Coordination in Supply Chain

Supply chain coordination improves if all stages of the chain take actions that are aligned and increase total supply chain surplus. Supply chain coordination requires each stage of the supply chain to share information and consider the impact its actions have on other stages.

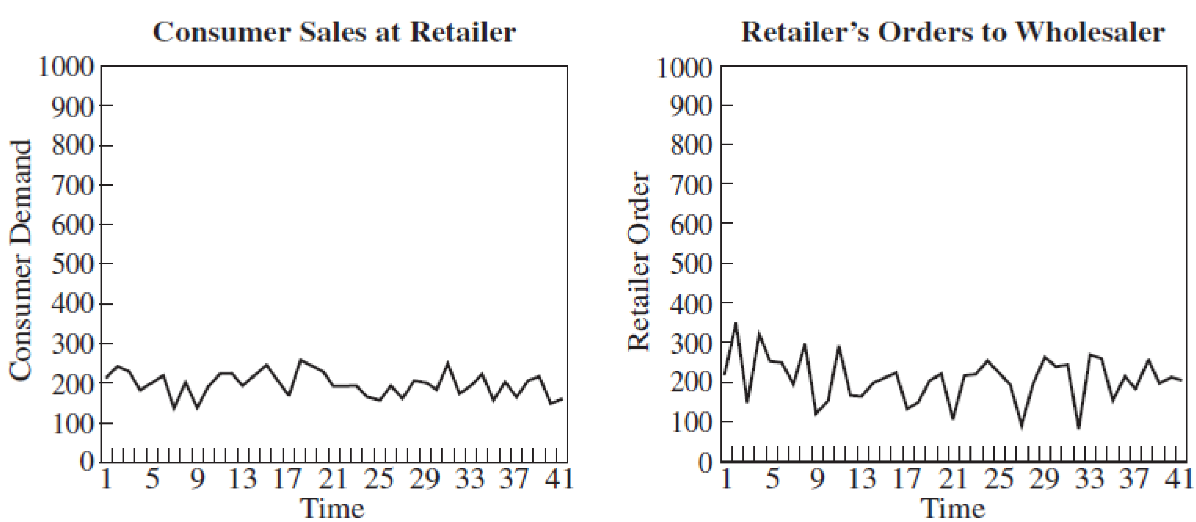
Lack of Supply Chain Coordination and the Bullwhip Effect

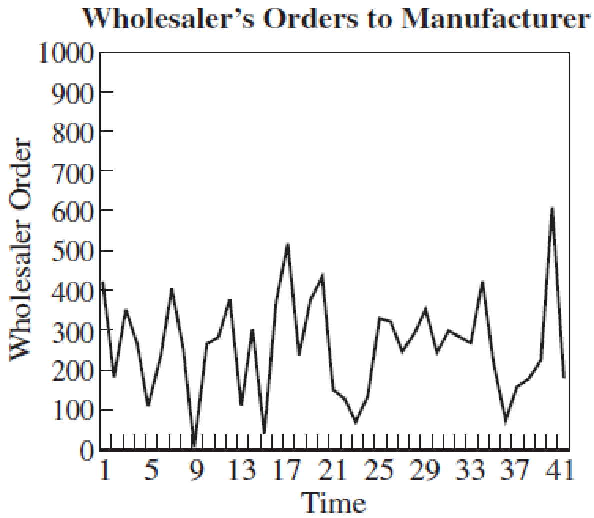
A lack of coordination occurs either because different stages of the supply chain have local objectives that conflict or because information moving between stages is delayed and distorted. Different stages of a supply chain may have conflicting objectives if each stage tries to maximize its own profits, resulting in actions that often diminish total supply chain profits. Today, supply chains consist of stages with different owners. The fundamental challenge today is for supply chains to achieve coordination in spite of multiple ownership and increased product variety.

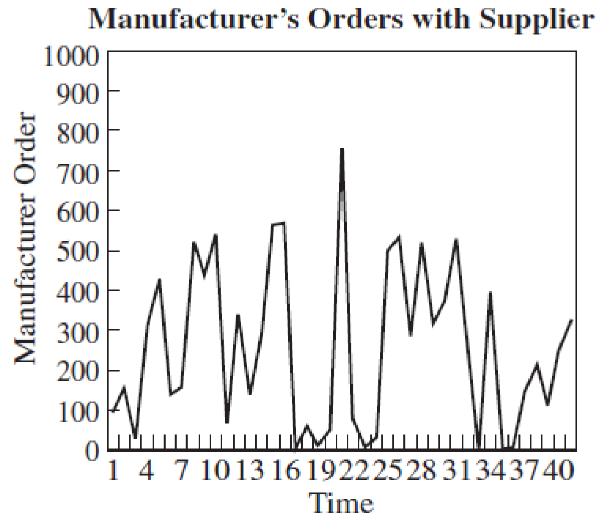
One outcome of the lack of supply chain coordination is the *bullwhip effect*, in which fluctuations in orders increase as they move up the supply chain from retailers to wholesalers to manufacturers to suppliers as shown in *Figure*. The *bullwhip effect* distorts demand information within the supply chain, with each stage having a different estimate of what demand looks like.

