, and variable costs. Fixed costs include land costs, equipment costs, construction costs, and production costs. These costs are incurred, independent of the quantity of products shipped or manufactured from a facility. Variable costs are incurred, based on the product shipped or produced. Generally, variable costs decrease to

an extent, with an increase in quantity ordered and then increase, when order quantity exceeds the Economic Order Quantity (EOQ) level. The aim of management is to identify the sites that should be used and the capacity to be allocated for each facility so that the total costs are minimized.

The problem size constraint can also be dealt with, using the decomposition technique. Generally, companies deal with multiple products or commodities, which are ordered by the customers in various combinations of quantities and products. The decomposition technique enables the firm to solve the multi-commodity problem, by breaking them into a series of single commodity problems.

5.5.3 Simulation Techniques

Another model that is gaining importance is the simulation technique. Simulation is a process of replicating the real-world problem situation into a model and conducting experiments with the variables for understanding the problem or evaluating the strategies. For this, the first step would be developing a conceptual model, which represents the behavior of the system that is under consideration. Then, the model needs to be converted into a computer program that solves the given equations, by executing the pre-determined rules or procedures. We also need to feed the data, pertaining to constraints, conditions, resources, etc., so that it represents the system.

The program is then supplied with the required parameters and external inputs, and simulation is performed depending upon the situation, which the firm wants to analyze. There are two types of simulation models- Dynamic or time-varying models and steady-state models. Dynamic models are more commonly used and are categorized into two types, namely, continuous, and discrete simulation models.

Continuous model assumes that the system changes in a continuous mode. So, at any given point the system behaves uniquely. Discrete model assumes that the system changes periodically, i.e. system changes at specific time intervals (also called events). During the time-period between the events, the system does not change.

Example: Optimization of Capacity Allocation Models with Effort Dependent Demand in Global Supply Chain

The focus of a global freight company was on the relationship between the Headquarters (HQ) and their multiple local sales offices on capacity allocation. The freight company was a carrier utilizing its own cargo vehicles, like: truck, ship, aircraft, etc. The firm sold long-term and spot sales contracts for cargo space.

Contd….

Different methods of capacity allocation: decentralization, centralization, and mixed, were investigated by conducting numerical studies, as optimal allocation of capacity to the demand had been a focus issue in a demand driven market.

Generally, increasing the location capacity was directly linked to expenses, and time in heavy industries. In the decentralization method, the HQ of the company allocated the total space of the carriers to the local sales offices before departure, and then the assigned amount of capacity was ensured. Based on the allocated size of the space, optimal efforts were made by local office to maximize its own profit, and in turn HQ aimed to maximize the profit at overall firm level. Decentralization method could be less profitable than the centralized control, when company had full information. In the centralization method, the HQ controlled the full space. The local sales offices had to compete for the total capacity. Mixed method naturally was a combination of the decentralization and centralization methods. Simulation studies were made to assess whether decentralization or centralization dominated the other. In the one supplier and two retailer's model, lexicographic allocation could generate more supply chain profit.

Source: https://www.mdpi.com/2071-1050/14/3/1375, January 2022, Accessed on 20/08/22

Activity 5.2

It has been 20 years since Apple entered India. Now the company is finally starting to sell directly to customers.

Apple launched its online store in the country, marking a critical milestone in its plans, for one of the world's biggest economies. The iPhone maker also wants to open its first physical store, next year. For years, Apple and other foreign retailers were restricted from setting up shop in India, unless they sourced at least 30% of raw material locally, forcing the California giant to rely on third-party resellers. That was changed last year when the Indian government relaxed some investment rules.

Identify different models available, for facility network design sales and service operations. Analyze the reasons for Apple deciding, to open its online store in India.

