Managing inventory in the supply chain

EE382

Learning objectives

- Appreciate the role and importance of inventory in the economy
- List the major reasons for carrying inventory
- Discuss the major types of inventory, their costs, and their relationships to inventory decisions
- Understand the fundamental differences among approaches to managing inventory
- Describe the rationale and logic behind the economic order quantity (EOQ) approach to inventory decision making, and be able to solve some problems of a simple nature
- Understand alternative approaches to managing inventory- Just-in-time (JIT), materials requirement planning (MRP), and distribution requirements planning (DRP)

- An organization would ideally want to have enough inventory to satisfy the demands of its customers for its products with no lost revenue because of stockouts

- However, the organization does not want to have too much inventory on hand because it consumes valuable working capital

- Balancing supply and demand is a constant challenge for organizations to master but is a necessity to compete in the marketplace

Inventory in the Firm: Rationale for Inventory

- Batching economies/ Cycle stocks
- Uncertainty/Safety stocks
- Time/In Transit and Work-in-Process stocks
- Seasonal Stocks
- Anticipatory Stocks

Batching economies/ Cycle stocks

Arises from three sources:

- Procurement
  - Price discounts for larger quantity
  - Price discount savings have to be compared to the additional cost of carrying inventory
- Transportation
  - Transportation firms usually offer price discounts for shipping larger quantities
  - Do the costs savings from the larger shipment offset the additional inventory carrying cost?
- Production
  - Production costs per unit are substantially lower when they have long production runs of the same product
  - Long production runs decrease the number of changeovers to a production line but increase the amount the cycle clock that must be stored until they are sold

Uncertainty/Safety stocks

- Demand side- uncertainty on how much customers will buy and whey they will buy it
- Supply side – uncertainty about obtaining what is needed from suppliers and how long it will take for the fulfillment of the order
- Transportation – uncertainty in terms of receiving reliable delivery

- Organization accumulate safety stock to buffer themselves against stockouts

Time/In Transit and Work-in-Process stocks

- Time associated with transportation and with the manufacture or assembly of a complex product
  - The longer the time period, the higher the cost

Example
ABC Power Tools- In-Transit Inventory Analysis

ABC Ships product in 40-foot containers from Europe to a customer in California

Current mode mix:

- Plant to European port: motor carrier drayage
- European port to U.S. port (East Coast): ocean carrier
- Eastern U.S. port to rail siding: motor carrier drayage
- Eastern U.S. rail siding to California rail siding: rail
- California rail siding to customer DC: motor carrier drayage

Assume that one 40 foot container holds 500 units of Product A:

- Manufactured cost per unit of Product A= $449

Assume ABC owns the inventory to delivery at customer DC

Assume ABC ships 100 containers per year to this customer

Transportation costs (per container):

- Motor carrier drayage:$150
- Ocean: $700
- Rail: $900
- Air:$2,500

Change modes: replace ocean and rail with air

ABC Power Tools In-Transit Inventory Analysis-Current

Supply Chain Move	Days	Inventory Value	Transportation Mode	Freight Cost
ABC plant to European port	1	$615.07	Drayage	$150.00
Through European port	2	1,230.14	-	-
European port to East Coast U.S. port	5	3,075.35	Ocean	700.00
Through U.S. Port	2	1,230.14	-	-
U.S. port to rail siding	1	615.07	Drayage	150.00
East Coast U.S. to California	10	6,150.70	Rail	900.00
California rail to customer	1	615.07	Drayage	150.00
Total	22	$13,531.54		$2,050.00

ABC Power Tools –In-Transit Inventory Analysis (Proposed)

Supply Chain Move	Days	Inventory Value	Transportation Mode	Freight cost
ABC plants to European airport	1	$615.07	Drayage	$150.00
Through European airport	1	$615.07	-	-
European airport to California airport	1	$615.07	Air	2,500
Through California airport	1	$615.07	-	-
California airport to customer	1	$615.07	Drayage	150.00
Total	5	$3,075.35		$2,800

Seasonal Stocks

- Organizations that are faced with seasonality issues are constantly challenged when determining how much inventory to accumulate

- Example agriculture products

Anticipatory Stocks

- An organization anticipates an unusual event might occur that will negatively impact its source of supply
- Organizations might accumulate inventory to hedge against the risk associated with the unusual event

Inventory costs

- Represents a significant component of logistics costs
- Inventory levels that an organization maintains at nodes in its logistics network will affect the level of service the organization can offer its customers
- Cost tradeoffs decisions in logistics depend on and impact inventory carrying costs

Major types of costs

- Inventory carrying costs
- Order/setup costs
- Expected Stockout cost
- In-Transit inventory carrying cost

Inventory carrying costs

- Capital cost
  - Interest or opportunity cost – focuses on the cost of capital tied up in inventory and the resulting lost opportunity from investing that capital elsewhere
- Storage Space cost
  - Handling costs and storage costs
- Inventory Service cost
  - Insurance and taxes
- Inventory Risk cost
  - Inventory dollars value might decline for reasons beyond on organization's control such as goods held in storage for long period of time might become obsolete and thus decrease in value

Example
ABC Power Tools Inventory carrying cost for Item 1

Assume that ABC Power Tools assembles industrial machine tools and hand-held tools for the construction industry

Item 1 is a heavy-duty band saw that is assembled at the plant and shipped to an ABC distribution center for storage, waiting for an order to be placed

Cost Category	Computation	Annual Cost
1. Direct materials, labor, overhead		$614.65
2. Inbound freight to DC		$32.35
3. Labor	$10 per unit received plus $1 per unit per month x 2 months	$22.00
4. Space	$0.30/sq.ft./month x 8 sq.ft. x 12 months	$28.80
5. Insurance	$2.00 per unit per year	$2.00
6. Interest	10%@ 614.65	$61.47
7. Taxes	$5 per $100 value @ 20%	$6.15
8. Loss and damage	3.9% per year @614.65	$23.97
9. Obsolescence	1% per year @614.65	$6.15
10. Total inventory carrying costs		$182.89
11. Inventory carrying cost percent	$182.89/$614.65	29.8%

ABC Power Tools- Inventory Carrying Costs for Item 1 to customer

Assume

- Inventory carrying costs begin to accrue at the ABC distribution center

- All value-based costs must be prorated for each supply chain location based on the days of supply for that location

The next table illustrates, the cost of moving/storing Item 1 increases almost three times from the ABC distribution center to the retail store