Hewlett-Packard (HP) found that the fluctuation in orders increased significantly as they moved from the resellers up the supply chain to the printer division to the integrated circuit division. Studies of the apparel and grocery industries have shown a similar phenomenon: The fluctuation in orders increases as one moves upstream in the supply chain from retail to manufacturing. Procter & Gamble (P&G) has observed the bullwhip effect in the supply chain for Pampers diapers (Lee, Padmanabhan, and Whang, 1997). The company found that raw material orders from P&G to its suppliers fluctuated significantly over time.

A similar phenomenon, over a longer time frame, has been observed in several industries that are quite prone to "*boom and bust*" cycles. A good example is the production of memory chips for personal computers. Between 1985 and 1998, at least two cycles occurred during which prices of memory chips fluctuated by a factor of more than three. These large fluctuations in price were driven by either large shortages or surpluses in capacity. The shortages were amplified by panic buying and overordering that was followed by a sudden drop in demand.







Impact of the Lack of Coordination on Supply Chain Performance

Performance Measure	Impact of the Lack of Coordination
Manufacturing cost	Increases
Inventory cost	Increases
Replenishment lead time	Increases
Transportation cost	Increases
Shipping and receiving cost	Increases
Level of product availability	Decreases
Profitability	Decreases

Obstacles to Coordination in a Supply Chain

Any factor that leads to either local optimization by different stages of the supply chain or an increase in information delay, distortion, and variability within the supply chain is an obstacle to coordination. If managers in a supply chain are able to identify the key obstacles, they can then take suitable actions to help achieve coordination. The major obstacles are divided into five categories:

- Incentive obstacles
- Information-processing obstacles
- Operational obstacles
- Pricing obstacles
- Behavioral obstacles

Incentive obstacles

Incentive obstacles occur in situations when incentives offered to different stages or participants in a supply chain lead to actions that increase variability and reduce total supply chain profits.

> *Local Optimization Within Functions or Stages of a Supply Chain Incentives* that focus only on the local impact of an action result in decisions that do not maximize total supply chain surplus. It is natural for any participant in the supply chain to take actions that optimize performance measures along which they are evaluated. For example, managers at a retailer make all their purchasing and inventory decisions to maximize retail profits, not total supply chain profits.
>
> *Sales Force Incentives* Improperly structured sales force incentives are a significant obstacle to coordination in a supply chain. In many firms, sales force incentives are based on exceeding sales thresholds during an evaluation period of a month or quarter. The sales typically measured by a manufacturer are the quantity sold to distributors or retailers (sell-in), not the quantity sold to final customers (sell-through). Measuring performance based on sell-in is often justified on the grounds that the manufacturer's sales force does not control sell-through. A sales force incentive based on sell-in thus results in order variability being larger than customer demand variability because the sales force tends to push product toward the end of the incentive period.

Information-Processing Obstacles

Information-processing obstacles occur when demand information is distorted as it moves between different stages of the supply chain, leading to increased variability in orders within the supply chain.

> *Forecasting Based on Orders and Not Customer Demand* When stages within a supply chain make forecasts that are based on orders they receive, any variability in customer demand is magnified as orders move up the supply chain to manufacturers and suppliers. In supply chains where the fundamental means of communication among different stages are the orders that are placed, information is distorted as it moves up the supply chain. Each stage views its primary role within the supply chain as one of filling orders placed by its downstream partner. Thus, each stage views its demand as the stream of orders received and produces a forecast based on this information. In such a scenario, a small change in customer demand becomes magnified as it moves up the supply chain in the form of customer orders.
>
> *Lack of Information Sharing* The lack of information sharing between stages of the supply chain magnifies the information distortion. A retailer such as Walmart may increase the size of a particular order because of a planned promotion. If the manufacturer is not aware of the planned promotion, it may interpret the larger order as a permanent increase in demand and place orders with suppliers accordingly. The lack of information sharing between the retailer and manufacturer thus leads to a large fluctuation in manufacturer orders.

Operational Obstacles

Operational obstacles occur when actions taken in the course of placing and filling orders lead to an increase in variability.

Ordering in Large Lots When a firm places orders in lot sizes that are much larger than those in which demand arises, variability of orders is magnified up the supply chain. Firms may order in large lots because a significant fixed cost is associated with placing, receiving, or transporting an order. Large lots may also occur if the supplier offers quantity discounts based on lot size.

