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CERTIFIED IN PLANNING
AND INVENTORY MANAGEMENT

MODULE 6: INVENTORY

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Module 6 Overview

Inventory

- Section A: Inventory Planning
- Section B: Inventory and Product Costs, Value, and Metrics
- Section C: Itemized Inventory Management
- Section D: Inventory Control

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SECTION A:
INVENTORY PLANNING

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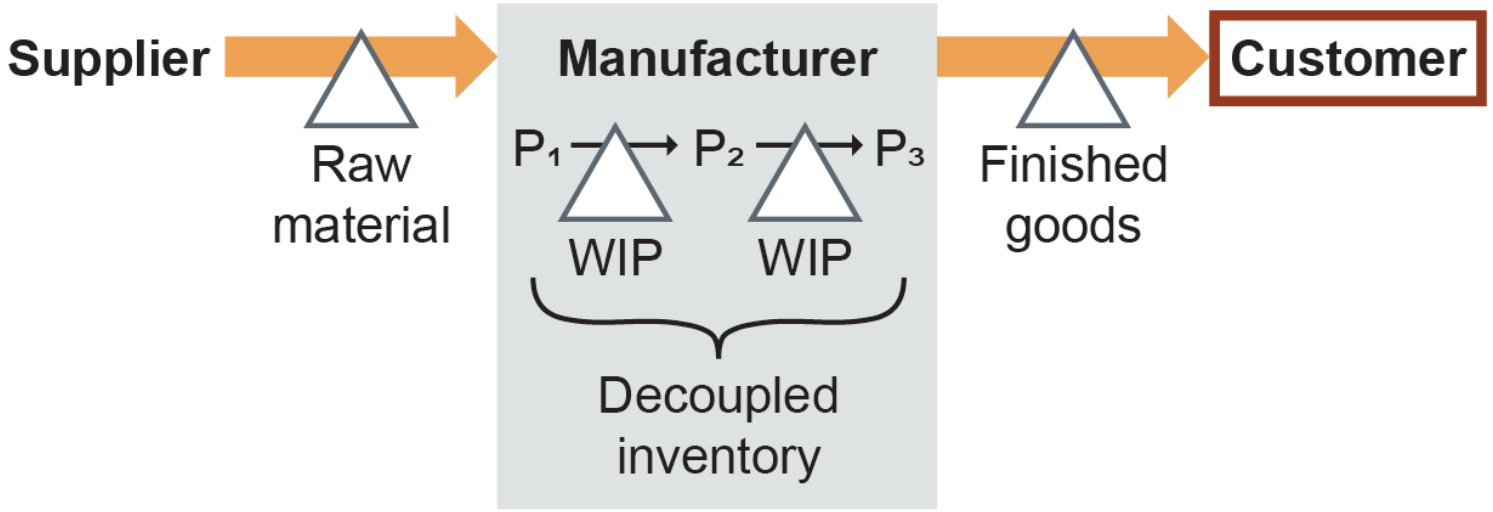
Section A Learning Objectives

- Purposes and goals of inventory
- Inventory types and classifications
- Functions of inventory (e.g., buffering supply and demand)
- How classifications can change over inventory life
- Inventory in service industries
- Aggregate versus itemized inventory policies
- Tradeoffs in inventory levels and accuracy targets
- ABC classification
- Item segmentation for special inventory

Purposes of Inventory Management



- **Better customer service**
- **Greater operating efficiency**
- **Longer production runs**
- **Volume purchases**
- **Optimal inventory investment**
- **Better sustainability**

Minimizing Inventory Investment

Total investment in inventory depends on perspective.

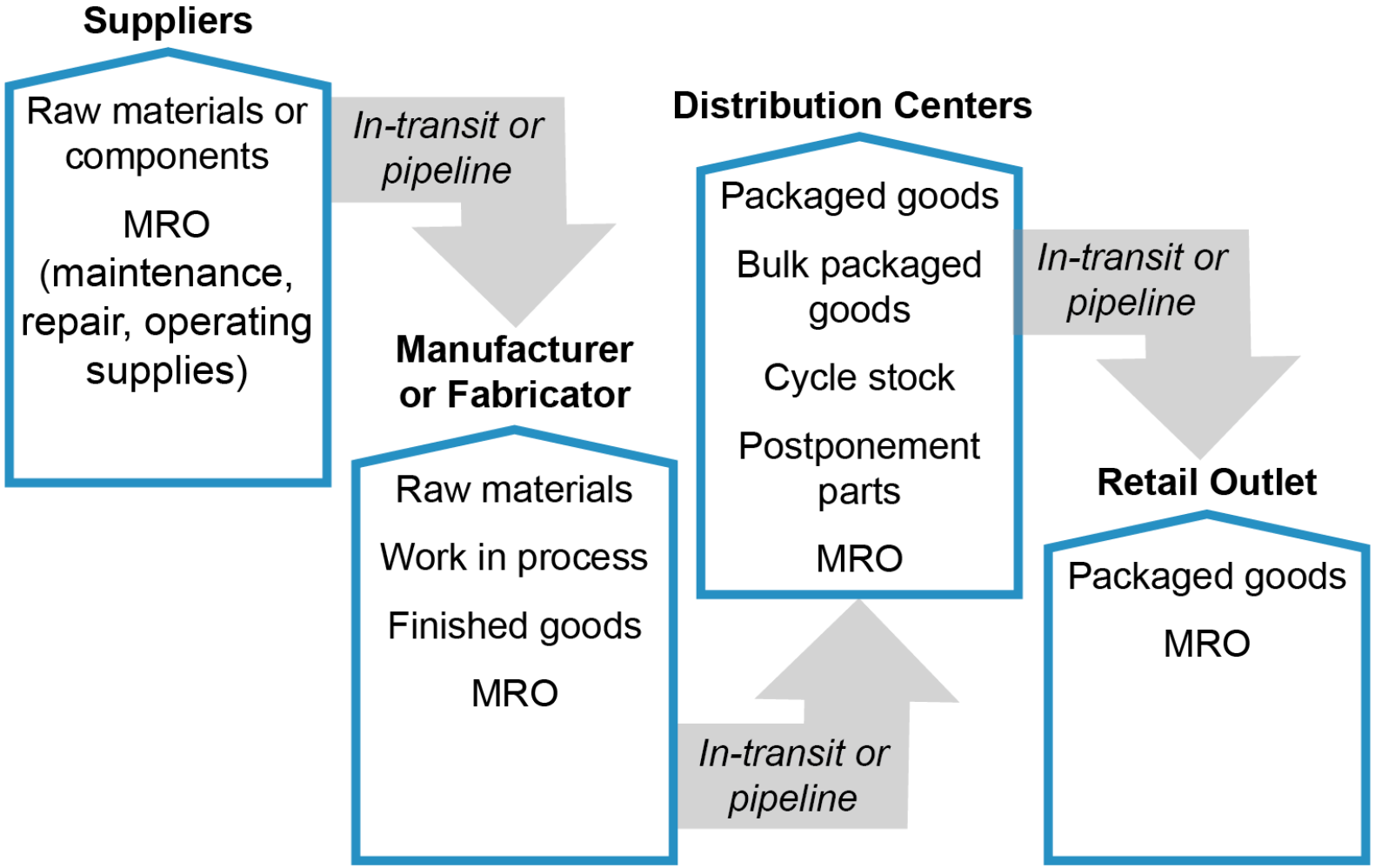
- Internal: Finance has incentive to push for low inventory levels. (Purchasing may or may not.)
- Entire organization: May minimize inventories at expense of others in supply chain.
  - If suppliers hold more, more smaller lots increase total.
- Supply chain and lean perspective: Minimize total inventory anywhere in supply chain; then sell more due to lower price. (Share savings.)

