Module V

Impact of Replenishment Policies in Safety Inventory:

- Role of information technology in inventory management,
- Transportation in supply chain.

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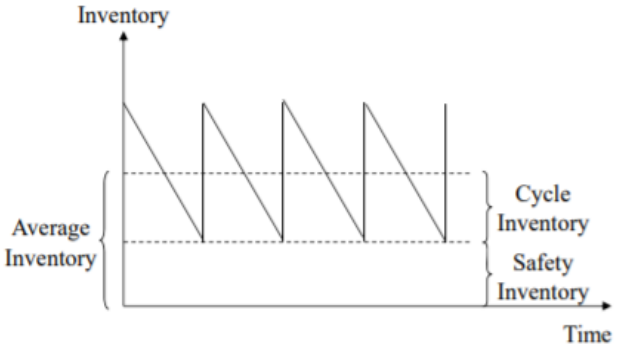
SAFETY STOCKS/INVENTORY/ BUFFER STOCK: -

Forecasts are rarely completely accurate.

If average demand is 1000 units per week, then half the time actual demand will be greater than 1000, and half the time actual demand will be less than 1000; what happens when actual demand is greater than 1000?

If you kept only enough inventory in stock to satisfy average demand, half the time you would run out.

Safety inventory: Inventory carried for the purpose of satisfying demand that exceeds the amount forecasted in a given period.



Safety stock is a term used by logisticians to describe a level of extra stock that is maintained to mitigate risk of stock outs caused by uncertainties in supply and demand. Adequate safety stock levels permit business operations to proceed according to their plans.

In addition, products which are stored for too long a time can spoil, expire, or break during the warehousing process.

Average inventory is therefore cycle inventory plus safety inventory

Average inventory = Cycle inventory + Safety inventory

There is a fundamental tradeoff:

Raising the level of safety inventory provides higher levels of product availability and customer service. Raising the level of safety inventory also raises the level of average inventory and therefore increases holding costs.

Ex: Very important in high-tech industries where obsolescence is a significant risk (where the value of inventory, such as PCs, can drop in value)

Two Questions to Answer in Planning Safety Inventory

(i) What is the appropriate level of safety inventory to carry?

(ii) What actions can be taken to improve product availability while reducing safety inventory?

Ex: Compaq and Dell in PCs, in 1998, when prices dropped. Compaq carried 100 days of inventory compared to Dell which carried only 10 days of inventory. Declining prices hurt Compaq much more, given the extra inventory that it carried. Compaq did not make any profit in the first quarter of 1998.

A key to Dell's success has been its ability to provide a high level of product availability while carrying very low levels of safety inventory in its supply chain.

Reasons for Carrying Safety Stock: [Source: efinancemanagement.com]

Carrying buffer stock is a necessity for a business because of the following reasons.

Unforeseen Supply Variation

No one has seen the future, so there might be scenarios when your supplier is unable to supply the raw materials. For instance, the coronavirus crisis has led to the disruption in the global supply chain, resulting in the closure of many businesses.

Inaccurate Demand Estimation

No matter how much experience a business has, it may not always predict the demand accurately. Thus, if you have a buffer stock, you will still be able to meet the order even if your demand estimates are not accurate.

Ensure Customer Satisfaction

The primary objective of keeping a buffer stock is to keep your customers happy. If you are always able to meet your customers' expectations, then they will not only keep coming back but will also recommend you to others.

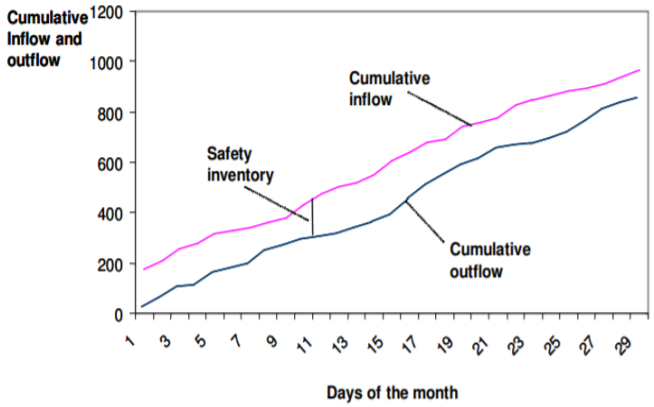
Prevent Chaos in Manufacturing or Deliveries

If you have a buffer stock, you and your workers won't have to worry about producing more products in an emergency. This way, they can focus on meeting the orders, rather than running around in chaos.

How Much Buffer Stock is Sufficient?

The buffer stock is a good thing from a customer satisfaction point of view, but a bad thing for the company's cash flows. If a company invests too much money in the buffer stock, then its cash flows might get disrupted. Also, you will not want to hold too much inventory so that your carrying or storage costs offset the gain from sales.