Large Replenishment Lead Times Information distortion is magnified if replenishment lead times between stages are long. Consider a situation in which a retailer has misinterpreted a random increase in demand as a growth trend. If the retailer faces a lead time of two weeks, it will incorporate the anticipated growth over two weeks when placing the order. In contrast, if the retailer faces a lead time of two months, it will incorporate into its order the anticipated growth over two months (which will be much larger). The same applies when a random decrease in demand is interpreted as a declining trend.

Rationing and Shortage Gaming Rationing schemes that allocate limited production in proportion to the orders placed by retailers lead to a magnification of information distortion. This can occur when a high-demand product is in short supply. In such a situation, manufacturers come up with a variety of mechanisms to ration the scarce supply of product among various distributors or retailers. This rationing scheme results in a game in which retailers try to increase the size of their orders to increase the amount supplied to them.

Pricing Obstacles

Pricing obstacles arise when the pricing policies for a product lead to an increase in variability of orders placed.

Lot-Size–Based Quantity Discounts Lot-size–based quantity discounts increase the lot size of orders placed within the supply chain because lower prices are offered for larger lots. As discussed earlier, the resulting large lots magnify the bullwhip effect within the supply chain.

Price Fluctuations Trade promotions and other short-term discounts offered by a manufacturer result in forward buying, by which a wholesaler or retailer purchases large lots during the discounting period to cover demand during future periods. Observe that the shipments during the peak period are higher than the sales during the peak period because of a promotion offered. The peak shipment period is followed by a period of low shipments from the manufacturer, indicating significant forward buying by distributors. The promotion thus results in a variability in manufacturer shipments that is significantly higher than the variability in retailer sales.

Behavioral Obstacles

Behavioral obstacles are problems in learning within organizations that contribute to information distortion. These problems are often related to the supply chain structure and the communications among different stages. Some of the behavioral obstacles are as follows:

1. Each stage of the supply chain views its actions locally and is unable to see the impact of its actions on other stages.

2. Different stages of the supply chain react to the current local situation rather than trying to identify the root causes.

3. Based on local analysis, different stages of the supply chain blame one another for the fluctuations, with successive stages in the supply chain becoming enemies rather than partners.

4. No stage of the supply chain learns from its actions over time because the most significant consequences of its actions occur elsewhere. The result is a vicious cycle in which actions taken by one stage create the very problems that the stage blames on others.

5. A lack of trust among supply chain partners causes them to be opportunistic at the expense of overall supply chain performance. The lack of trust also results in significant duplication of effort. More important, information available at different stages either is not shared or is ignored because it is not trusted.

Achieving Coordination in Practice

1. Quantify the bullwhip effect. Companies often have no idea that the bullwhip effect plays a significant role in their supply chain. Managers should start by comparing the variability in the orders they receive from their customers with the variability in orders they place with their suppliers. This helps a firm quantify its own contribution to the bullwhip effect. Once its contribution is visible, it becomes easier for a firm to accept the fact that all stages in the supply chain contribute to the bullwhip effect, leading to a significant loss in profits.

2*. Get top management commitment for coordination*. More than any other aspect of supply chain management, coordination can succeed only with top management's commitment. Coordination requires managers at all stages of the supply chain to subordinate their local interests to the greater interest of the firm, and even of the supply chain. Coordination often requires the resolution of trade-offs in a way that requires many functions in the supply chain to change their traditional practices. These changes often run counter to approaches that were put in place when each function focused only on its local objective. Such changes within a supply chain cannot be implemented without strong top management commitment. Top management commitment was a key factor in helping Walmart and P&G set up collaborative forecasting and replenishment teams.

3. Devote resources to coordination. Coordination cannot be achieved without all parties involved devoting significant managerial resources to this effort. One of the best ways to solve coordination problems is through teams made up of members from different companies throughout the supply chain. These teams should be made responsible for coordination and given the power to implement the changes required. Coordination teams can be effective only once a sufficient level of trust builds between members from different firms. If they are used properly, coordination teams can provide significant benefit, as has happened with the collaborative forecasting and replenishment teams set up by Walmart and P&G.

4. Focus on communication with other stages. Good communication with other stages of a supply chain often creates situations that highlight the value of coordination for both sides. Companies often do not communicate with other stages of the supply chain and are unwilling to share information. However, often all companies in the supply chain are frustrated by the lack of coordination and would be happy to share information if it helped the supply chain operate in a more effective manner. Regular communication helps different stages of the supply chain share their goals and identify common goals and mutually beneficial actions that improve coordination.

5. Try to achieve coordination in the entire supply chain network. The full benefit of coordination is achieved only when the entire supply chain network is coordinated. It is not enough for two stages in a supply chain to coordinate. The most powerful party in a supply chain should make an effort to achieve coordination in the entire network. Toyota has been very effective in achieving knowledge sharing and coordination in its entire network.