Purposes and Goals of Inventory

Maximizing Manufacturing Efficiency

- Smooth, uninterrupted flow; no over- or undercapacity.
- Decoupling supply from demand:
  - Supplier from customer
  - Work center from work center (diverse rates, spontaneous bottlenecks)
  - Capacity or materials available sooner than needed
- Other: Level strategy, long runs, few setups, large lots.
- Only good reason to hold inventory is when not carrying it would be more costly overall.

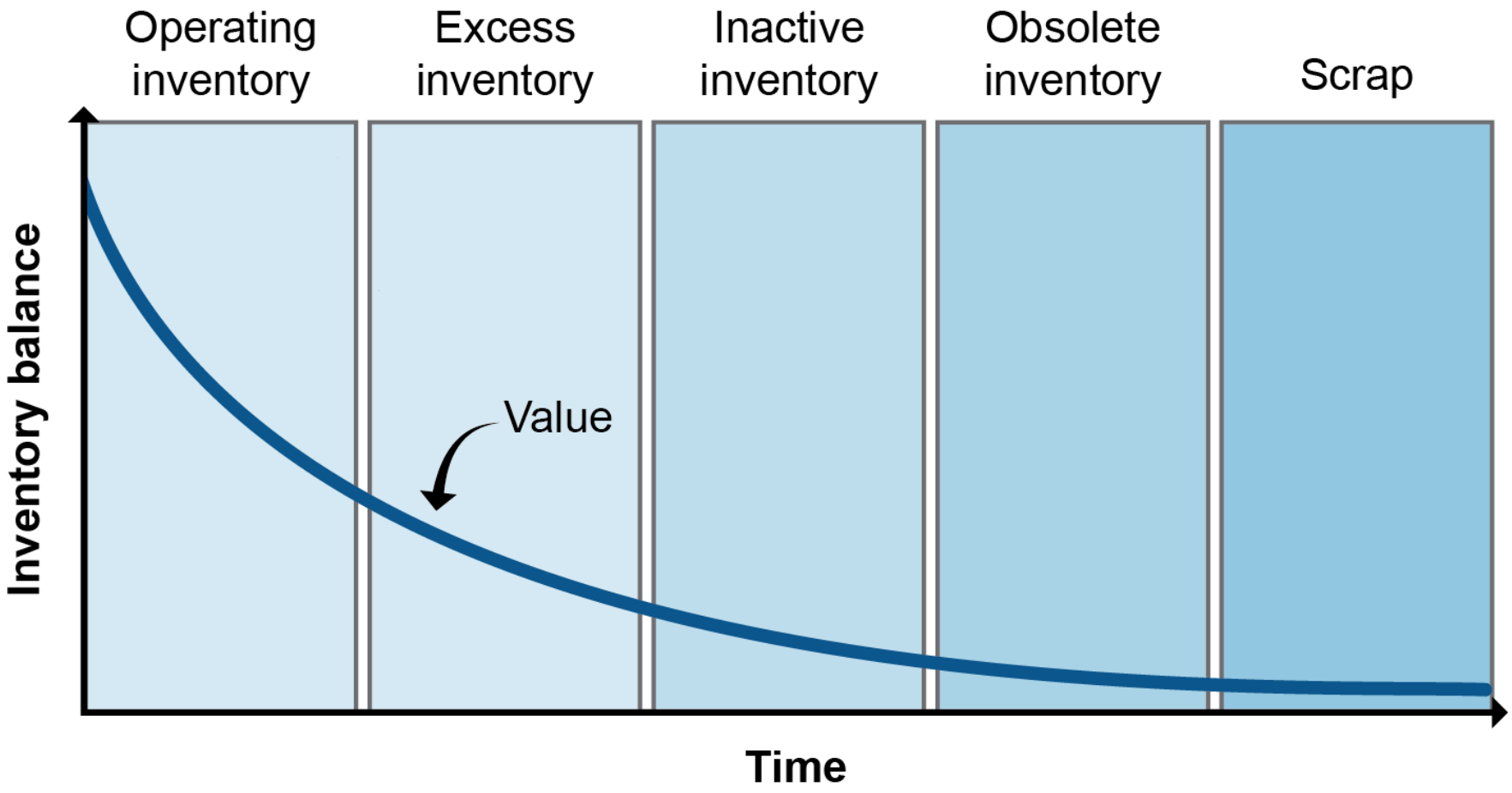
Inventory in the Supply Chain



Inventory Functions

- Safety stock
- Decoupling/buffers
  - Material/backlog
  - TOC material or time buffer
- Anticipation inventory
- Lot-size inventory (cycle stock)
- Transportation inventory
- Hedge inventory