Category	ABC Plant	ABC DC	Retail DC	Retail Store
1. Days of supply	0	60	45	30
2. Direct manufactured cost	$614.65	$614.65	$614.65	$614.65
3. Variable-based costs:				
Freight	$0	$32.35	$32.35	$32.35
Labor	0	12.00	11.50	11.00
Space	0	4.80	3.60	2.40
Insurance	0	0.33	0.25	0.17
4. Total variable-based costs (cumulative)	$0	$49.48	$97.18	143.10
5. Total value Item 1 (2+4)	$614.65	$664.13	$711.83	$757.75
6. Value-based costs (based on 5):				
Interest (10% per year)	$0	$11.07	$8.90	$6.31
Taxes	0	6.64	7.12	7.58
Loss and exchange	0	4.32	3.47	2.46
Obsolescence	0	1.11	0.89	0.63
7. Total value-based costs (cumulative)	$0	$23.14	$43.52	$60.50
8. Total costs (4+7)	$0	$72.62	$140.70	$203.60
9. Carrying cost percent (8/$614.65)	0	11.8%	22.9%	33.1%

Inventory and Carrying Costs for ABC Power Tools

- As average inventory increases for ABC Power Tools for Item 1 at its distribution center, annual carrying costs increase, and vice versa

- Carrying cost is variable and is directly proportional to the average number of items in inventory or the average inventory value

Inventory and carrying costs for ABC power tools

Order period (week)	Number of orders per year	Average inventory*		Total Annual Inventory Carrying cost***
		Unit	Value**	
1	52	25	$15,366.25	$4,440.85
2	26	50	30,732.50	8,881.69
4	13	100	614,650.00	17,763.39
13	4	325	199,761.25	57,731.00
26	2	650	399,522.50	115,462.00
52	1	1,300	799,045.00	230,924.00

*One week's inventory supply is 50 items. Average Inventory =beginning inventory (units)- ending inventory (assumed to be zero)/2
** value per unit is $614.65
*** carrying cost =28.9%

Order/Set up Cost

- The expense of placing an order for additional inventory and does not include the cost or expense of the product itself

- Order cost
  - Associated with ordering inventory have both fixed and variable components
  - Costs include reviewing inventory stock levels, preparing and processing order requisitions or purchase orders, preparing and processing receiving reports etc.
- Set up cost
  - Expenses incurred each time an organization modifies a production or assembly line to produce a different item for inventory

- Nature of cost
  - More frequent order placement results in customer placing a larger number of smaller orders per year
  - Both small and large orders incur the variable expense of placing an order, total annual order cost will increase in direct proportion to the number of orders placed per year
  - As long as annual sales and demand remain the same, total annual order or setup cost will relate directly to the number of orders or setups per year and will relate inversely to individual order size or individual production run length

Order Frequency and Order cost for computer hard disks

Order Frequency (week)	Number of orders per year	Total annual order cost*
1	52	$10,400
2	26	5,200
4	13	2,600
13	4	800
26	2	400
52	1	200

*Assuming a cost per order of $200

Carrying cost versus Order cost

- Order cost and carrying cost respond in opposite ways to changes in the number of orders or size of individual orders

- Order costs initially decrease more rapidly than carrying costs increase, which decreases total costs
  - A positive tradeoff occurs, since the marginal savings in order costs exceed the marginal increase in inventory carrying costs
- At certain point, this relationship begins to change and total costs start to increase
  - A negative tradeoff occurs because the marginal order cost savings are less than the marginal carrying cost increase

Summary of inventory and order cost

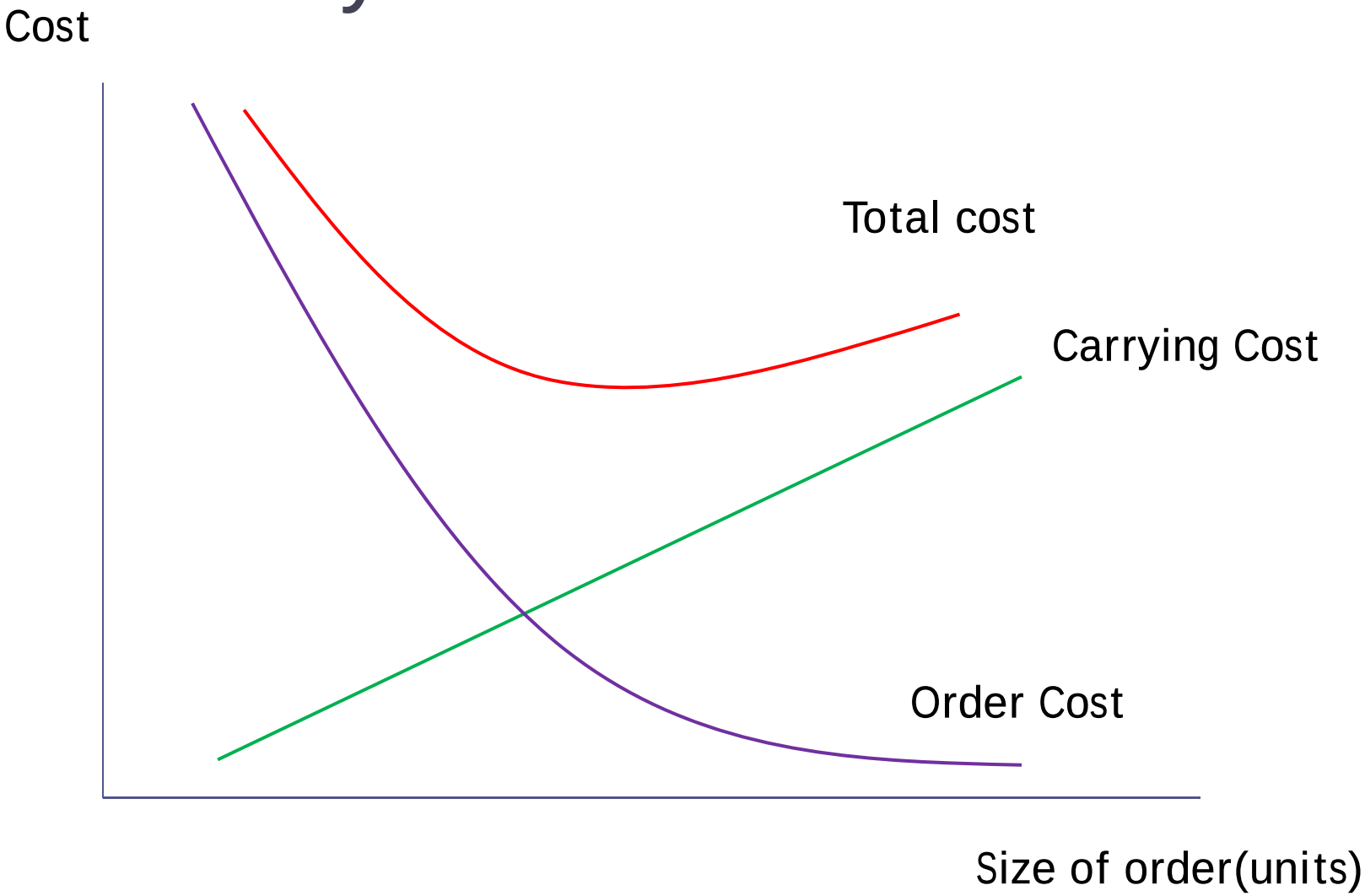
Order period (week)	Number of orders per year	Average inventory* (units)	Total annual order cost**	Change in total order cost	Total annual inventory carrying cost***	Change in total carrying cost	Total cost
1	52	50	$10,400		1,250		$11,650
2	26	100	5,200	-5,200	2,500	+1,250	7,700
4	13	200	2,600	-2,600	5,000	+2,500	7,600
13	4	650	800	-1,800	16,250	+11,250	17,050
26	2	1,300	400	-400	32,500	+16,250	32,900
52	1	2,600	200	-200	65,000	+32,500	65,200