So, the best thing is to calculate inventory or the optimal stocking level. However, you must remember that your sales must cover the carrying costs of sold products as well as the carrying costs of the products in the safety stock.



A point to note is that you should not solely depend on the formula, instead use your trade experience as well. For instance, you can adjust the safety stock level obtained from the formula for seasonality. If you believe some months have more demand, then you can carry a bigger buffer stock. And, if you expect the order to be less, you could carry a lower buffer stock.

Also, you should take into account stock-out costs and carrying costs. Meaning, the company must always strive to minimize its stock-out costs and carrying costs.

Importance of Safety Stock

Safety stock does put more burden on the company, in terms of costs and storage. However, it acts as insurance, helping the company to meet demand at a crucial time.

If a company fails to estimate the safety stock level accurately, it could result in the loss of revenue, customers, market share, and profit. A simple thing that a business must never forget is if you can't meet the demand of your customers someone else will.

Also, accurately estimating buffer stock helps a company not only with the above things (profit, revenue, etc.) but also boosts the storage efficiency.

Alternative for Just-in-Time

With the advent of technology, many companies now use Just-in-time inventory systems. Under this, the company orders a small number of products or materials at regular intervals. This concept does away with the need for storage of the product or raw materials.

However, many companies are unable to use a just-in-time inventory system. It could be because of budget constraints, supplies are far away, etc. For such companies, buffer stock is a good option. Under this, they hold more inventory than what they expect to sell. This strategy will ensure that the company always has items at hand to meet any increase in customer demand.

Determining the Appropriate Level of Safety Inventory involves:

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- → Measuring demand uncertainty.
- → Measuring product availability.
- → Replenishment policies.

→ Evaluating cycle service level and fill rate.
→ Evaluating safety level given desired cycle service level or fill rate.
→ Impact of required product availability and uncertainty on safety inventory

Appropriate level of safety inventory is determined by:

a. Supply or demand uncertainty
b. Desired level of product availability.

Higher levels of supply or demand uncertainty require higher levels of safety inventory given a particular desired level of product availability.

When a new Palm (PDA) model is introduced in the market, demand is highly uncertain, and the retailer B&M thus carries a much higher level of safety inventory relative to demand. As the market's reaction to the new model becomes clearer, uncertainty is reduced, and demand is easier to predict.

Higher levels of desired product availability require higher levels of safety inventory given a particular level of supply or demand uncertainty. If B&M targets a higher level of product availability for the new Palm model, it must carry a higher level of safety inventory for that model.

Measuring Demand Uncertainty

→ Demand has a systematic component and a random component. The goal of forecasting is to predict the systematic component and estimate the random component.
→ The estimate of the random component is the measure of demand uncertainty.
→ Random component is usually estimated by the standard deviation of demand or forecast error.

Notation:

D = Average demand per period
SD = standard deviation of demand per period
L = lead time = time between when an order is placed and when it is received.

Uncertainty of demand during lead time, and not just a single period, is what is important.

Measuring Product Availability

Product availability: a firm's ability to fill a customer's order out of available inventory.

Stock out: a customer order arrives when the product is not available.

Product fill rate (fr): fraction of the product's demand that is satisfied from product in inventory.

Assume that B&M provides Palms to 90% of its customers from inventory (10% lost to competitors), it achieves a fill rate of 90%.

Order fill rate: fraction of orders that are filled from available inventory, also, like fill rate measured over a specified number of orders. In the case of B&M, a customer may order a Palm along with a calculator. The order is filled in from inventory only if both the Palm and the calculator are available through the store. It tends to be lower than '**fr**' because all products must be in stock for an order to be filled (for single product situations, the two are same).

The Economic Order Quantity (EOQ): is the number of units that a company should add to inventory with each order to minimize the total costs of inventory—such as holding costs, order costs, and shortage costs. Since the model assumes instantaneous replenishment, there are no inventory shortages or associated costs.

Cycle service level (CSL): fraction of replenishment cycles that end with all the customer demands being met. It is the probability of not having a stock out in a replenishment cycle.

A replenishment cycle: is the interval between two successive replenishment deliveries.

If B&M manages inventory such that the store does not run out of inventory in 6 out of 10 replenishment cycles, the store achieves a CSL of 60%.

Replenishment Policies

Inventory replenishment is the process of moving stock items along the supply chain to ensure inventory levels are sufficient to cover demand. Effective inventory replenishment processes ensure that order fill rates can be achieved whilst keeping inventory carrying costs under control.

Replenishment policy: decisions regarding when to reorder and how much to reorder. These decisions determine the cycle and safety inventories along with fr and CSL. It takes the following two forms.

Continuous review: inventory is continuously monitored, and an order of size Q is placed when the inventory level reaches the reorder point (ROP). B&M managers orders 600 Palms when the inventory falls below 400. Size of the order remains constant, time between orders may fluctuate given variable demand.