Inventory Over Time

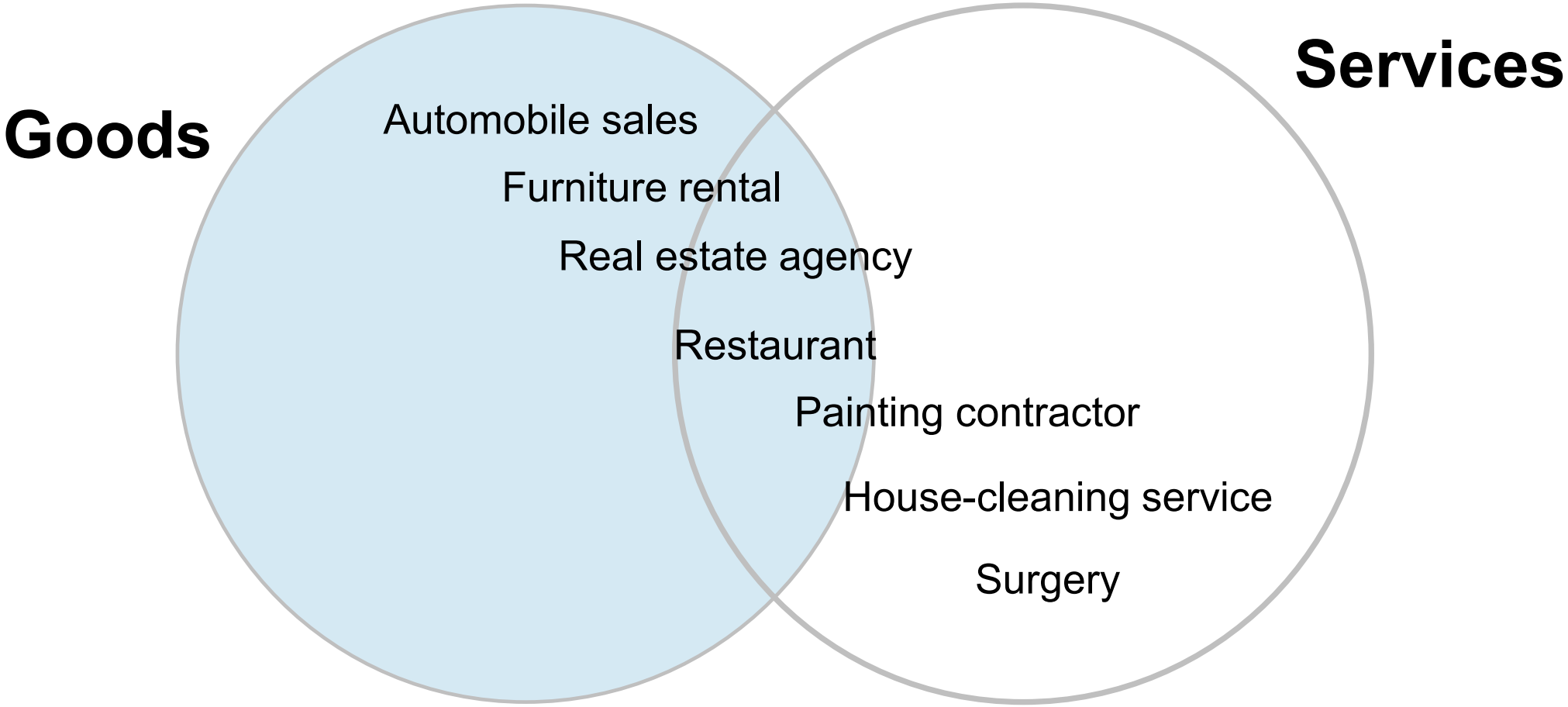


Inventory in the Service Industry

- Goods that facilitate delivery of service
- Subject to same challenges of excess inventory, insufficient inventory, perishability
- Major influence on how the service “product” is designed

Inventory Types and Classifications

Goods and Services Exercise



Negotiating Tradeoffs in Competing Views

	Marketing	Operations	Finance
Conventional objective	**Increase revenue and satisfy customers**	**Reduce manufacturing cost**	**Increase profit and cash flow, reduce investment**
Customer service	↑	↓	↑
Production efficiency	↓	↑	↑
Inventory investment	↑	↑	↓

Impact of Sourcing Risks on Inventory Planning

- STEEPLE risks: sociocultural (or social), technological, economic, environmental, political, legal/regulatory, and ethical.
- Sourcing risks cannot be offset entirely by inventory policies that create buffers, since inventory has inherent risks (e.g., theft, damage, obsolescence).
- Best practice is to prioritize safety stocks for critical inventory and develop resiliency in supply chain to manage residual risks.

ABC Inventory Control

Pareto's law (80–20) basis for ABC classification*

	Items	Value
A	10–20%	50–70%
B	20%	20%
C	60–70%	10–30%

- **A:** critical few. High security, tightly controlled safety stock, frequent counting.
- **B:** average. Average controls and ordering.
- **C:** trivial many. Order many few times a year, minimal control or counting.

Value (factors may affect individual ranking)

- Annual dollar usage (units × cost)
- Bottleneck materials
- Shelf life
- Replenishment lead time
- Importance of stockout to customers
- Turnover

*All percentages from *ASCM Supply Chain Dictionary* definition of ABC classification.

Possible Impacts of ABC Classification

- Frequency of counting
- Frequency of forecast reviews
- Reengineering of products
- Amount of safety stock or safety lead time
- Where an item is stored
- How it is controlled and replenished

ABC Inventory Control Steps (Annual Dollar Usage)

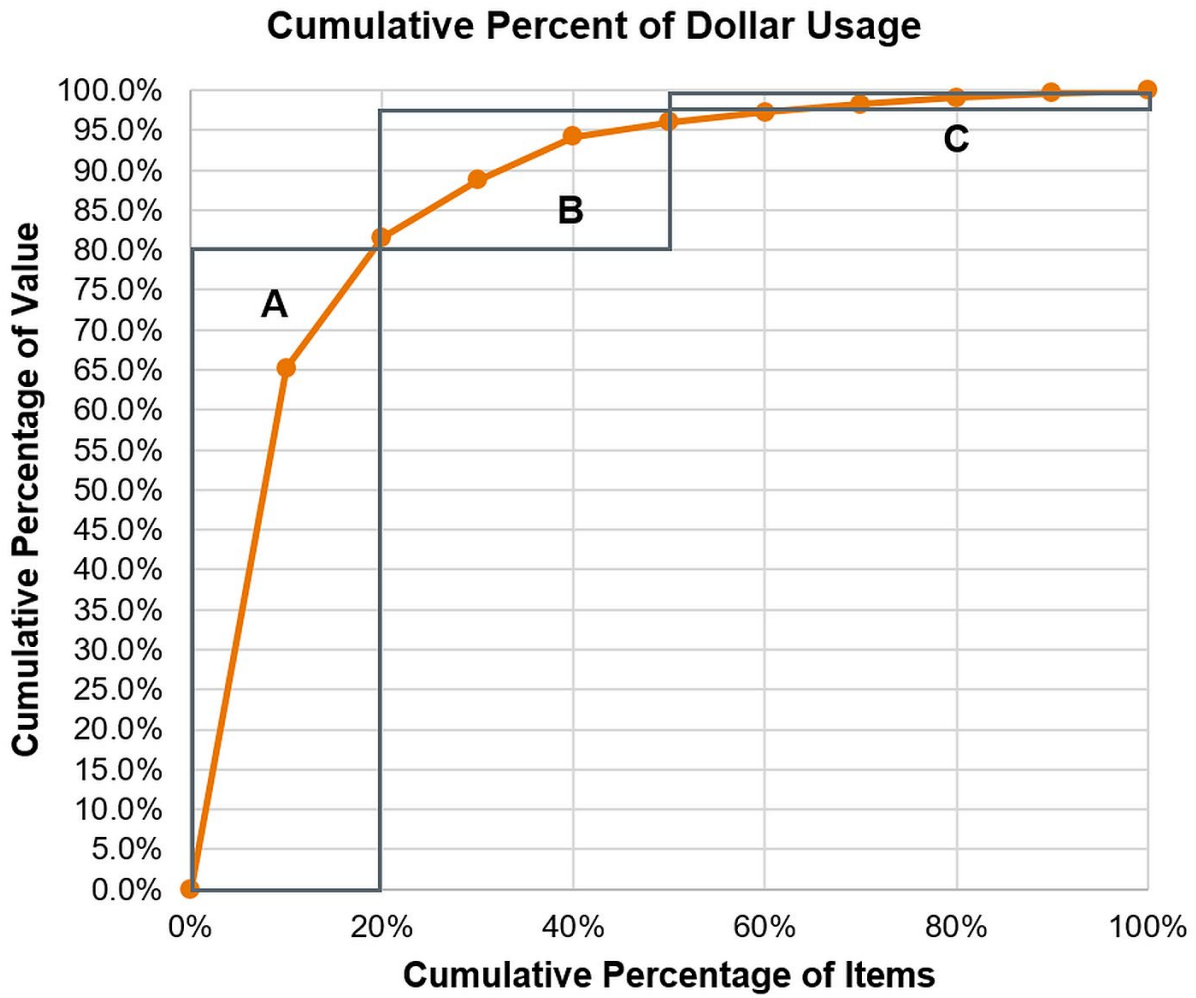
1. Multiply annual unit usage by unit cost to find annual dollar usage per product or product family.
2. Rank products by annual dollar usage (highest to lowest).
3. Calculate cumulative percentage of total items.
4. Calculate cumulative percentage of annual dollar usage.
5. Assign A, B, and C classifications based on step 4 (A: 50%–70% of value; B: 20%; C: 10%–30%*).