6. Use technology to improve connectivity in the supply chain. The Internet and a variety of software systems can be used to increase the visibility of information throughout the supply chain. The major benefits of IT systems can be realized only if the systems help increase visibility across the supply chain and facilitate coordination. If firms are to realize the full benefit of the huge investments they make in current IT systems, particularly ERP systems, it is crucial that they make the extra effort required to use these systems to facilitate collaborative forecasting and planning across the supply chain. The Internet should be used to share information and increase connectivity in the supply chain.

7. Share the benefits of coordination equitably. The greatest hurdle to coordination in the supply chain is the belief on the part of any stage that the benefits of coordination are not being shared equitably. Managers from the stronger party in the supply chain relationship must be sensitive to this fact and ensure that all parties perceive that the way benefits are shared is fair.

Collaborative Planning, Forecasting and Replenishment

The CPFR has defined as "a business practice that combines the intelligence of multiple partners in the planning and fulfillment of customer demand.". It is important to understand that successful CPFR can be built only on a foundation in which the two parties have synchronized their data and established standards for exchanging information.

Sellers and buyers in a supply chain may collaborate along any or all the following four supply chain activities:

1. Strategy and planning. The partners determine the scope of the collaboration and assign roles, responsibilities, and clear checkpoints. In a joint business plan, they then identify significant events such as promotions, new product introductions, store openings/closings, and changes in inventory policy that affect demand and supply.

2. Demand and supply management. A collaborative sales forecast projects the partners' best estimate of consumer demand at the point of sale. This is then converted to a collaborative order plan that determines future orders and delivery requirements based on sales forecasts, inventory positions, and replenishment lead times.

3. Execution. As forecasts become firm, they are converted to actual orders. The fulfillment of these orders then involves production, shipping, receiving, and stocking of products.

4. Analysis. The key analysis tasks focus on identifying exceptions and evaluating metrics that are used to assess performance or identify trends.

A fundamental aspect of successful collaboration is the identification and resolution of exceptions. Exceptions refer to a gap between forecasts made by the two sides or some other performance metric that is falling or is likely to fall outside acceptable bounds. These metrics may include inventories that exceed targets or product availability that falls below targets. For successful CPFR, it is important to have a process in place that allows the two parties to resolve exceptions.

Four Common CPFR Scenarios

CPFR Scenario	Where Applied in Supply Chain	Industries Where Applied
Retail event collaboration	Highly promoted channels or categories	All industries other than those that practice EDLP
DC replenishment collaboration	Retail DC or distributor DC	Drugstores, hardware, grocery
Store replenishment collaboration	Direct store delivery or retail DC-to-store delivery	Mass merchants, club stores
Collaborative assortment planning	Apparel and seasonal goods	Department stores, specialty retail

Retail Event Collaboration

In many retail environments, such as supermarkets, promotions and other retail events have a significant impact on demand. Stockouts, excess inventory, and unplanned logistics costs during these events affect financial performance for both the retailer and the manufacturer. In such a setting, collaboration between retailers and suppliers to plan, forecast, and replenish promotions is effective.

Retail event collaboration requires the two parties to identify brands and specific SKUs (Stock keeping units) that are included in the collaboration. Details of the event—such as timing, duration, price point, advertising, and display tactics—are shared. It is important for the retailer to update this information as changes occur. Event-specific forecasts are then created and shared. These forecasts are then converted to planned orders and deliveries. As the event unfolds, sales are monitored to identify any changes or exceptions, which are resolved through an iterative process between the two parties.

DC (Distribution center) Replenishment Collaboration

DC replenishment collaboration is perhaps the most common form of collaboration observed in practice and the simplest to implement in this scenario, the two trading partners collaborate on forecasting DC withdrawals or anticipated demand from the DC to the manufacturer. These forecasts are converted to a stream of orders from the DC to the manufacturer that are committed or locked over a specified time horizon. This information allows the manufacturer to include anticipated orders in future production plans and build the committed orders on demand. The result is a reduction in production cost at the manufacturer and a reduction of inventory and stockouts at the retailer.

DC replenishment collaboration is relatively easy to implement because it requires collaboration on aggregate data and does not require sharing of detailed POS (point of sale) data. As a result, it is often the best scenario with which to start collaboration. Over time, this form of collaboration can be extended to include all storage points in the supply chain, from retail shelves to raw material warehouses.

Store Replenishment Collaboration

In store replenishment collaboration, trading partners collaborate on store-level POS forecasts. These forecasts are then converted to a series of store-level orders, with orders committed over a specified time horizon. This form of collaboration is much harder to implement than a DC-level collaboration, especially if stores are small; it is easier for large stores. The benefits of store-level collaboration include greater visibility of sales for the manufacturer, improved replenishment accuracy, improved product availability, and reduced inventories.