*Assume sales or usage at 100 units per week. Average Inventory =(beginning inventory- ending inventory)/2

** cost per order is $200

*** Value is $100 and carrying cost is 25%

Inventory costs



Expected Stockout cost

- Cost associated with not having a product available to meet demand

In-Transit inventory carrying cost

Example

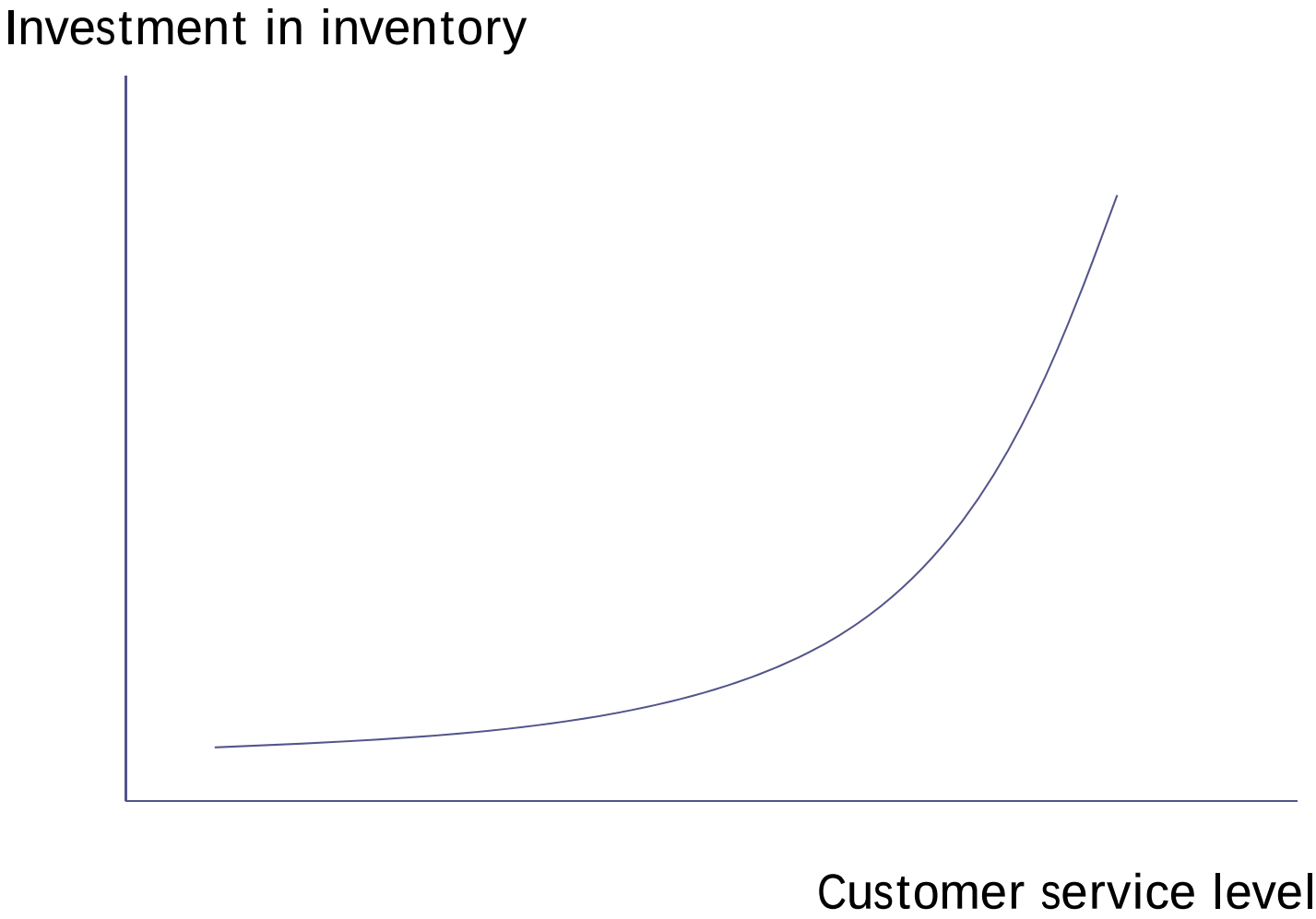
An organization selling its products “Free on Board” (FOB) destination is responsible for transporting the products to its customers, since title doesn’t pass until the products reach the customer’s facility

- The product remains under the ownership of the shipper until it is unloaded from the transportation vehicle at the customer’s location
- This moving inventory is shipper-owned until delivered to the customer, the shipper should consider its delivery time part of its inventory carrying cost
- The faster delivery occurs, the sooner the transaction is completed and the faster the shipper receives payment for the shipment
- Tradeoff between transportation cost and the cost of carrying inventory in transit

Fundamental Approaches to Managing Inventory

- **How much to order and when to order?**

Relationship between inventory and customer service level



Factors that make this objective achievable

- Real time order management systems
- Improved technologies to manage logistics information
- More flexible and reliable transportation resources
- Improvements in the ability to position inventories so that they will be available when and where they are needed

Key Difference Among Approaches to Managing Inventory

- Dependent versus Independent demand
- Pull versus Push
- System-Wide versus Single-Facility Solutions

Dependent versus Independent demand

- **Independent**
  - Demand is unrelated to the demand for other items

- **Dependent**
  - Demand is related or derived from, the demand for another inventory item or product
  - Demand for raw materials and component parts depends on the demand for the finished product
  - Forecasting is less relevant for items having dependent demand, since the required quantities for these items depend entirely on the demand for the end-use product

Pull versus Push

- Pull approach
  - Relies on customer orders to move product through a logistics system
  - Can respond quickly to sudden changes in demand
  - Run in the short term forecasts
  - Just-in-Time Approach
- Push approach
  - Uses inventory replenishment techniques in anticipation of demand to move products
  - Use longer term forecasts that allow for scale economies in manufacturing but result in high finished goods inventories