*All percentages from *ASCM Supply Chain Dictionary* definition of ABC classification.

ABC Inventory Ranked by Annual Dollar Usage

Part Number	Annual Dollar Usage	Cumulative Dollar Usage	Cumulative Percent of Total Items	Cumulative Percent of Dollar Usage	Class
			0%	0.0%	
232	$36,000	$36,000	10%	65.2%	A
332	9,000	45,000	20%	81.5%	A
343	4,000	49,000	30%	88.8%	B
665	3,000	52,000	40%	94.2%	B
443	1,000	53,000	50%	96.0%	B
875	700	53,700	60%	97.3%	C
218	500	54,200	70%	98.2%	C
989	500	54,700	80%	99.1%	C
783	300	55,000	90%	99.6%	C
163	200	$55,200	100%	100.0%	C
SUM	$55,200				

Cumulative Percent of Dollar Usage



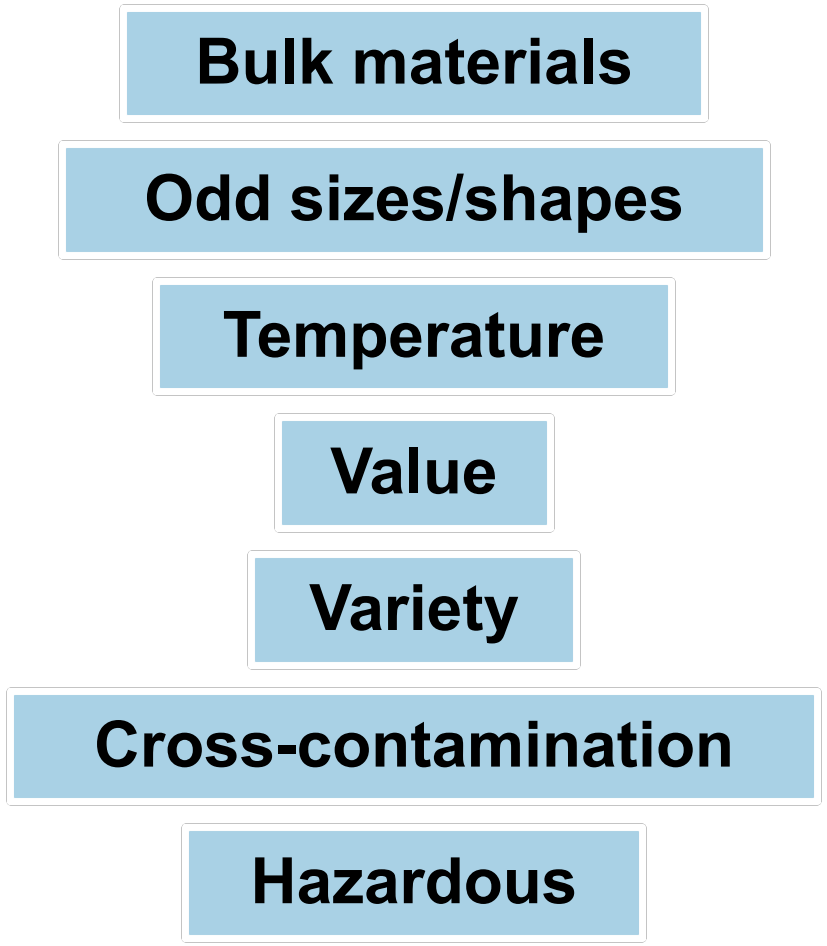
ABC Classification Exercise

Item number	Annual dollar usage
1	$13,189
2	156,127
3	344
4	8,493
5	42,749
6	5,589
7	19,562
8	241,873
9	1,962
10	10,112
Total	$500,000

ABC Classification Exercise

Item number	Annual dollar usage	Cumulative dollar usage	Cumulative percent dollar usage	Cumulative percent of items	Class
8	241,873	241,873	48.37	10	A
2	156,127	398,000	79.60	20	A
5	42,749	440,749	88.15	30	B
7	19,562	460,311	92.06	40	B
1	13,189	473,500	94.70	50	B
10	10,112	483,612	96.72	60	C
4	8,493	492,105	98.42	70	C
6	5,589	497,694	99.54	80	C
9	1,962	499,656	99.93	90	C
3	344	500,000	100.00	100	C
	500,000				

Inventory That Requires Special Handling



Characteristics of inventory may create unique risks that must be managed through transportation, warehousing, and inventory policy.

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SECTION B:
INVENTORY AND PRODUCT COSTS, VALUE, AND METRICS

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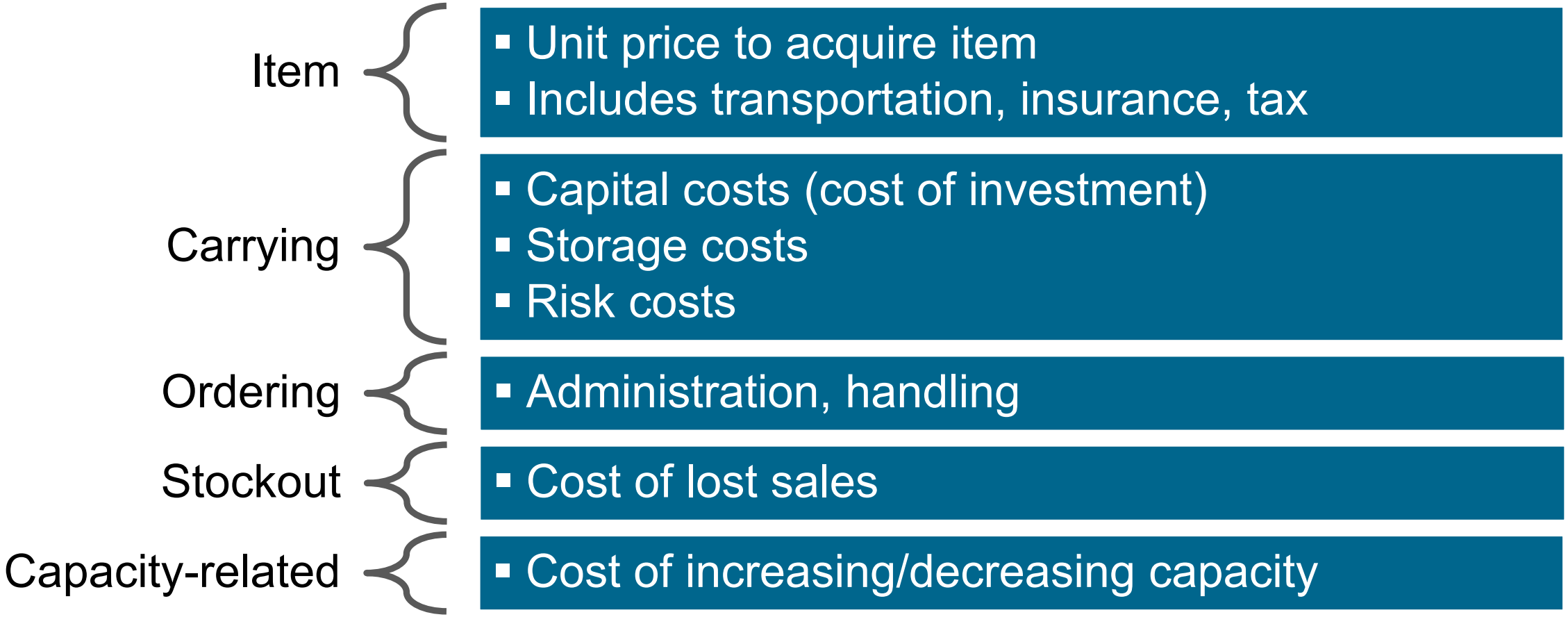
Section B Learning Objectives