Periodic review: inventory is checked at regular (periodic) intervals and an order is placed to raise the inventory to a specified threshold (the "order-up-to" level). Every Saturday, employees at B&M check film inventory and the manager orders enough so that the available inventory and the size of the order total equals 1,000 films. Time between orders is fixed, size of each order, can fluctuate, given variable demand.

Importance of the Level of Product Availability

Product availability measured by cycle service level or fill rate. Also referred to as the customer service level
Product availability affects supply chain responsiveness.

Trade-off:

- → High levels of product availability Ł increased responsiveness and higher revenues
- → High levels of product availability Ł increased inventory levels and higher costs

Product availability is related to profit objectives, and strategic and competitive issues (e.g., Nordstrom, power plants, supermarkets, e-commerce retailers)

Factors Affecting the Optimal Level of Product Availability

- → Cost of overstocking
- → Cost of understocking
- → Possible scenarios
- → Seasonal items with a single order in a season
- → Continuously stocked items
- → Demand during stock out is backlogged.
- → Demand during stock out is lost.

The cost of overstocking (Co) = the loss incurred by a firm for each unsold unit at the end of the selling season.

The cost of understocking (Cu) = the margin lost by a firm for each lost sale because of stockout.

The relationship between the cost of overstocking and the cost of understocking determine the optimal level of product availability.

Higher Business Management - Understocking and Overstocking Deliveries arriving too early or too late cause problems for firms. The same goes with having too much stock or indeed having too little. This is called understocking and overstocking.

A major disadvantage to holding too much inventory on hand is the negative cost implications. Holding too much inventory ultimately affects the cash flow of the business, especially when the inventory is sitting in storage and is not being sold for profit.

A Balancing Act b/w Understocking and Overstocking:

In avoiding the knock-on effects of understocking, you also need to avoid overstocking. Therefore, getting it right can be a real balancing act. Below are three tips for preventing both extremes.

- → Communicate Between Departments

  It is essential that your supply chain can flow smoothly with as few errors as possible. This is much easier when you make interdepartmental communication a priority, so that no one is caught off guard.

- → Adjust sales predictions.

  Understocking is often a symptom of inadequate or outdated sales predictions. That is why you must consider how both internal and external factors may influence the demand for products, so that you can adjust stock levels accordingly. Factors such as economic changes and changing social climates must be taken into consideration.

- → Plan for scarcity

When implementing such a strategy, you must pay exceptionally close attention to the relationship between supply and demand.

Measuring Demand Uncertainty

- Uncertainty within lead time
  - Assume that demand for each period i, $i = 1,\ldots,k$ is normally distributed with a mean D_i and standard deviation σ_i .
  - The total demand during k period is normally distributed with a mean of P and a standard deviation of Ω :

$$P = \sum_{i=1}^{k} D_i \qquad \Omega = \sqrt{\sum_{i=1}^{k} \sigma_i^2 + 2\sum_{i>j} Cov(i,j)} = \sqrt{\sum_{i=1}^{k} \sigma_i^2 + 2\sum_{i>j} \rho\sigma_i\sigma_j}$$

  - If demand in each period is independent and normally distributed with a mean of D and a standard deviation of σ_D , then

$$P = kD \qquad \Omega = \sqrt{k}\sigma_D$$

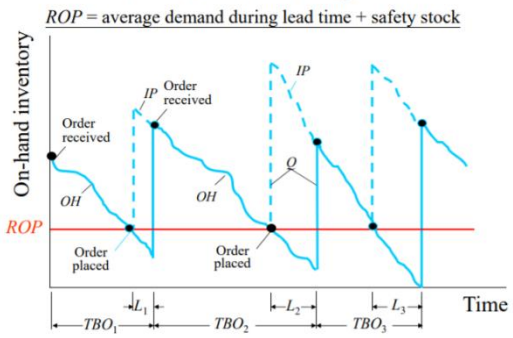
- Coefficient of variation

$$CV = \sigma / \mu$$

Continuous Review System

- The remaining quantity of an item is reviewed each time a withdrawal is made from inventory, to determine whether it is time to reorder.
- **Other names are:** Reorder point system, fixed order quantity system
- **Inventory position**
  - $IP = OH+SR-BO$
  - where:
    - IP = inventory position
    - OH = on-hand inventory
    - SR = scheduled receipts (open orders)
    - BO = units backordered or allocated
- **Decision rule**
  - Whenever a withdrawal brings IP down to the reorder point (ROP), place an order for Q (fixed) units.

Continuous Review System



The advantage of the continuous review system:

→ Provide real-time updates of inventory counts
→ Make easier to know when to order
→ Provide accurate accounting

The disadvantage of the continuous system:

→ Involves additional cost

The periodic review system, evaluate inventory at specific times like counting inventory at the end of each month. It is inexpensive to administer since counting takes place at a particular time, but a higher level of safety is required to buffer against uncertainty in demand over longer planning horizon.