Collaborative Assortment Planning

Fashion apparel and other seasonal goods follow a seasonal pattern of demand. Thus, collaborative planning in these categories has a horizon of a single season and is performed at seasonal intervals. Given the seasonal nature, forecasts rely less on historical data and more on collaborative interpretation of industry trends, macroeconomic factors, and customer tastes. In this form of collaboration, the trading partners develop an mixed plan jointly. The output is a planned purchase order at the style/color/size level. The planned order is shared electronically in advance of a show, at which sample products are viewed and final merchandising decisions are made. The planned orders help the manufacturer purchase long-lead-time raw materials and plan capacity. This form of collaboration is most useful if capacity is flexible enough to accommodate a variety of product mix and raw materials have some commonality across end products.

Organizational and Technology Requirements for Successful CPFR

A successful CPFR implementation requires changes in the organizational structure and, to be scalable, requires the implementation of appropriate technology. Effective collaboration requires manufacturers to set up cross-functional, customer-specific teams that include sales, demand planning, and logistics, at least for large customers. Such a focus has become feasible with the consolidation in retailing. For smaller customers, such teams can be focused by geography or sales channel. Retailers should also attempt to organize merchandise planning, buying, and replenishment into teams around suppliers. This can be difficult, given the large number of suppliers that consolidated retailers have. They can then organize the teams by categories that include multiple suppliers. For retailers that have multiple levels of inventory, such as DCs and retail stores, it is important to combine the replenishment teams at the two levels. Without collaborative inventory management at the two levels, duplication of inventories is common.

The CPFR process is not dependent on technology but requires technology to be scalable. CPFR technologies have been developed to facilitate sharing of forecasts and historical information, evaluating exception conditions, and enabling revisions. These solutions must be integrated with enterprise systems that record all supply chain transactions.

Risks and Hurdles for a CPFR Implementation

It is important to realize that there are risks and hurdles for a successful CPFR implementation. Given the large-scale sharing of information, there is a risk of information misuse. Often one or both CPFR partners have relationships with the partner's competitors. Another risk is that if one of the partners changes its scale or technology, the other partner will be forced to follow suit or lose the collaborative relationship. Finally, the implementation of CPFR and the resolution of exceptions require close interactions between two entities whose cultures may be very different. The inability to foster a collaborative culture across the partner organizations can be a major hurdle for the success of CPFR. One of the biggest hurdles to success is often that partners attempt store-level collaboration, which requires a higher organizational and technology investment. It is often best to start with an event- or DC-level collaboration, which is more focused and easier to collaborate on. Another major hurdle for successful CPFR is that demand information shared with partners is often not used within the organization in an integrated manner. It is important to have integrated demand, supply, logistics, and corporate planning within the organization to maximize the benefits of a CPFR effort with a partner.

The Role of Cycle Inventory in a Supply Chain

A lot or batch size is the quantity that a stage of a supply chain either produces or purchases at a time. Cycle inventory is the average inventory in a supply chain due to either production or purchases in lot sizes that are larger than those demanded by the customer.

Let's consider the cycle inventory of jeans at Jean-Mart, a department store. The demand for jeans is relatively stable at D = 100 pairs of jeans per day. The store manager at Jean-Mart currently purchases in lots of Q = 1,000 pairs. Because purchases are in lots of Q = 1,000 units, whereas demand is only D = 100 units per day, it takes 10 days for an entire lot to be sold. Over these 10 days, the inventory of jeans at Jean-Mart declines steadily from 1,000 units (when the lot arrives) to 0 (when the last pair is sold). When demand is steady, cycle inventory and lot size are related as follows: Cycle inventory = lot size/ 2 = Q/2.

For a lot size of 1,000 units, Jean-Mart carries a cycle inventory of Q/2 = 500 pairs of jeans. A supply chain in which stages produce or purchase in larger lots has more cycle inventory than a supply chain in which stages produce and purchase in smaller lots. Lot sizes and cycle inventory also influence the flow time of material within the supply chain.

Average flow time =average inventory/average flow rate = Q/2D=5 days

The larger the cycle inventory, the longer the lag time between when a product is produced and when it is sold. A lower level of cycle inventory is always desirable, because long time lags leave a firm vulnerable to demand changes in the marketplace. A lower cycle inventory also decreases a firm's working capital requirement.

The average price paid per unit purchased is a key cost in the lot-sizing decision. A buyer may increase the lot size if this action results in a reduction in the price paid per unit purchased.

The fixed ordering cost includes all costs that do not vary with the size of the order but are incurred each time an order is placed. There may be a fixed administrative cost to place an order, a fixed trucking cost to transport the order, and a fixed labor cost to receive the order.

Holding cost is the cost of carrying one unit in inventory for a specified period of time, usually one year. It is a combination of the cost of capital, the cost of physically storing the inventory, and the cost that results from the product becoming obsolete. The holding cost is denoted by H and is measured in rupee per unit per year.