- Categories/interactions of inventory costs
- Risk pooling
- Financial versus managerial accounting
- Basics of financial statements
- Inventory metrics
- Inventory valuation
- Standard or actual costs, transfer pricing
- Cost classifications
- Absorption and variable costing
- Product costing: throughput, variable, full absorption, and life cycle
- Job-order, process, and operation costing
- Activity-based costing
- Measuring variances
- Non-value-added activities

Types of Inventory Costs and their Interactions



Calculating Carrying Costs

Capital costs

- Financing cost
- Opportunity cost

Storage costs

- Space
- Personnel
- Equipment

Risk costs

- Obsolescence
- Damage
- Pilferage
- Insurance
- Deterioration

Example:

- Capital costs 9%
- Storage costs 8%
- Risk costs 7%
- Carrying cost rate 24%
- Average inventory $3 million annually

Carrying cost = 0.24 × $3 million = $720,000 per year

Carrying Cost = Carrying Cost Rate × Average Inventory Level in Dollars

Calculating Ordering Costs

- Purchasing cycle costs (managing and expediting)
  - Cost of each PO or each release against contract
- Factory costs
  - Production control
  - Setup (includes teardown)
  - Lost capacity

Example:

- $200k in annual wages
- $80k in operating expenses
- 4,000 orders per year
- $100 setup per order

$$\text{Average Ordering Cost per Order} = \frac{\text{Fixed Cost}}{\text{Number of Orders}} + \text{Variable Cost}$$

$$= \frac{\$200{,}000 + \$80{,}000}{4{,}000 \text{ orders}} + \$100 \text{ per order}$$

$$= \$170 \text{ per order}$$

Tradeoff Calculation

	Quarter 1	Quarter 2	Quarter 3	Quarter 4
Sales forecast	2,000	3,000	4,000	3,000
Production	3,000	3,000	3,000	3,000
Ending inventory	1,000	1,000	0	0
Average inventory	500	1,000	500	0
Inventory cost	$1,500	$3,000	$1,500	$0
Total cost of carrying inventory = $6,000				

Annual Cost Calculations

These are the annual costs and order numbers for an import warehouse:

- Wages for purchasing: $80,000; purchasing expenses: $70,000; customs brokerage: $45 per order
- Estimated cost of inventory financing: 10 percent; storage costs: 7 percent; risk costs: 10 percent
- Average inventory: $500,000
- Orders placed in a year: 10,000

What are the annual ordering costs, carrying costs, and average ordering cost?

Annual ordering cost	=	$80,000 + $70,000 + ($45 × 10,000) = $600,000
Annual carrying cost	=	0.27 × $500,000 = $135,000
Total annual cost	=	$600,000 + $135,000 = $735,000
Average ordering cost	=	$600,000 ÷ 10,000 = $60 per order

Risk Pooling

Aggregates demand and centralizes inventory, reducing effect of variability in demand and lowering stockout and carrying costs.

However, risk pooling works best when

- Demand patterns are similar among markets.
- Customer lead time remains acceptable.
- Net effect of inbound and outbound transportation costs is lower.

Financial vs. Managerial Accounting

Financial accounting

- For external audiences
  - Shareholders
  - Creditors
  - Tax authorities
  - Regulators
- Must be GAAP-/IFRS-compliant
- Content, format, and timing all defined

Managerial accounting

- For internal audiences (managers)
- Not necessarily GAAP- or IFRS-compliant
- Can omit some things to aid decision making
- More timely
- More varied in focus and scope

Balance Sheet

- Assets = Liabilities + Owners' Equity; Owners' Equity = Assets − Liabilities
- Example (assets: $5,000, liabilities: $3,000):
  - Owners' equity = $2,000 (If initial investment was $1,000, firm value went up.)
  - Pay $1,000 dividend: Assets go down by $1,000 (cash, an asset) and owners' equity goes down by $1,000.
  - Still in balance: Assets are $4,000, liabilities are $3,000, and owners' equity is $1,000.
- Inventory is often large percentage of assets, but more assets require more liabilities or owner investment.

Balance Sheet for Two Years

Assets =
Liabilities + Owners' Equity

Average Inventory = $\frac{\$59.9 + \$60.4}{2}$

BALANCE SHEETS December 31,	In Millions (000,000) Year 2	 Year 1
Assets		
Current Assets		
Cash and Cash Equivalents	$96.5	$56.3
Inventory	59.9	60.4
Accounts Receivable	48.4	44.3
Total Current Assets	**204.9**	**161.1**
Fixed Assets		
Gross Property, Plant, and Equipment	70.0	60.0
Less: Accumulated Depreciation	12.1	7.5
Net Property, Plant, and Equipment	57.9	52.5
Total Assets	**$262.8**	**$213.6**
Liabilities		
Current Liabilities		
Accounts Payable	20.0	19.6
Short-Term Notes Payable	7.5	6.0
Total Current Liabilities	27.5	25.6
Long Term Liabilities		
Long-Term Debt	60.0	60.0
Total Liabilities	**87.5**	**85.6**
Owners' Equity		
Common Stock (Par Value)	11.0	10.0
Additional Paid-In Capital	66.0	54.0
Retained Earnings	98.3	64.0
Total Owners' Equity	175.3	128.0
Total Liabilities and Owners' Equity	**$262.8**	**$213.6**

Income Statement

- Income = Revenue − Expenses
- Deductions occur in stages:
  - Revenue − COGS = Gross Profit
  - Gross Profit − Operating Expenses − Depreciation − Interest Expense = Net Income Before Taxes
  - Net Income Before Taxes − Taxes = Profit (Loss)
- Raw materials and WIP made into finished goods and sold are in COGS as an expense that reduces profit.
- Unsold inventory is asset on balance sheet (ties up cash) but is not revenue or expense yet.