System-Wide versus Single-Facility Solutions

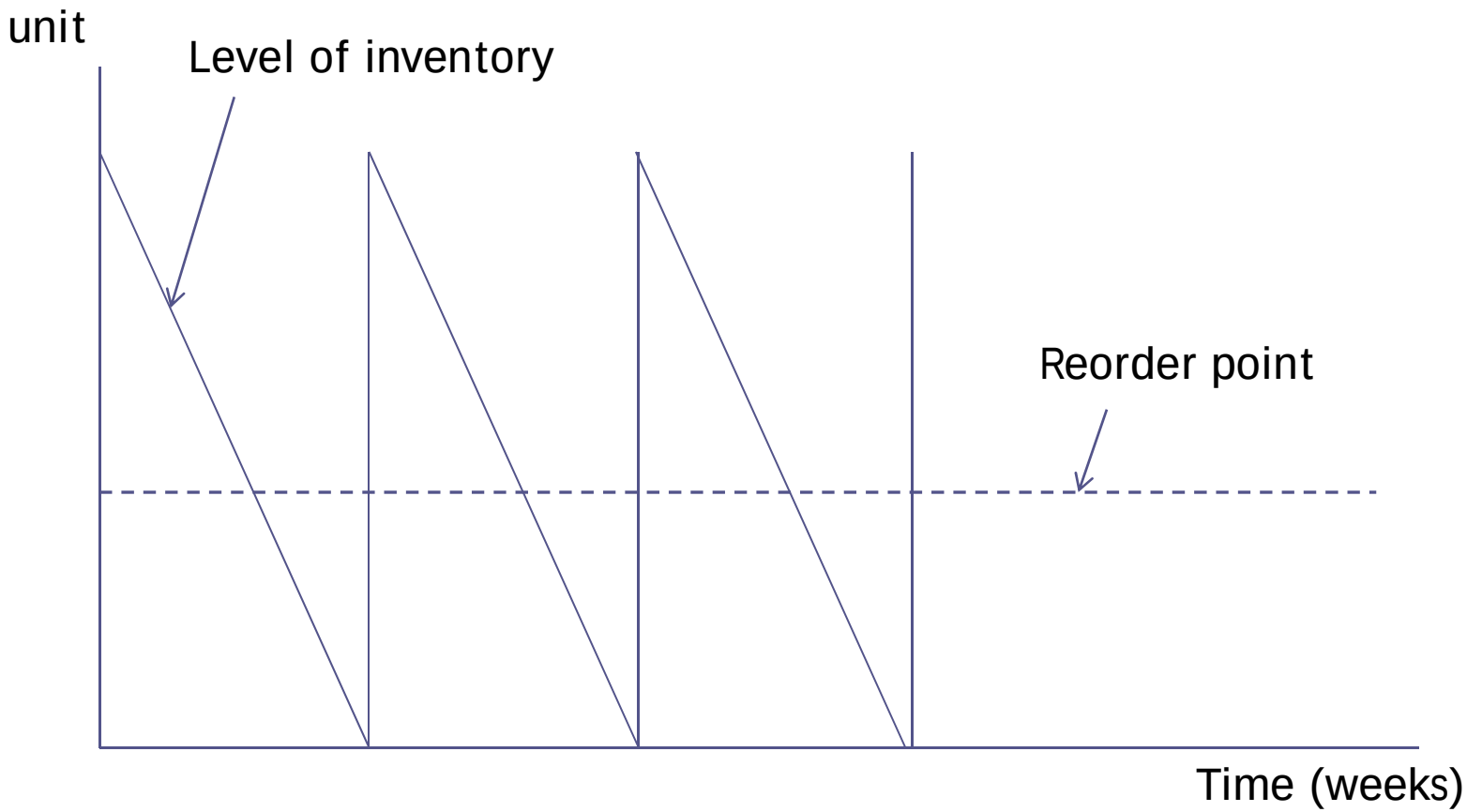
- System wide
  - Approach plans and executes inventory decisions across multiple nodes in the logistic system
  - Materials Requirements Planning
  - Distribution Requirements planning

- Single-Facility
  - Distribution center
  - Fixed order quantity (EOQ) and Just-in-Time Approach

Fixed Order Quantity Approach (Condition of Certainty)

- Fixed amount of product each time reordering takes place
- Need to develop a minimum stock level to determine when to reorder the fixed quantity (reorder point)
- The reorder point triggers the next order
- The two-bin model
  - When the first bin is empty, the organization places an order
  - The amount of inventory in the second bin represents the quantity needed until the new order arrives

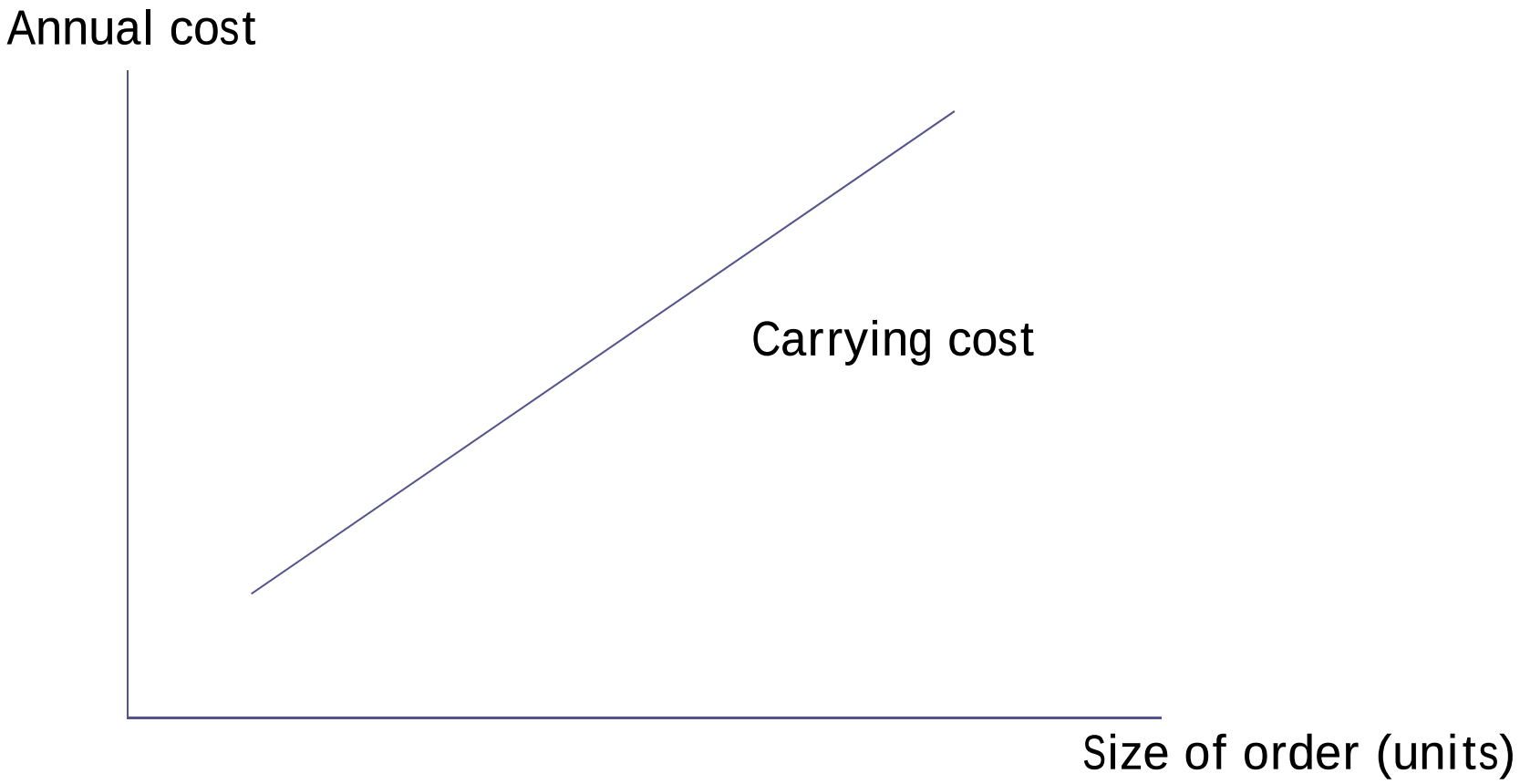
Fixed order Quantity Model Under the Condition of Certainty