To summarize, the following costs must be considered in any lot-sizing decision:

- Average price per unit purchased, Rs C/unit
- Fixed ordering cost incurred per lot, Rs. S/lot
- Holding cost incurred per unit per year, Rs H/unit/year = h C

Where 'h' is a fraction of the unit cost of the product required to hold one year

Estimating Cycle Inventory-Related Costs in Practice

When setting cycle inventory levels in practice, a common hurdle is estimating the ordering and holding costs. Identify incremental costs that change with the lot-sizing decision. Ignore costs that are unchanged with a change in lot size.

Inventory Holding Cost

Holding cost is estimated as a percentage of the cost of a product and is the sum of the following major components:

- Cost of capital: This is the dominant component of holding cost for products that do not become obsolete quickly.
- Obsolescence (or spoilage) cost: The obsolescence cost estimates the rate at which the value of the stored product drops because its market value or quality falls. Perishable products have high obsolescence rates. Products such as crude oil that take a long time to spoil or become obsolete. For such products, a low obsolescence rate may be applied.
- Handling cost: Handling cost should include only incremental receiving and storage costs that vary with the quantity of product received. Quantity-independent handling costs that vary with the number of orders should be included in the order cost. The quantity dependent handling cost often does not change if quantity varies within a range. If the quantity is within this range (e.g., the range of inventory a crew of four people can unload per period of time), incremental handling cost added to the holding cost is zero. If the quantity handled requires more people, an incremental handling cost is added to the holding cost.
- Occupancy cost: The occupancy cost reflects the incremental change in space cost due to changing cycle inventory. Occupancy costs often take the form of a step function, with a sudden increase in cost when capacity is fully utilized and new space must be acquired.

• Miscellaneous costs: The final component of holding cost deals with a number of other relatively small costs. These costs include theft, security, damage, tax, and additional insurance charges that are incurred. Once again, it is important to estimate the incremental change in these costs on changing cycle inventory.

Ordering Cost

The ordering cost includes all incremental costs associated with placing or receiving an extra order that are incurred regardless of the size of the order. Components of ordering cost include the following:

• Buyer time: Buyer time is the incremental time of the buyer placing the extra order. This cost should be included only if the buyer is utilized fully. The incremental cost of getting an idle buyer to place an order is zero and does not add to the ordering cost. Electronic ordering can significantly reduce the buyer time to place an order.

• Transportation costs: A fixed transportation cost is often incurred regardless of the size of the order. For instance, if a truck is sent to deliver every order, it costs the same amount to send a half-empty truck as it does a full truck. Less-than-truckload pricing also includes a fixed component that is independent of the quantity shipped and a variable component that increases with the quantity shipped. The fixed component should be included in the ordering cost.

• Receiving costs: Some receiving costs are incurred regardless of the size of the order. These include any administration work such as purchase order matching and any effort associated with updating inventory records. Receiving costs that are quantity dependent should not be included here.

• Other costs: Each situation can have costs unique to it that should be considered if they are incurred for each order regardless of the quantity of that order. The ordering cost is estimated as the sum of all its component costs.

Economic Order Quantity

The inputs of Economic Order Quantity are given below

D = Annual demand of the product

S = Fixed cost incurred per order

C = Cost per unit of product

h = Holding cost per year as a fraction of product cost

The purchasing manager makes the lot-sizing decision to minimize the total cost for the store. He or she must consider three costs when deciding on the lot size:

• Annual material cost

• Annual ordering cost

• Annual holding cost

Because purchase price is independent of lot size, we have

Annual material cost = CD

The number of orders must suffice to meet the annual demand D. Given a lot size of Q, thus have

Number of orders per year = D/Q

Because an order cost of S is incurred for each order placed, we infer that

Annual ordering cost = (D/Q)S

Given a lot size of Q, we have an average inventory of Q/2. The annual holding cost is thus the cost of holding Q/2 units in inventory for one year and is given as

Annual holding cost = H(Q/2)=(Q/2)hC

The total annual cost, TC, is the sum of all three costs and is given as

Total annual cost, TC = CD + S(D/Q) + (Q/2)hC

Economic order quantity obtains By equating annual ordering cost and annual holding cost

Q=Sqrt(2DS/hC)

Ex 1.Demand for the Deskpro computer at Best Buy is 1,000 units per month. Best Buy incurs a fixed order placement, transportation, and receiving cost of Rs 4,000 each time an order is placed. Each computer costs Best Buy Rs 500 and the retailer has a holding cost of 20 percent. Evaluate the number of computers that the store manager should order in each replenishment lot.

Analysis:

In this case, the store manager has the following inputs:

Annual demand, D = 1,000 * 12 = 12,000 units

Order cost per lot, S = Rs 4,000

Unit cost per computer, C = Rs 500

Holding cost per year as a fraction of unit cost, h = 0.2 and using the EOQ formula the optimal lot size is

Q*= Sqrt(2DS/hC) = Sqrt(2 * 12,000 * 4,000/ 0.2 * 500)

To minimize the total cost at Best Buy, the store manager orders a lot size of 980 computers for each replenishment order. The cycle inventory is the average resulting inventory is given by

Cycle inventory = Q*/2= 980/2 =490

For a lot size of Q* = 980, the store manager evaluates Number of orders per year= D/Q*=12.24

Annual ordering and holding cost = SD/Q*+hCQ*/2= Rs 97980

Average flow time =Q*/2D=490/1200=0.041 year=0.49 month

Each computer thus spends 0.49 month, on average, at Best Buy before it is sold because it was purchased in a batch of 980.