Income Statement for Two Years

INCOME STATEMENTS	(000,000s) except per share amts.	
For the Years Ending	Year 2	Year 1
Revenue (Sales)	**$302.6**	**$276.9**
Direct Labor	38.3	37.6
Direct Materials	101.5	99.7
Factory Overhead	26.6	26.1
Less: Cost of Goods Sold (COGS)	166.4	163.4
Gross Profit	**136.2**	**113.5**
Less: Operating Expenses		
Selling Expenses	30.3	24.9
General and Administrative	27.2	22.2
Lease Expense	12.1	8.3
Less: Total Operating Expenses	69.6	55.4
Less: Depreciation	4.6	4.0
Less: Interest Expense	3.9	3.9
Net Income (Profit) Before Taxes	**58.1**	**50.3**
Less: Income Taxes	16.3	14.1
Net Income (Profit)	**$41.8**	**$36.2**
Net Income (as a Pct. of Revenue)	14%	13%
Net Income Per Share-Basic	**$3.95**	**$3.78**

"The bottom line"

Net Income Exercise

Revenue		$1,500,000
Cost of goods sold		
Direct labor	$300,000	
Direct material	$500,000	
Overhead	$400,000	
Total cost of goods sold		$1,200,000
Gross margin (gross profit)		$300,000
General and administrative expenses		$150,000
Net income (profit)		$150,000

Basic Accounting and Inventory

Statement of Cash Flows for Two Years

CASH FLOW STATEMENTS Year	In Millions (000,000) Year 2	 Year 1
Operating Section		
After-Tax Net Income	$41.8	$36.2
Depreciation Add-Back	4.6	4.0
(Increase)/Decrease in Inventory	0.5	(8.6)
(Increase)/Decrease in Accounts Receivable	(4.1)	(4.1)
Increase/(Decrease) in Accounts Payable	0.4	1.8
Cash Flow from Operations	**43.2**	**29.3**
Investing Section		
Capex Spend (Capital Expenditures)	(10.0)	(10.0)
Cash Flow from Operations and Investment	**33.2**	**19.3**
Financing Section		
Additional Equity Capital	13.0	7.0
Less Dividends Paid	(7.5)	(5.0)
Increase/(Decrease) in Long-Term Debt	-	-
Increase/(Decrease) in Short-Term Notes	1.5	(1.5)
Cash Flow from Operations, Investments, and Financing	**40.2**	**19.8**
Beginning Cash Balance	56.3	36.5
Ending Cash Balance	**$96.5**	**$56.3**

Less cash

Average Inventory and Inventory Turnover

- Converting inventory quickly to sales is highly valued.
- Average inventory from balance sheet (two years).
- Cost of goods sold (COGS) from income statement.

$$\text{Average Inventory} = \frac{\text{Inventory at Period Start} + \text{Inventory at Period End}}{2}$$

$$= \frac{\$60{,}400{,}000 + \$59{,}900{,}000}{2} = \$60{,}150{,}000$$

$$\text{Inventory Turnover} = \frac{\text{Annual COGS}}{\text{Average Inventory in Dollars}}$$

$$= \frac{\$166{,}400{,}000}{\$60{,}150{,}000} = 2.77 \text{ Times}$$

Inventory Turnover Exercise

Annual cost of goods sold is $48 million, and the average inventory is $12 million. Calculate the following:

- Inventory turnover: $= \frac{\$48{,}000{,}000}{\$12{,}000{,}000} = 4$
- Average inventory if inventory turns are increased to 10 times per year: $= \frac{\$48{,}000{,}000}{10} = \$4{,}800{,}000$
- Reduction in inventory with this improvement: $= \$12{,}000{,}000 - \$4{,}800{,}000 = \$7{,}200{,}000$
- Annual savings if cost of carrying is 20% of average: $= 20\% \times \$7{,}200{,}000 = \$1{,}440{,}000$

Calculating Inventory Turnover

A snacks manufacturer lists a COGS of $15 million on its income statement on revenue of $90 million.

At the beginning of the year, inventory was valued at $2.5 million; at the year's end, it was $2 million.

What is the company's inventory turnover?

Answer:

$$\$15 \text{ million} / \frac{(\$2.5m + \$2m)}{2} = 6.67 \text{ turns}$$

Days of Supply

- How long units will last at average daily usage if nothing new is made.
- Policy may be set at certain number of days of supply:
  - This may be very few units for slow-selling inventory.
  - When to reorder: If 10 days' lead time, order 10 days of supply.
- Example: 2,000 units on hand, 200 units sold per day

$$\text{Days of Supply} = \frac{\text{Inventory on Hand}}{\text{Average Daily Usage}}$$

$$= \frac{\text{2,000 Units}}{\text{200 per Day}} = 10 \text{ Days}$$

FIFO, LIFO, Average Cost, and Specific Identification

	First In, First Out	Last In, First Out	Average Cost
To describe inventory movement (can mix methods)	Pick from oldest items first.	Pick from newest items first.	Can't pick average item; may account for bulk storage.
Accounting method (just one), prices rising . . .	COGS understated	Actual current COGS	Can't get actual cost from average.
. . . prices falling	COGS overstated		
Value of unsold inventory	Fairly current	Given inflation, can be grossly understated.	Halfway between FIFO and LIFO.
Specific identification tracks specific units purchased and their cost.			

Standard Cost Accounting

- Management decision tool or inventory valuing method.
- Standard hours, standard materials.
- Period end: differences from actual as variances.
- Accountants still must use LIFO, FIFO, average cost, or specific identification for financial statements.

Variances and Transfer Pricing

Variances

- Baseline: budget or standard cost
- Positive or negative variances
- Materiality
- Aggregate to study total variance
- High-value items = higher impact
- Standard costing: rate and volume

Transfer pricing

- Transfer inventory and related costs from one internal subsidiary to another.
- Cost, market price, or negotiated price. (Consider incentives each creates.)
- Tax authorities scrutinize (e.g., high-tax to low-tax country transfers), and there are numerous regulations.

Cost Classifications and Their Purpose

Cost Classification	Purpose
Manufacturing and non-manufacturing costs	External reporting
Direct and indirect costs	Product pricing and performance control
Product and period costs	External reporting
Variable and fixed costs	Analyzing cost behavior under different conditions
Differential, sunk, and opportunity costs	Analyzing investment alternatives
Costs of quality	Assessing value gained or lost through quality practices

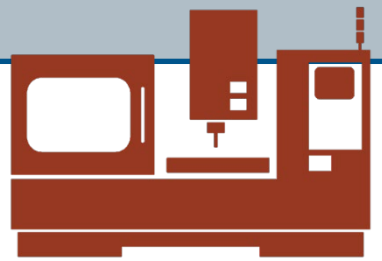
Manufacturing Costs

- Raw materials
- Components

Direct materials

- Labor assignable to creating a unit

Direct labor



- Indirect materials
- Indirect labor
- Maintenance and repair
- Utilities
- Property costs