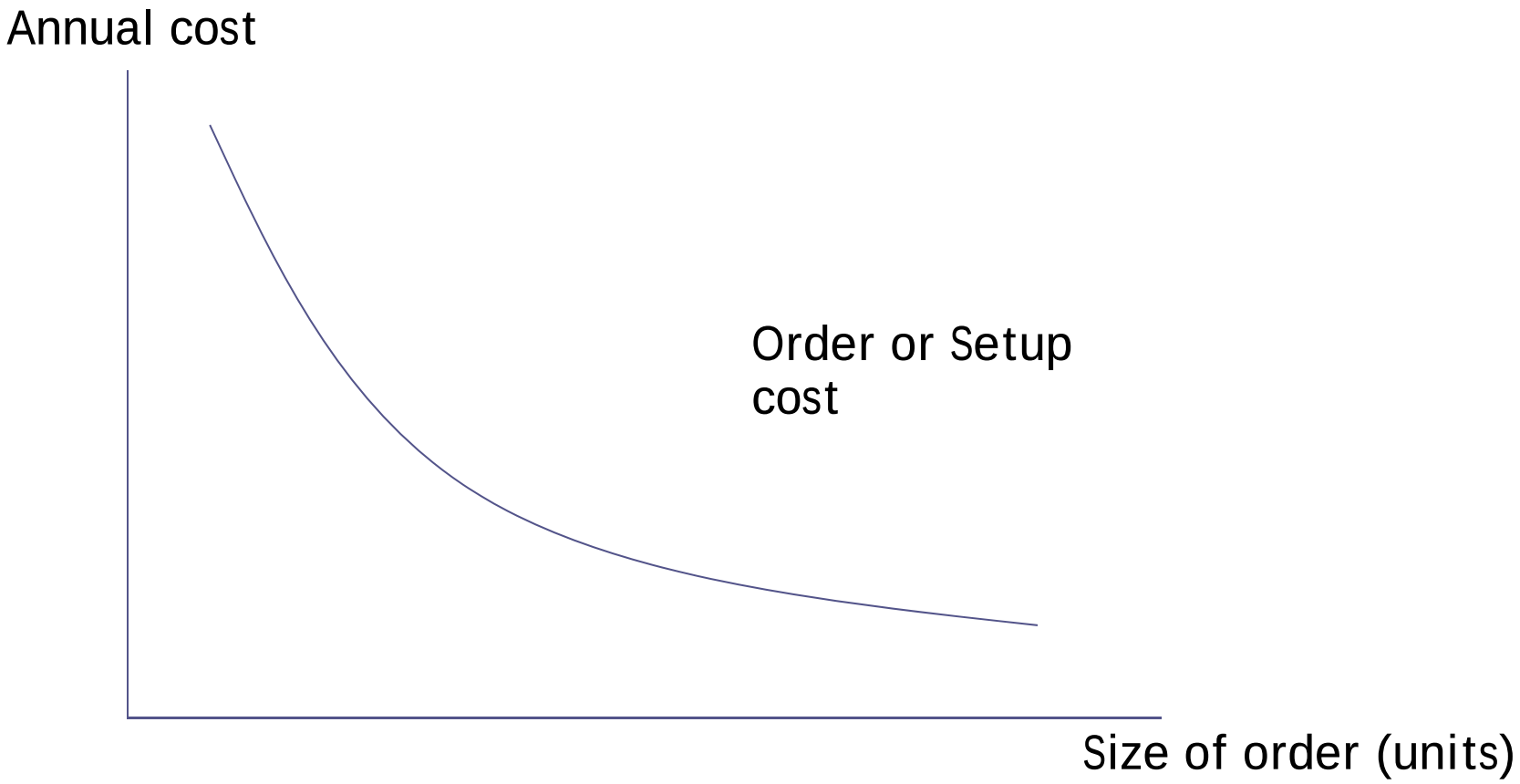
Simple EOQ model

- A continuous, constant, and known rate of demand
- A constant and known replenishment or lead time
- All demand is satisfied
- A constant price or cost that is independent of the order quantity
- No inventory in transit
- One item of inventory or no interaction between items
- Infinite planning horizon
  - Assume that constraints are not imposed on the length of the time periods
- Unlimited capital
  - There are no financial reasons to limit the quantity ordered