Example

- Given the following data

  Average demand per week, $D = 2{,}500$

  Standard deviation of weekly demand, $\sigma_D = 500$

  Average lead time for replacement, $L = 2$ weeks

  Reorder point, $ROP = 6{,}000$

  Average lot size, $Q = 10{,}000$

- Safety inventory, $ss = ROP - DL = 6{,}000 - 5{,}000 = 1{,}000$

  Cycle inventory $= Q/2 = 10{,}000/2 = 5{,}000$

  Average inventory $= 5{,}000 + 1{,}000 = 6{,}000$

  Average flow time = Average inventory / Throughput

  $= 6{,}000/2{,}500 = 2.4$ weeks

Periodic Review System

- **Other names are**: fixed interval reorder system or periodic reorder system.

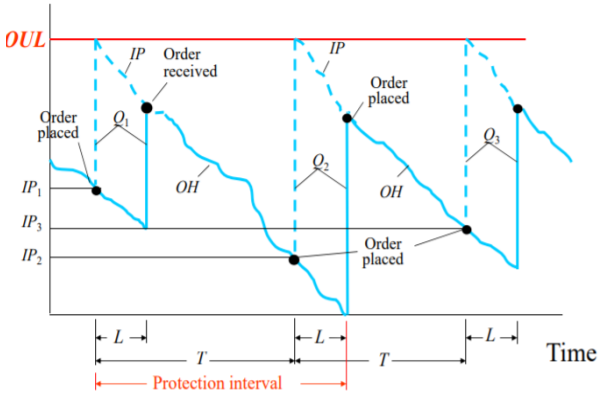
- **Decision Rule**

  Review the item's inventory position *IP* every *T* time periods. Place an order equal to (*OUL*-*IP*) where *OUL* is the target inventory, that is, the desired *IP* just after placing a new order.

- The periodic review system has two parameters: *T* and *OUL*.

- Here *Q* varies, and time between orders (*TBO*) is fixed.

Periodic Review System



Finding *OUL*

- The new order must be large enough to make the inventory position, *IP*, last beyond the next review, which is *T* periods from now, but also for one lead time (*L*) after the next review. *IP* must be enough to cover demand over a protection interval of $T + L$.

- $OUL =$ Average demand during protection interval $+$ Safety stock for protection interval

  $= (T + L)D + F_s^{-1}(CSL) \times \sqrt{T + L} \times \sigma_D$

The advantage of the periodic review system:

→ Reduce time for business owner to analyze inventory counts.
→ Allows the business owner having more time to run another aspect of the business.
→ Simple to administer.
→ Save labor cost for counting.

The disadvantage of the periodic review system:

→ It may not provide an accurate inventory count when there is a high volume of sale.
→ It may also make accounting inaccurate.
→ There is little control over inventory movement.

Selecting the Reorder Interval (T)

- Administratively convenient (such as each Friday)
- Approximation of EOQ

$$T = \frac{EOQ}{D}(52) \text{ weeks}$$

- Example: Suppose $D = 1200$ /year and $EOQ = 100$

$$T = \frac{100}{1200}(52) = 4.3 \text{ weeks or } 4 \text{ weeks}$$

Example

- Given the following data

$D = 2{,}500 / \text{week}$
$\sigma_D = 500$
$L = 2$ weeks
$T = 4$ weeks
$CSL = 0.9$

- $D_{T+L} = (T+L)D = (4+2)\times 2{,}500 = 15{,}000$
$\sigma_{T+L} = \sqrt{T+L}\,\sigma_D = \sqrt{4+2}\times 500 = 1{,}225$
$ss = F_s^{-1}(CSL)\times\sigma_{T+L} = F_s^{-1}(0.9)\times\sigma_{T+L} = 1{,}570$
$OUL = D_{T+L} + ss = 15{,}000 + 1{,}570 = 16{,}570$

Periodic System Vs Continuous System

Feature	Continuous review system	Periodic review system
Order quantity	Q-constant	Q-variable
When to place order	When quantity on hand drops to the reorder level	When the review period arrives
Recordkeeping	Each time a withdrawal or addition is made	Counted only at review period
Size of inventory	Less than periodic system	Larger than continuous system
Factors driving safety inventory	Demand uncertainty Replenishment lead time	Demand uncertainty Replenishment lead time Reorder interval
Type of items	Higher-priced, critical, or important items	

Methods to Calculate Safety Stock/Buffer Inventory

The following are the methods to determine the safety stock:

Fixed Safety Stock

In this, the company takes the help of the production planners. These planners don't use any formula; instead, decide on the buffer stock based on maximum daily usage over time. The amount of safety stock remains the same until the planner revises it.

Time-based Calculation

In this, the buffer stock is calculated based on future expectations. Usually, the company determines the stock under this method for a specific period. This method takes into account the actual

demand and the forecasted demand using statistical techniques. One drawback of using such a technique is that it does not consider business uncertainties.