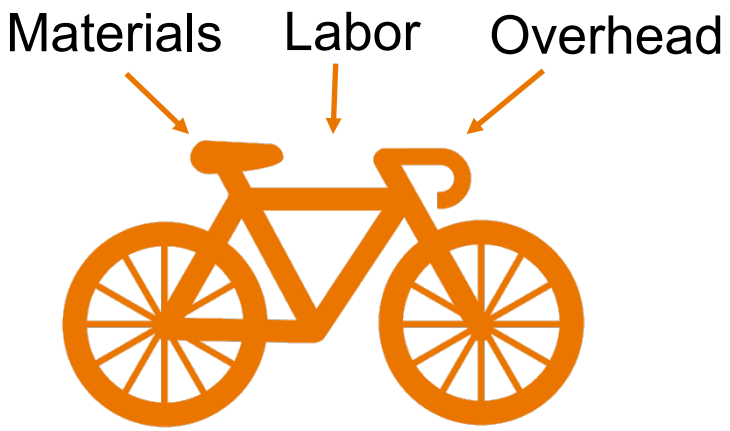
Overhead

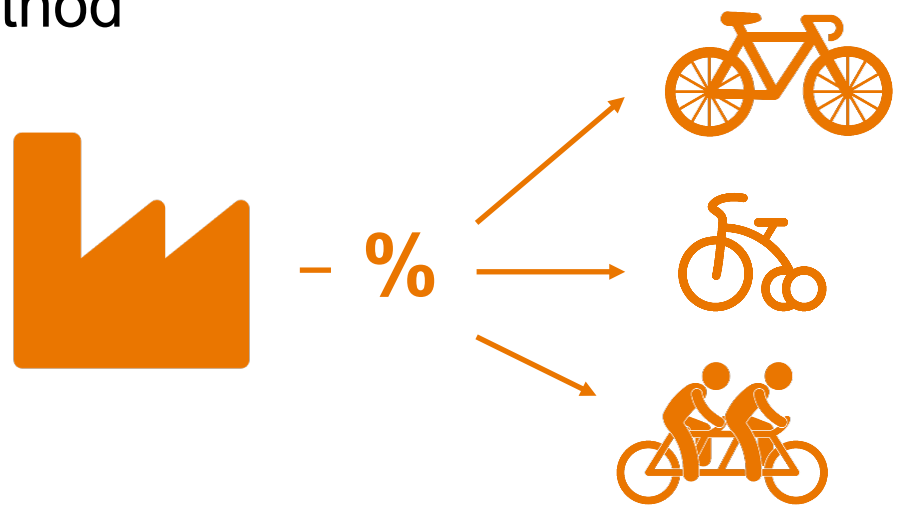
Non-Manufacturing Costs

- Marketing or selling costs
  - Advertising
  - Shipping
  - Selling expenses
  - Warehousing
- Administrative costs
  - Accounting
  - HR
  - Management

Direct and Indirect Costs

Direct costs	Indirect costs
Variable costs (materials and labor and some overhead) that can be attached to a particular job/operation	Overhead expenses that are allocated to units of goods by some standard method





When Recognized (Posted) on Income Statement?

Product costs	Period costs
▪ Recognized when item is sold. ▪ Before then, value of material is shown as inventory on balance sheet. ▪ Include direct materials and labor and assignable overhead.	▪ Expensed at time of purchase. ▪ Include selling and administrative expenses. ▪ Not included in COGS.

Variable and Fixed Costs

Variable cost	Fixed cost
Increases with number of items produced (e.g., direct materials consumed, sales commissions)	Does not vary with production volume (e.g., rent, property tax, some salaries)

1 bike = $500
2 bikes = $1,000
10 bikes = $5,000

Factory fire insurance monthly cost

Product Costing Methods

	Throughput costing	Variable costing	Full absorption costing	Life-cycle costing
Direct materials	●	●	●	●
Direct labor		●	●	●
Variable factory overhead		●	●	●
Fixed factory overhead			●	●
Non-factory costs (sales, administration, distribution)				●
R&D, design, customer service, disposal				●

Absorption and Variable Costing Approaches

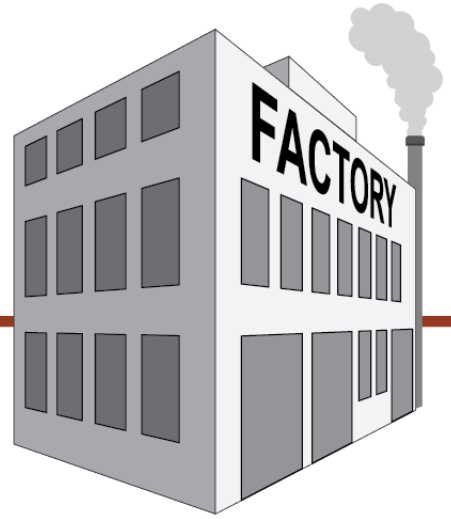
Absorption costing	Variable costing
▪ Variable costs + portion of fixed costs are assigned to each unit. ▪ Includes costs beyond a manager's control.	▪ Only variable costs are assigned, not overhead. ▪ Useful for internal planning because it isolates production costs under a manager's control.

How much does it cost to make product X?

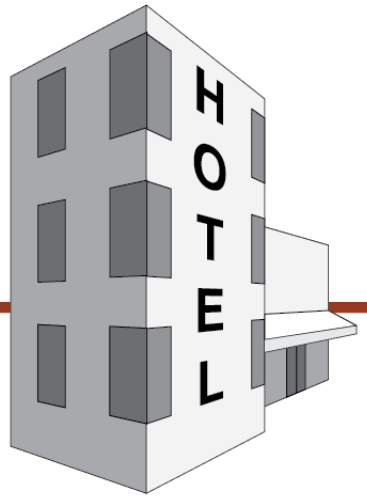
Job-Order, Process, and Operation Costing

Job-Order	Process	Operation
Direct costs assigned to particular job/order	Costs collected for time period and averaged	Costs assigned by runs, with variations
Indirect costs assigned with overhead rate	For continuous manufacturing	For batch manufacturing environments (has both job-order and process costing elements)

Activity-Based Cost Accounting



- Order volume
- Machine/labor hours
- Average scrap
- Non-revenue-producing activities (e.g., maintenance and repairs, inspections)