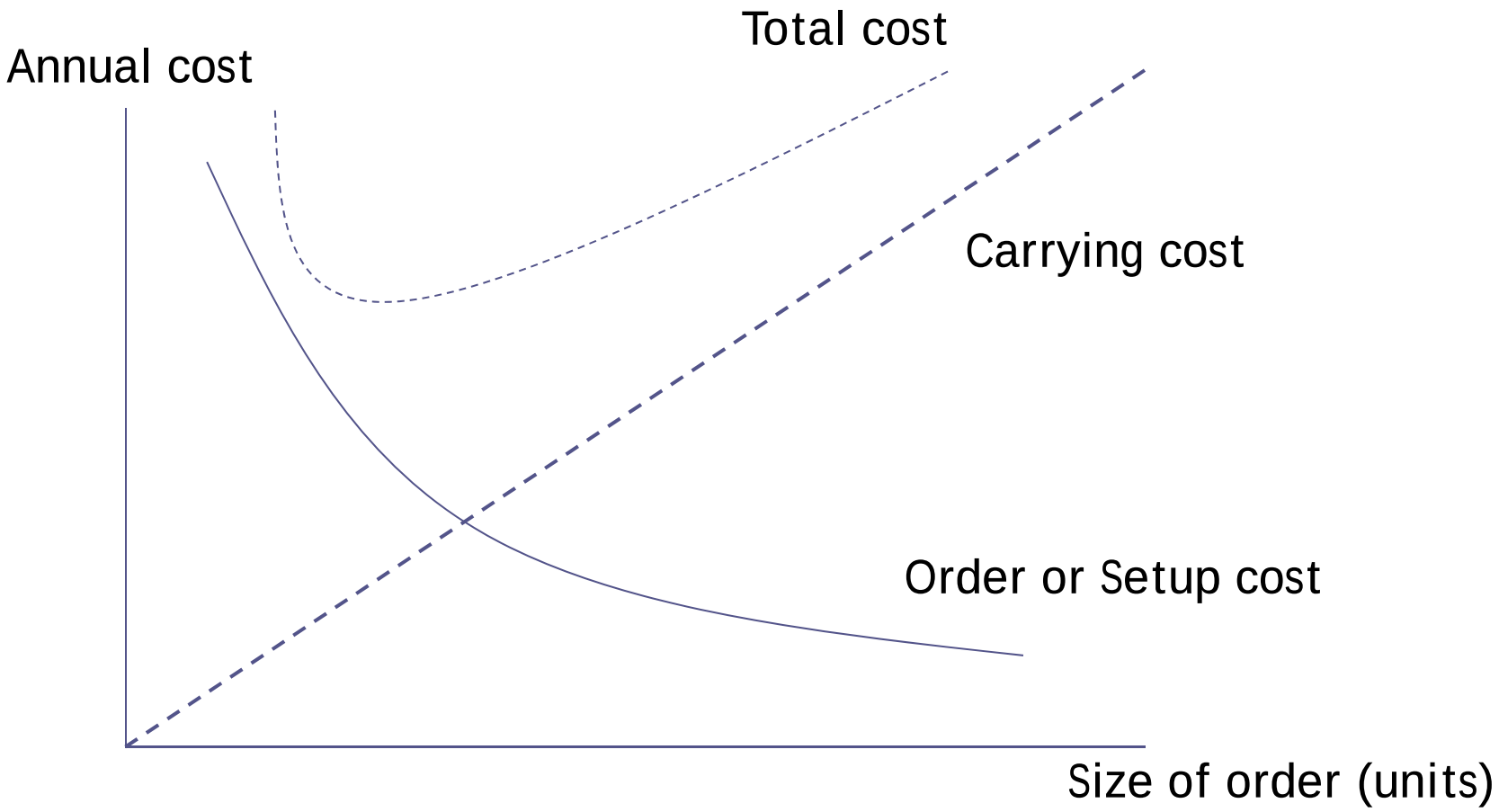
Inventory Carrying Cost



Order or Setup Cost



Inventory Costs



Summary and Evaluation of the fixed order quantity approach

- Many organizations have become more sophisticated in their use of EOQ based approaches, adapting them to include a push as well as a pull orientation

- Shortcoming of the EOQ approach
  - Suit inventory decision making at a single facility more than it suits decision making at multiple locations in a logistics network

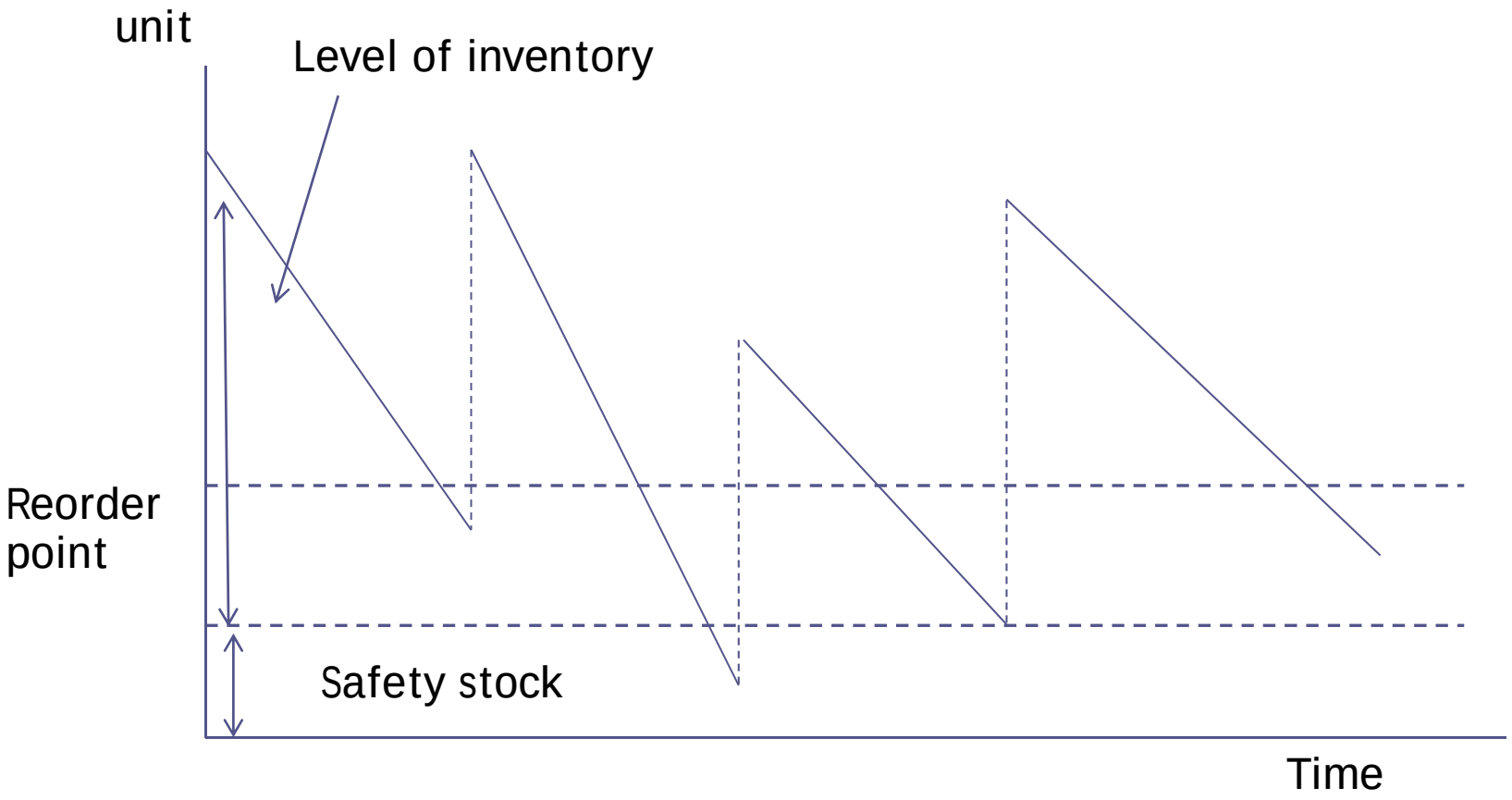
- Organizations associate EOQ based approaches with independent, rather than dependent, demand