Relationship Between Desired Lot Size and Ordering Cost

Ex 2. The store manager at Best Buy would like to reduce the optimal lot size from 980 to 200. For this lot size reduction to be optimal, the store manager wants to evaluate how much the ordering cost per lot should be reduced.

Analysis:

In this case, Desired lot size, $Q^* = 200$

Annual demand, $D = 1{,}000 * 12 = 12{,}000$ units

Unit cost per computer, C = Rs 500

Holding cost per year as a fraction of inventory value, h = 0.2

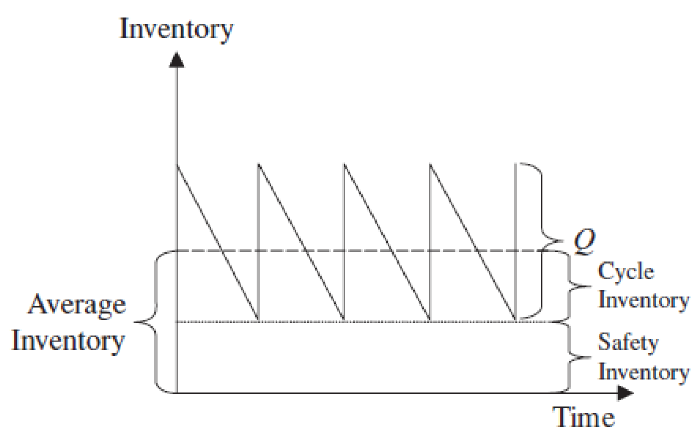
Using the EOQ formula the desired order cost is = $S = hC(Q^*)^2/2D$=Rs 166.27

Thus, the store manager at Best Buy would have to reduce the order cost per lot from Rs 4,000 to Rs 166.7 for a lot size of 200 to be optimal.

MANAGING UNCERTAINTIES IN INVENTORY

The *safety inventory* can help a supply chain improve product availability in the presence of supply and demand variability. To maintain or even improve product availability first study the various measures of product availability then reduce the amount of safety inventory required.

Safety inventory is inventory carried to satisfy demand that exceeds the amount forecast. Safety inventory is required because demand is uncertain, and a product shortage may result if actual demand exceeds the forecast demand.



Inventory Profile with Safety Inventory

In today’s business environment, it has become easier for customers to search across stores for product availability. The increased ease of searching puts pressure on firms to improve product availability. Simultaneously, product variety has grown with increased customization. As a result, markets have become increasingly heterogeneous and demand for individual products is unstable and difficult to forecast. Both the increased variety and the greater pressure for availability push firms to raise the level of safety inventory they hold. Given the product variety and high demand uncertainty in most high-tech supply chains, a significant fraction of the inventory carried is safety inventory.

Factors affecting the Level of Safety Inventory

The appropriate level of safety inventory is determined by the following two factors:

- The uncertainty of both demand and supply
- The desired level of product availability

As the uncertainty of supply or demand grows, the required level of safety inventories increases. Demand for milk at a supermarket is quite predictable. As a result, supermarkets can operate with low levels of safety inventory relative to demand. In contrast, demand for spices at the same supermarket is much harder to predict. Thus, the supermarket needs to carry high levels of safety inventory for spices relative to demand. Whereas most of the milk inventory at a supermarket is cycle inventory (with very little being safety inventory), most of the spice inventory is safety inventory carried to deal with uncertainty of demand.

Measuring Product Availability

Product availability reflects a firm’s ability to fill a customer order out of available inventory. A stockout results if a customer order arrives when product is not available. There are several ways to measure product availability. Some of the important measures are listed next.

1. *Product fill rate (fr)* is the fraction of product demand that is satisfied from product in inventory. Fill rate is equivalent to the probability that product demand is supplied from available inventory. Fill rate should be measured over specified amounts of demand rather than over time.

2. *Order fill rate* is the fraction of orders that are filled from available inventory. Order fill rate should also be measured over a specified number of orders rather than over time. In a multiproduct scenario, an order is filled from inventory only if all products in the order can be supplied from the available inventory. Order fill rates tend to be lower than product fill rates because all products must be in stock for an order to be filled.

3.*Cycle service level (CSL)* is the fraction of replenishment cycles that end with all the customer demand being met. A replenishment cycle is the interval between two successive replenishment deliveries. The CSL is equal to the probability of not having a stockout in a replenishment cycle. CSL should be measured over a specified number of replenishment cycles.