Formula-based

One popular formula that many analysts use to calculate the buffer inventory is based on the average safety stock that a company will need in case of a stock out.

Safety stock = (Maximum daily usage * Maximum lead time in days) – (Average daily usage * Average lead time in no of days).

Max daily usage is the maximum units that a company uses or sells in a day, while max lead time is the maximum time it takes the supplier to deliver. Similarly, average daily usage is the average of the maximum and minimum units that a company uses or sells. The avg. lead time is the average of the maximum and minimum time it takes the supplier to deliver the product or raw material.

Ex:

Q) A Company ABC in the U.S. sells handwoven shawls, which it imports from India. It takes on an average of 55 days to get shawls from India, while ABC sells about 10 shawls a day. On weekends or holidays, the ABC can sell on average 14 shawls a day. The importer also knows that the lead time had once stretched to 60 days due to the political unrest in India. Calculate the safety stock.

A) In the above example,

The average lead time is = 55 days,
While the maximum lead time is = 60 days.
The average daily usage is = 10 shawls,
While maximum daily usage is = 14 shawls.
Safety stock = (14 x 60) – (10 x 55) = 290

That means Company ABC will need a safety stock 290 units to protect itself against any fluctuations in demand.

Heizer & Render's formula

Analysts use such a formula in case of high uncertainty on the supplier's end. It gives a better idea by using the standard deviation of the lead time distribution. Thus, it provides a clearer and accurate idea about the lead time and frequency of late shipments. However, this formula does not take into account the demand changes.

$$\text{Safety Stock} = Z * \sigma_{dLT}$$

Z is number of standard normal deviations (Z-score), while σ_{dLT} represent the deviation in lead time. Or, we can say that σ_{dLT} is the variation (by degree and frequency) between the average and actual lead time. At the same time, Z score is how sure you are on the need for safety stock. Moreover, A low Z score would mean you expect higher chances of running out of stock.

Greasley's formula

Unlike the Heizer & Render's formula, this formula takes into account the lead time, as well as demand fluctuations. This way, it gives even a better idea of the level of safety stock. However, this formula doesn't consider the stock already in the production process.

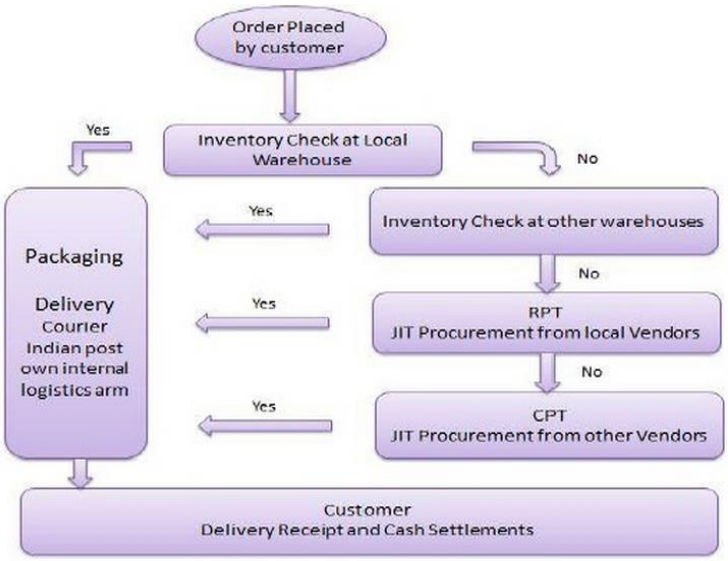
$$\text{Safety Stock} = \sigma_{dLT} * D_{Avg} * Z$$

σ_{dLT} is the standard deviation in lead time, with the average demand as D_{Avg} and with Z score.

ROLE OF INFORMATION TECHNOLOGY IN INVENTORY MANAGEMENT:

Flipkart's inventory management

Flipkart is an electronic commerce company and among India's largest online retailers with reported sales of $12.5million. Flipkart initially started with selling books online but has diversified today into a generic e-commerce website, selling CDs/DVDs, mobile phones and electronics. The mission of the



organization is to provide a memorable online shopping experience to the customers so that they come back again and they use innovative services like 30 day replacement, Cash on Delivery, free shipping, EMI options mainly for electronics and on-time delivery.

Amazon:

Inventory Management at Amazon: A Brief about E-Commerce Industry: Types of Business Models:

- → Buy and Sell: Products are purchased by the company and stacked in warehouses. These products are displayed on the website.
- → Market Place: Products from multiple vendors are displayed in the website. Company take care of marketing and transactions and shipping, doesn't hold the inventory.
- → Sells products such as books, DVDs, Electronics online in more than 60 Countries.
- → Uses Amazon-to-Buyer Sale Approach
- → Multi-level E-Commerce Company.
- → Operates 7 websites that support their business operation globally and offers 20 million items for sale.