Fixed Order Quantity Approach (Condition of Uncertainty)

Most organizations would not operate under conditions of certainty for a variety of reasons

- Consumers usually purchase products somewhat sporadically
- Several factors can affect lead time

Fixed order Quantity Model Under the Condition of Uncertainty



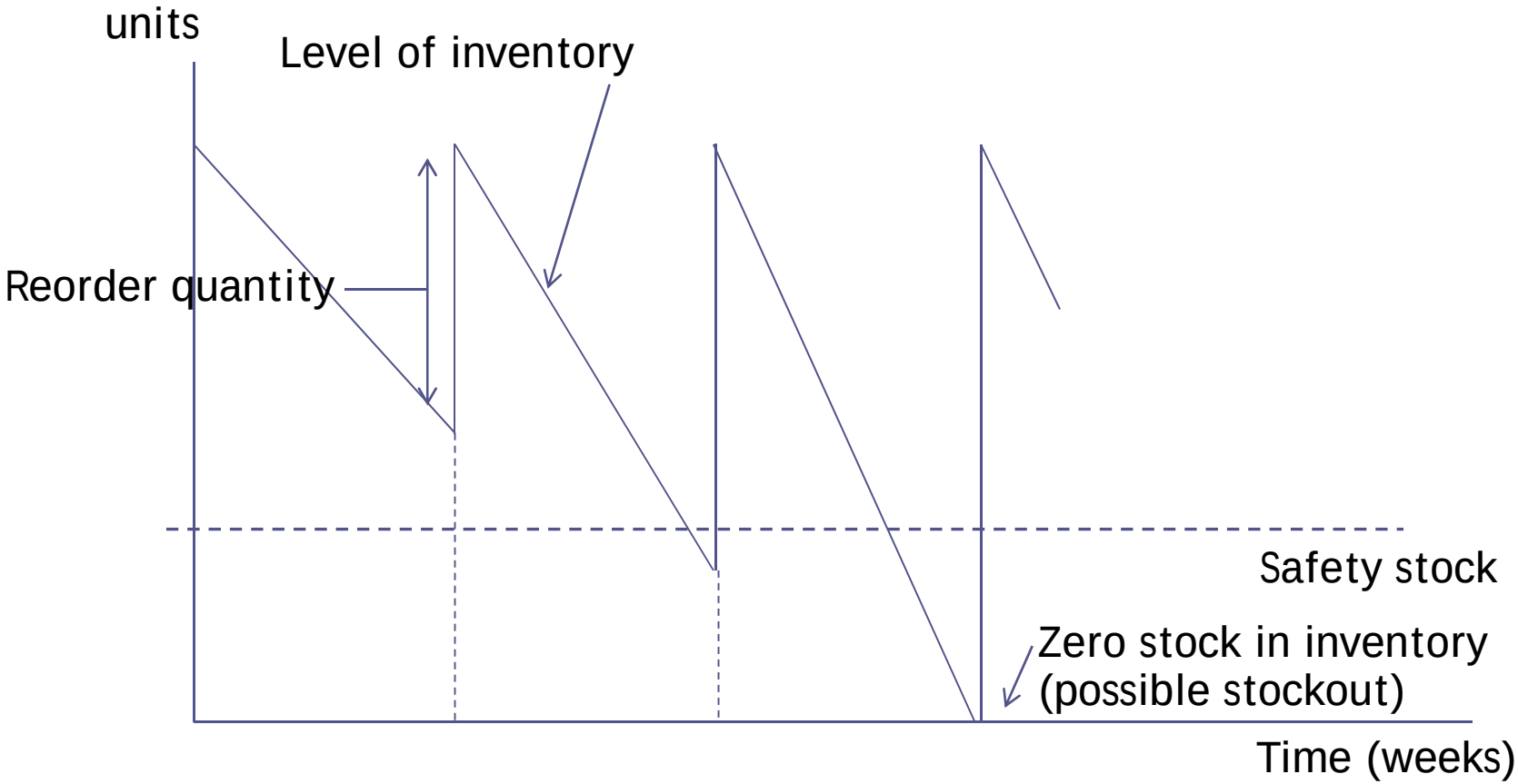
Uncertainty of Demand

- A constant and known replenishment or lead time
- A constant price or cost that is independent of the order quantity
- No inventory in transit
- One item of inventory or no interaction between items
- Infinite planning horizon

Fixed Order Interval Approach

- Fixed period or fixed review period approach
- Involves ordering inventory at fixed or regular intervals
- The amount ordered depends on how much is in stock and available at the time of review

Fixed order Internal Model Under the Condition of Certainty



Summary and Evaluation of EOQ Approaches to inventory management

- A fixed order quantity (EOQ) and fixed order interval approaches have proven to be effective inventory management tools when demand and lead time are relatively stable as well as when significant variability and uncertainty exist

The Just-in-Time Approach

- Inventories should be available when an organization needs them not any earlier or later

- An operating concept based on delivering materials in exact amounts and at the precise times that organizations need them – thus minimizing inventory costs

- Four major elements underlie the JIT concept
  - Zero inventories
  - Consistent lead times
  - Frequent replenishment quantities
  - High quality or Zero defects

EOQ versus JIT Attitudes and Behaviors

Factor	EOQ	JIT
Inventory	Asset	Liability
Safety stock	Yes	No
Production runs	Long	Short
Setup times	Amortize	Minimize
Lot sizes	EOQ	1 for 1
Queues	Eliminate	Necessary
Lead times	Tolerate	Shorter
Quality inspection	Important parts	100% process
Suppliers/ customers	Adversaries	Partners
Supply sources	Multiple	Single
Employees	Instruct	Involve

JIT versus EOQ Approaches to Inventory Management

- JIT attempts to eliminate excess inventories for both the buyer and the seller
- JIT systems involve short production runs and require production activities to change frequently from one product to another
- JIT minimizes wait time by delivering materials and products when and where an organization needs them
- The JIT concept uses short, consistent lead times to satisfy the need for inventory in a timely manner
- JIT based systems rely on high-quality incoming parts and components and on exceptionally high-quality inbound logistics systems
- JIT concept requires a strong, mutual commitment between the buyer and the seller, one that emphasizes quality and seeks win-win decisions for both parties