Check Your Progress - 2

6. Which, of the following, is not a part of the Facility Network Design Decision Process?
   a. Developing a supply chain strategy
   b. Studying the regional market configuration
   c. Identifying a set of potential sites
   d. Obtaining the host country's approval
   e. Selecting the location
7. Which is the most important basis, for developing a supply chain strategy?
   a. Core competence
   b. Availability of resources
   c. Availability of financial support
   d. Availability of customer network
   e. Anticipated customer requirements
8. In India, when the Central/ State Government decides to establish a power plant, the public opposes it. What might be the reason?
   a. Climate change concerns
   b. Political reasons
   c. Safety concerns
   d. Lobby of MNCs
   e. Fear of loss of livelihood
9. Which, of the following, is not a popular model for facility Network Design and Capacity Allocation?
   a. Gravity Location Model
   b. Linear Programming Model
   c. Facility Design of the parent company
   d. Heuristic Models
   e. Simulation techniques
10. Proactively speaking, which is the best criterion, while choosing a location for an MNC?
    a. Availability of skilled labor
    b. Availability of best designers
    c. Availability of power and water
    d. Availability of transportation facilities
    e. Ease of doing business

5.6 Summary

- Facility network design decisions are important decisions, in supply chain management. Several factors influence these decisions.
- Facilities that are present in a supply chain are locations, at which material, work-in-progress, or finished inventories are handled and stored.
- Facility decisions have to be taken, after proper evaluation. Once the facility is set up, it is very difficult to close it down or shift it to another place, because of the huge capital investment involved.
- Facility decisions have a profound impact on business operations. This is because, within the facility network, the company has to move the inventory, transport goods, and exchange information so as to cater to the needs of customers, at minimal costs.
- A framework is necessary for taking facility decisions.
- There are several techniques used in facility network design decision-making.

5.7 Glossary

Contributor facility: The contributor facility performs a dual role, where it not only serves the local market but also helps the parent company, in other value-added activities like new product development initiatives, process enhancements, product customization, etc.

Lead facility: The lead facility provides the entire gamut of activities, which add value to the product for its parent company.

Offshore facility: Facilities that are set up outside the country.

Outpost facility: The outpost facility is set up primarily to benefit from the local knowledge and skills that are unique to that particular region.

Server facility: The role of the server facility is to act as a supply source for the market where it is set up.

Simulation: Simulation is a process of replicating the real-world problem situation into a model and conducting experiments with the variables for understanding the problem or evaluating the strategies.

Source facility: The purpose of the source facility is not only providing goods to the firm at a lower cost but also acting as a key provider of the product, for its total global operations.

5.8 Self-Assessment Test

1. Which are the factors, influencing decisions of Facility Network Design? Elaborate.
2. Describe the process of Facility Network Design.
3. Which are all the models for Facility Network Design and Capacity Allocation, and what are their specific advantages?

5.9 Suggested Readings /Reference Material

1. Ashley McDonough, Operations and Supply Chain Management Essentials You Always Wanted to Know: 15 (Self Learning Management Series) Paperback – 1 January 2020
2. Russel and Taylor, Operations and Supply Chain Management, 10ed, ISV Paperback – October 2019
3. Chopra and Kalra, Supply Chain Management 6/e Paperback – 17 June 2016

5.10 Answers to Check Your Progress Questions

1. (e) Competitive

The location should be competitive for an Indian company planning to start a facility in Africa.

2. (a) Strategic

The location selected by Microsoft for Indian operations is strategic.

3. (e) Business growth

Suzuki's decision to establish more units in India is for business growth.

4. (a) Serving only local market

A company's contributor facility does not engage in serving only local market.

5. (d) Contributor facility

This is how the automobile MNCs establishing manufacturing units elsewhere is described.

6. (d) Obtaining the host country's approval

This is not a part of facility network design decisions.

7. (a) Core competence

Core competence is the most important basis for developing a supply chain strategy.

8. (e) Fear of loss of livelihood

It is the reason for public opposing establishment of power plants

9. (c) Facility Design of the parent company

This is not a popular model for facility design and capacity allocation.

10. (e) Ease of doing business

It is the best criterion for any MNC to choose a location outside their country.

Supply Chain Management

Course Structure

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