Amazon.com Multi-Tier Inventory Model

Amazon Inventory management-Technology usage

- → The Central Amazon Data warehouse is made up of 28 Hewelett Packard servers, with four CPUs per node, running Oracle 9i database software.
- → The architecture handles millions of back-end operations and third-party seller queries.

Amazon has Strategic Alliances with many vendors for procuring various products.

- → Ashford.com (Online retailing of luxury and premium products)
- → Drugstore.com (Online retail and information source for health, beauty, wellness, personal care and pharmacy).

What Is the Main Purpose of Inventory Management?

The primary purpose of inventory management is to ensure there is enough goods or materials to meet demand without creating overstock, or excess inventory.

What Are the Advantages of Inventory Management?

Accurate inventory management is key to running a successful product business. Tracking stock regularly can help avoid stock errors and other problems.

The following are the benefits of strong inventory management:

- → **Better Inventory Accuracy:** With solid inventory management, you know what's in stock and order only the amount of inventory you need to meet demand.
- → **Reduced Risk of Overselling:** Inventory management helps track what's in stock and what's on backorder, so you don't oversell products.
- → **Cost Savings:** Stock costs money until it sells. Carrying costs include storage handling and transportation fees, insurance and employee salaries. Inventory is also at risk of theft, loss from natural disasters or obsolescence.

- → **Avoiding Stockout and Excess Stock:** Better planning and management helps a business minimize the number of days, if any, that an item is out of stock *and* avoid carrying too much inventory. Learn more about solving for stock outs in our "Essential Guide to Inventory Control."
- → **Greater Insights:** With inventory tracking and stock control, you can also easily spot sales trends or track recalled products or expiry dates.
- → **Better Terms with Vendors and Suppliers:** Inventory management also provides insights about which products sell and in what volume. Use that knowledge as leverage to negotiate better prices and terms with suppliers.
- → **More Productivity:** Good inventory management solutions save time that could be spent on other activities.
- → **Increased Profits:** A better understanding of both availability and demand leads to higher inventory turnover, which leads to greater profits.
- → **A More Organized Warehouse:** An efficient warehouse with items organized based on demand, which items are often sold together, and other factors reduces labor costs and speeds order fulfilment.
- → **Better Customer Experience:** Customers that receive what they order on time are more loyal.

Benefits of Inventory Management Software Integrated with ERP

Inventory management practices can help you save money and keep an accurate stock count. However, you can see more benefits when you add an ERP system with inventory management capabilities.

With this type of system in place, you'll be able to:

- → **Understand Inventory Levels Across the Business:** ERP systems can provide an end-to-end view into orders through all departments, from sales to accounting to fulfilment. Centralized purchasing reduces duplication when replenishing stock and having the ability to purchase in bulk saves money. Further benefits abound when you integrate your inventory software with accounting and back-office processes.
- → **Automate Manual Tasks:** Barcode and RFID scanning can speed stock-taking, receiving and fulfilment. Using software reduces errors from manual entries and frees staff from repetitive tasks.
- → **Greater Visibility with Real-Time Data:** The right inventory management software will give you access to real-time information on all SKUs, in all facilities. It will deliver this data to all devices, no matter where you are.
- → **Improve Forecasting:** Software that handles data collection and analytics can provide insights into trends. And when you understand trends, you can improve your stock forecasting.
- → **Data-Driven Decision Making:** Leverage the analytics capabilities of inventory management software to make data-driven stock decisions. Save money by reducing inventory and carrying costs.
- → **Support Uninterrupted Production:** By forecasting both demand and lead time, you can ensure production never experiences a shortage.
- → **Harmonize Multiple Inventory Locations:** Get an overview of stock levels in all your warehouses, distribution centers as well as retail stores and suppliers.
- → **Optimize All Inventory:** A robust inventory management software system helps maintain the right mix of stock and quantities, and at the best carrying costs. It'll help you ensure you never have too much or too little on-hand.
- → **Scale Inventory as Your Business Grows:** You can't accurately track 1,000 SKUs in 15 facilities manually. Inventory management software can handle that task for you.
- → **Ensure Compliance with Generally Accepted Accounting Principles (GAAP):** Correctly valuing stock is vital for financial transparency. Inventory management software provides the accuracy that GAAP requires.
- → **Improve Product Visibility in Recalls:** Digital systems allow managers to use lot or serial number records to trace products by date and location.