Summary and Evaluation of JIT

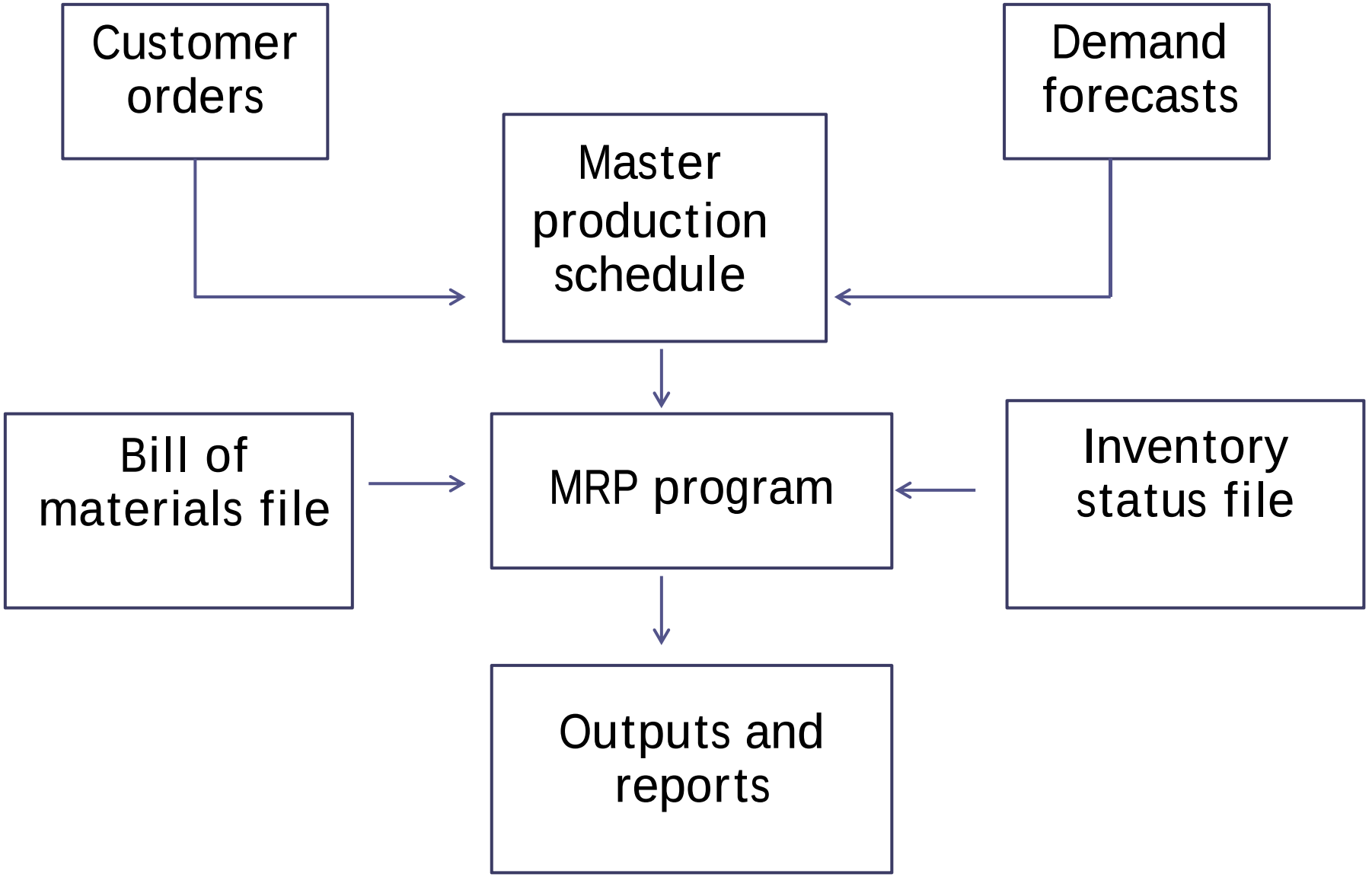
- JIT can enable logistics managers to reduce unit costs and to enhance customer service
- JIT commitment to short, consistent lead times and to minimizing or eliminating inventories
- JIT saves money on downstream inventories by placing greater reliance on improved responsiveness and flexibility
- Successful JIT applications place a high priority on efficient and dependable manufacturing processes
  - Since JIT systems require the delivery of parts and materials when and where the demand arises, they rely heavily on the accuracy of the forecasting process used to anticipate finished product demand

Materials Requirement Planning

- Deals specifically with supplying materials and component parts whose demand depends on the demand for a specific end product

- The goals of an MRP system
  - Ensure the availability of materials, components, and products for planned production and for customer delivery
  - Maintain the lowest possible inventory levels that support service objectives
  - Plan manufacturing activities, delivery schedules, and purchasing activities

An MRP system



Summary and evaluation of MRP systems

- A time-phased approach to inventory scheduling and inventory receipt
- A push approach
- Advantages of most MRP based systems
  - Attempt to maintain reasonable safety stock levels and to minimize or eliminate inventories whenever possible
  - Can identify process problems and potential supply chain disrupting long before they occur and take the necessary corrective actions
  - Schedules are based on actual demand as well as on forecasts of independent demand items
  - Coordinate materials ordering across multiple points in an organization's logistics network
  - Most suitable for batch, intermittent assembly, or project processes

Shortcomings of MRP based approaches include the following

- Computer intensive and making changes is sometimes difficult once the system is in operation
- Both ordering and transportation costs might rise as an organization reduces inventory levels and possibly moves toward a more coordinated system of ordering product in smaller amounts to arrive when the organization needs it
- Are not usually as sensitive to short-term fluctuations in demand as are order point approaches

Distribution Requirements Planning

- Outbound logistics systems to help determine the appropriate level of inventory to be held to meet both cost and service objectives
- Determine replenishment schedules between an organization's manufacturing facilities and its distribution centers
- Is usually coupled with MRP systems in an attempt to manage the flow and timing of both inbound materials and outbound finished goods

Summary and evaluation of DRP

- DRP systems accomplish for outbound shipments what MRP accomplishes for inbound shipments

- Focal point for combining these two systems is the manufacturing facility where the optimum flow of material is critical

- The key to a successful DRP approach
  - Having accurate demand forecasts by stock keeping unit by distribution center
  - Consolidating this demand by stock keeping unit and incorporating lead times and safety stock requirements allows the manufacturing facility to determine the master production schedule
  - Once the MRP is determined, MRP can be used to coordinate the flow and timing of material into the manufacturing facility so it can meet the desired shipments to the distribution centers
  - Combining MRP with DRP results in an approach that coordinates the flow of materials from raw materials suppliers through the manufacturing facility and on the distribution centers to meet the shipment demands of customers

References

- Coyle J.J., Langley C.J. Jr., Novack R.A., Gibson, B.J. (2013). Managing Supply Chains A Logistics Approach. 9th edition. South-Western, Cengage Learning.