Ex 3. Assume that weekly demand for phones at B&M Office Supplies is normally distributed, with a mean of 2,500. The manufacturer takes two weeks to fill an order placed by the B&M manager. The store manager currently orders 10,000 phones when the inventory on hand drops to 6,000. Evaluate the safety inventory, the average inventory carried by B&M and evaluate the average time a phone spends at B&M.

Analysis:

Under this replenishment policy, Average demand per week, D = 2,500

Average lead time for replenishment, L = 2 weeks

Reorder point, ROP = 6,000

Average lot size, Q = 10,000

Safety inventory, ss = ROP - D * L = 6,000 - 5,000 = 1,000

B&M thus carries a safety inventory of 1,000 phones.

Cycle inventory = Q / 2 = 10,000 / 2 = 5,000

We thus have Average inventory = cycle inventory + safety inventory = 5,000 + 1,000 = 6,000

B&M thus carries an average of 6,000 phones in inventory.

Average flow time = average inventory/throughput = 6,000 / 2,500 = 2.4 weeks

Impact of Supply Uncertainty on Safety Inventory

In many practical situations, supply uncertainty also plays a significant role. Supply uncertainty arises because of many factors, including production delays, transportation delays, and quality problems. Supply chains must account for supply uncertainty when planning safety inventories.

In practice, variability of supply lead time is caused by practices at both the supplier and the party receiving the order. Suppliers sometimes have poor planning tools that do not allow them to schedule production in a way that can be executed. Today, most supply chain planning software suites have good production planning tools that allow suppliers to promise lead times that can be met. This helps reduce lead time variability. The lack of visibility for a supplier into future customer plans is also a significant factor that increases supply chain uncertainty.

Replenishment Policies

A replenishment policy consists of decisions regarding when to reorder and how much to reorder. These decisions determine the cycle and safety inventories along with the fill rate and the cycle service level CSL. Replenishment policies may take any of several forms. The two types of replenishment policies given below:

1. Continuous review: Inventory is continuously tracked, and an order for a lot size Q is placed when the inventory declines to the reorder point (ROP). The time between orders may fluctuate, given variable demand.

2. Periodic review: Inventory status is checked at regular periodic intervals, and an order is placed to raise the inventory level to a specified threshold. In this case, the time between orders is fixed. The size of each order, however, can fluctuate given variable demand.

Impact of Replenishment Policies in Safety Inventory

The evaluation of safety inventories for both continuous and periodic review replenishment policies. We highlight the fact that periodic review policies require more safety inventory than continuous review policies for the same level of product availability.

Continuous Review Policies

When using a continuous review policy, a manager orders Q units when the inventory drops to the ROP. Clearly, a continuous review policy requires technology that monitors the level of available inventory. A manager using a continuous review policy has to account only for the uncertainty of demand during the lead time. This is because the continuous monitoring of inventory allows the manager to adjust the timing of the replenishment order, depending on the demand experienced. If demand is very high, inventory reaches the ROP quickly, leading to a quick replenishment order. If demand is very low, inventory drops slowly to the ROP, leading to a delayed replenishment order. The manager, however, has no recourse during the lead time once a replenishment order has been placed. The available safety inventory thus must cover for the uncertainty of demand over this period. Typically, in continuous review policies, the lot size ordered is kept fixed between replenishment cycles.

Periodic Review Policies

In periodic review policies, inventory levels are reviewed after a fixed period of time T and an order is placed such that the level of current inventory plus the replenishment lot size equals a prespecified level called the order-up-to level (OUL). The review interval is the time T between successive orders. Observe that the size of each order may vary, depending on the demand experienced between successive orders and the resulting inventory at the time of ordering. Periodic review policies are simpler for retailers to implement because they do not require that the retailer have the capability of monitoring inventory continuously. Suppliers may also prefer them because they result in replenishment orders placed at regular intervals.

The Role of Information Technology in Inventory Management

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 much 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 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 many 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. 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 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 is 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 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

• Air (includes truck and 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 cost 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 planning decision, whereas the choice of transportation mode for a 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 cost, 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 cost 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 largefraction 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.

Transportation Cost and Customer Responsiveness Trade-Off

The transportation cost a supply chain incurs is closely linked to the degree of responsiveness the supply chain aims to provide. If a firm has high responsiveness and ships all orders within a day of receipt from the customer, it will have small outbound shipments, resulting in a high transportation cost. If it decreases its responsiveness and aggregates orders over a longer time horizon before shipping them out, it will be able to exploit economies of scale and incur a lower transportation cost because of larger shipments. Temporal aggregation is the process of combining orders across time. Temporal aggregation decreases a firm’s responsiveness because of shipping delay, but also decreases transportation costs because of economies of scale that result from larger shipments.

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 carriers lower costs and become more responsive to changes.

4. Design flexibility into the transportation network. When designing transportation networks, managers should consider 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 shipment, including them in the transportation option.