- It is no exaggeration to state that the use of IT systems to improve inventory management has contributed much of the cost savings achieved so far in most supply chains. Until the 1980s, inventory was generally managed using rules of thumb such as holding three months of demand in the warehouse. These levels were often (although not always) far from appropriate, resulting in too many of the wrong items and too little of the right ones. The errors were often very large when products had high demand variability or varying levels of criticality. A second major contributor to excess inventories was the fact that each location managed its inventories independently, ignoring inventories at other facilities. The end result was a bloated inventory system with relatively poor service levels.
- The first contribution of IT systems was to move inventory management from rules of thumb to setting inventories based on historical demand and desired service levels. IT systems allowed this analysis for potentially millions of SKUs and for the inventory levels to be recalculated as demand changed. The ability to analyze and change inventories in response to changes in demand often results in significantly.
- Lower inventories and improved service levels at the same time. Over time, IT inventory management systems have evolved to incorporate more sophisticated techniques for managing inventory. They include different types of demand distributions beyond the normal distribution to better model demand.
- One of the major improvements since the mid-1990s has been the incorporation of multi echelon modeling that allows the analysis of inventories across the supply chain network rather than at each separate location. Local analysis often leads to duplication of inventories because each location sets its inventory levels independently.
- Multi echelon analysis, in contrast, attempts to reduce total network inventories by positioning inventories appropriately. More advanced companies have linked their inventory systems to those of their suppliers and customers. This is important, as the amount of inventory you want to hold depends on how much your customer holds and how much your suppliers have or what they are producing. IT systems also allow inventory management applications to be linked to production planning so that inventory decisions are taken in conjunction with production decisions.
- With the growth in product variety, decrease in product life cycles, and rapid fluctuations in demand, it is almost impossible to manage inventories today without the use of IT systems. IT systems improve inventory management through their ability to act on a large number of products, to be frequently updated, and finally, to coordinate with other demand and supply planning systems both within the enterprise and across the supply chain.
- There is, however, plenty of room for improvement in inventory management systems. One area for improvement is the modeling of demand in different circumstances. The use of oversimplified demand distributions is often inaccurate and can even lead to inventory levels that are worse than the use of rules of thumb. As an example, consider stocking demand for spare parts in a production facility. The mean demand for a part might be quite low, but when it is needed, not only is it critical, but perhaps a specific set of other parts are also needed. Modeling the demand as normal and independent across parts is likely to give poor results.
- Another area for improvement in inventory management systems is the integration with other IT systems across the supply chain. Inventory buffers the variation of demand and supply within the supply chain. Thus, if inventory management systems do not communicate seamlessly with other planning and execution systems, inventory levels are unlikely to be optimal. In particular, it is important that inventory management systems communicate with demand planning systems to incorporate the impact of seasonality and promotions. The inability of inventory management systems to provide visibility and communicate effectively with other IT systems is often the biggest hurdle to their success. Given the importance of inventories, vendors of inventory management systems are the core supply chain management software providers.
- Thus, inventory management systems have played a central role in improving supply chain performance. The significance of IT is likely to grow in the future as more supply chain partners are beginning to set their inventory levels based on their partners' inventory and capabilities.

TRANSPORTATION IN SUPPLY CHAIN.

- → Transportation refers to the movement of a product from one location to another as it makes its way from the beginning of a supply chain to the customer.
- → Transportation is an important supply chain driver because products are rarely produced and consumed in the same l9cation.
- → Transportation is a significant component of the costs incurred by most supply chains.
- → The role of transportation is even more significant in global supply chains.
- → Transportation network is a collection of nodes and links.
- → Transportation originates and ends at nodes and travels on links.
- → For most modes of transportation, infrastructure such as ports, roads, waterways, and airports are required both at the nodes and links.
- → Most transportation infrastructure is owned and managed as a public good throughout the world. It is very important that infrastructure be managed in such a way that monies are available for maintenance and investment in further capacity as needed.
- → Transportation policy sets direction for the number of national resources that go into improving transportation infrastructure.
- → Transportation policy also aims to prevent abuse of monopoly power, promote fair competition, and balance environmental, energy, and social concerns in transportation.

MODES OF TRANSPORTATION AND THEIR PERFORMANCE CHARACTERISTICS

Mode

- → Air
- → Truck
- → Rail
- → Water
- → Pipeline
- → Multimodal

Supply chains use a combination of the following modes of transportation:

• Air • Package carriers • Truck • Rail • Water • Pipeline • Intermodal

TRADE-OFFS IN TRANSPORTATION DESIGN

All transportation decisions made by shippers in a supply chain network must take into account their impact on inventory costs, facility and processing costs, the cost of coordinating operations, as well as the level of responsiveness provided to customers. For example, Dell's use of package carriers to deliver PCs to customers increases transportation costs but allows Dell to centralize its facilities and reduce inventory costs. If Dell wants to reduce its transportation costs, the company must either sacrifice responsiveness to customers or increase the number of facilities and resulting inventories to move closer to customers.

The cost of coordinating operations is generally hard to quantify. Shippers should evaluate different transportation options in terms of various costs as well as revenues and then rank them according to coordination complexity. A manager can then make the appropriate transportation decision.

Managers must consider the following tradeoffs when making transportation decisions:

- → Transportation and inventory cost trade-off
- → Transportation cost and customer responsiveness trade-off

TRANSPORTATION AND INVENTORY COST TRADE-OFF

The trade-off between transportation and inventory costs is significant when designing a supply chain network. Two fundamental supply chain decisions involving this tradeoff are.

- → Choice of transportation mode
- → Inventory aggregation

Choice of Transportation Mode

Selecting a transportation mode is both a planning and an operational decision in a supply chain. The decision regarding carriers with which a company contracts is a planned decision, whereas the choice of transportation mode for a particular shipment is an operational decision. For both decisions, a shipper must balance transportation and inventory costs. The mode of transportation that results in the lowest transportation cost does not necessarily lower total costs for a supply chain. Cheaper modes of transport typically have longer lead times and larger minimum shipment quantities, both of which result in higher levels of inventory in the supply chain. Modes that allow for shipping in small quantities lower inventory levels but tend to be more expensive.

Inventory aggregation

Transportation costs, however, generally increases when inventory is aggregated. If inventories are highly disaggregated, some aggregation can also lower transportation costs. Beyond a point, however, aggregation of inventories raises total transportation costs. Consider a bookstore chain such as Borders. The inbound transportation cost to Borders is due to the replenishment of bookstores with new books. There is no outbound cost because customers transport their own books home. If Borders decides to close all its bookstores and sell only online, it will have to incur both inbound and outbound transportation costs. The inbound transportation cost to warehouses will be lower than to all bookstores. On the outbound side, however, transportation costs will increase significantly because the outbound shipment to each customer will be small and will require an expensive mode such as a package carrier. The total transportation cost will increase on aggregation because each book travels the same distance as when it was sold through a bookstore, except that a large fraction of the distance is on the outbound side using an expensive mode of transportation. As the degree of inventory aggregation increases, total transportation cost goes up. Thus, all firms planning inventory aggregation must consider the trade-offs among transportation, inventory, and facility costs when making this decision.

Inventory aggregation is a good idea when inventory and facility costs form a large fraction of a supply chain's total costs. Inventory aggregation is useful for products with a large value-to-weight ratio and for products with high demand uncertainty. For example, inventory aggregation is very valuable for new products in the PC industry, because PCs have a large value-to-weight ratio and demand for new products is uncertain. Inventory aggregation is also a good idea if customer orders are large enough to ensure sufficient economies of scale on outbound transportation. When products have a low value-to-weight ratio and customer orders are small, however, inventory aggregation may hurt a supply chain's performance because of high transportation costs. Compared to PCs, the value of inventory aggregation is smaller for best-selling books that have a lower value-to-weight ratio and more predictable demand.

MAKING TRANSPORTATION DECISIONS IN PRACTICE

1. **Align transportation strategy with competitive strategy.** Managers should ensure that a firm's transportation strategy supports its competitive strategy. They should design functional incentives that help achieve this goal. Historically, the transportation function within firms has been evaluated based on the extent to which it can lower transportation costs. Such a focus leads to decisions that lower transportation costs but hurt the level of responsiveness provided to customers and may raise the firm's total cost. If the dispatcher at a DC is evaluated based solely on the extent to which trucks are loaded, he or she is likely to delay shipments and hurt customer responsiveness to achieve a larger load. Firms should evaluate the transportation function based on a combination of transportation cost, inventory cost, and the level of responsiveness achieved with customers.
2. **Consider both in-house and outsourced transportation.** Managers should consider an appropriate combination of company-owned and outsourced transportation to meet their needs. This decision should be based on a firm's ability to handle transportation profitably as well as the strategic importance of transportation to the success of the firm. In general, outsourcing is a better option when shipment sizes are small, whereas owning the transportation fleet is better when shipment sizes are large and responsiveness is important. For example, Wal-Mart uses responsive transportation to reduce inventories in its supply chain. Given the importance of transportation to the success of its strategy, it owns its transportation fleet and

manages it itself. This is made easier by the fact that it achieves good utilization from its transportation assets because most of its shipments are large.

3. **Use technology to improve transportation performance.** Managers must use information technology to decrease costs and improve responsiveness in their transportation networks. Software helps managers do transportation planning, modal selection, and build delivery routes and schedules. Available technology allows carriers to identify the precise location of each vehicle as well as the shipments the vehicle carries. Satellite based communication systems allow carriers to communicate with each vehicle in their fleet. These technologies help carrier's lower costs and become more responsive to changes.

4. **Design flexibility in the transportation network.** When designing transportation networks, managers should take into account uncertainty in demand as well as availability of transportation. Ignoring uncertainty encourages a greater use of inexpensive and inflexible transportation modes that perform well when everything goes as planned. Such networks, however, perform very poorly when plans change. When managers account for uncertainty, they are more likely to include flexible, though more expensive, modes of transportation within their network. Although these modes may be more expensive for a particular shipment, including them in the transportation option.