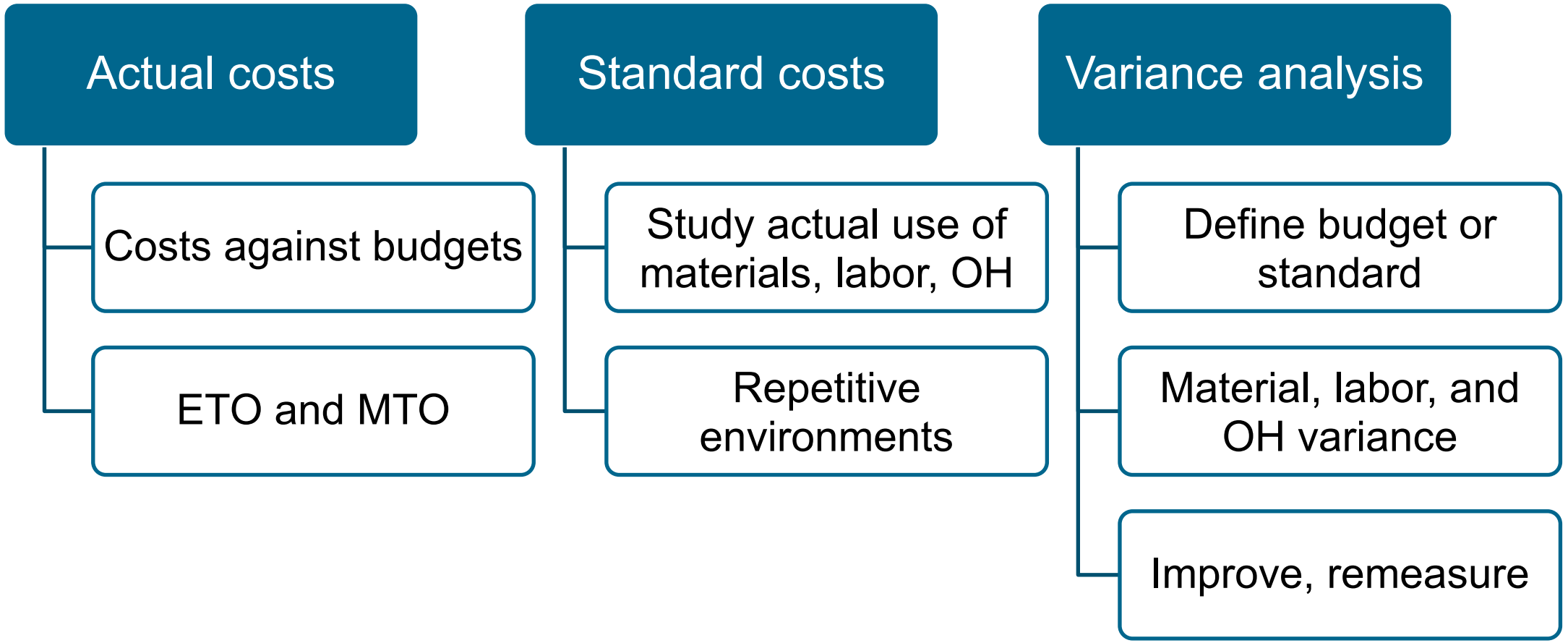


- Capacity utilization (e.g., number of occupied rooms)
- Service level (e.g., ratio of staff to guests)

What are the key cost drivers for an activity?

- Only costs associated with capacity used to produce a product are assigned to it.
- Does not include costs associated with excess capacity.

Identifying Variances in Cost



Forms of Waste

Waste	Description
Waste of **overproduction**	Making more components/finished goods than needed
Waste of **waiting**	Queuing delays
Waste of **transportation**	Excess or unneeded movement
Waste of **stocks**	Inventory not needed to fill orders; keeping of unnecessary raw materials, parts, work-in-process
Waste of **motion**	Wasted operator actions that add no value
Waste of **making defects**	Product or service not meeting specifications
Waste of **processing itself**	Unnecessary or inefficient steps in a process, doing more than customer requires
Waste of **people skills**	Waste of human potential, capabilities, knowledge

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SECTION C:
ITEMIZED INVENTORY MANAGEMENT

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Section C Learning Objectives

- When to order: item ordering policies (order point and periodic review)
- Order point triggers
- How much to order: economic order quantity (EOQ) constraints, modifiers, and uses
- Lot size techniques (fixed order quantity, lot for lot)
- Calculating safety stock
- Safety lead time
- Managing special inventory, including for remanufacturing industry

Push or Pull Replenishment

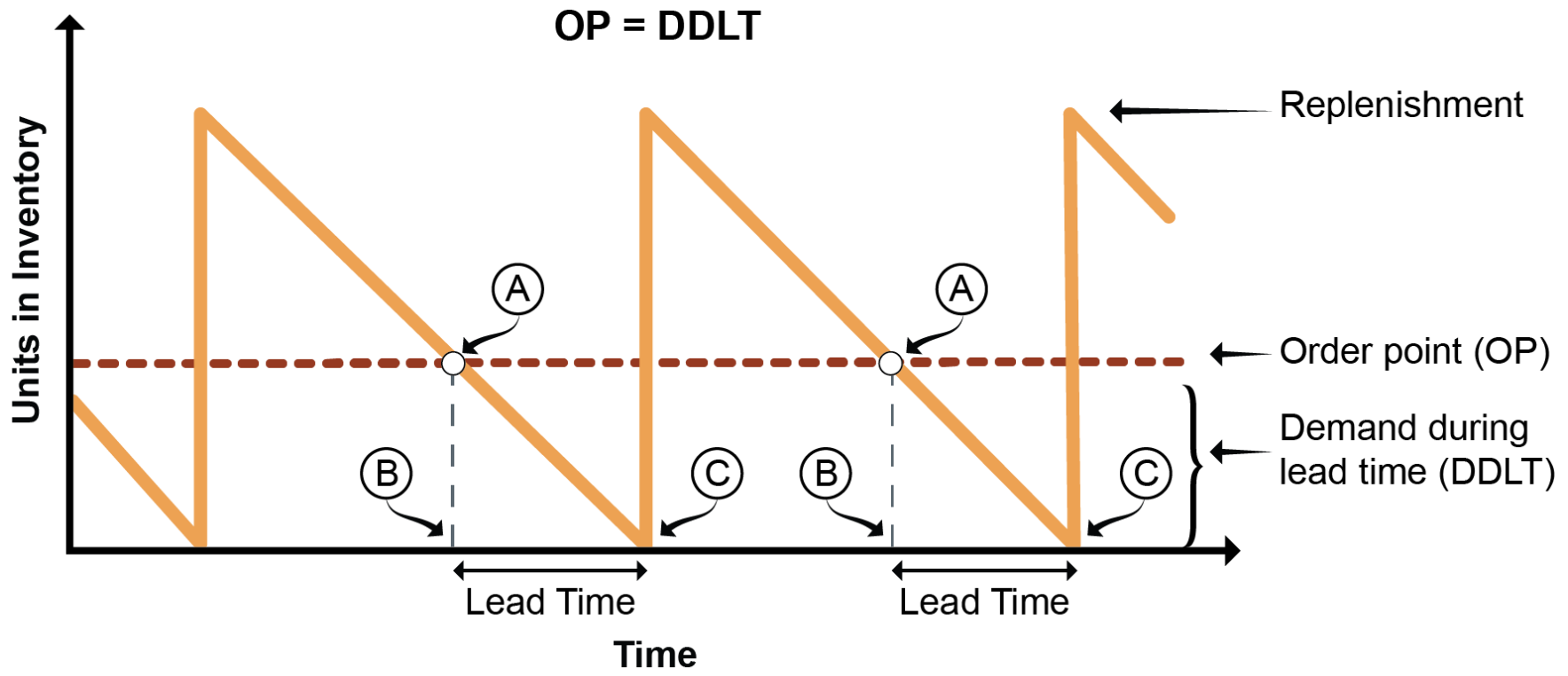
Push, Pull, and Push-Pull

Push	Pull
What/When to Make	
▪ Inventory on hand ▪ Make to forecast/DC orders	▪ Low or no inventory ▪ Make to specific orders
Issues	
▪ Bullwhip effect ▪ Obsolescence ▪ Poor customer service	▪ Demand variability ▪ Supply disruptions ▪ Long lead times
Who Orders and How	
▪ Central supply ordering ▪ Fair distribution ▪ Requires ownership or agreement	▪ Independent demand ordering ▪ Autonomy ▪ Shortages, but market pricing rations goods

Push-Pull Replenishment
▪ Schedule delivery (push) but DC sets quantity (pull), or ▪ EOQ/minimum (push) but DC sets timing (pull)

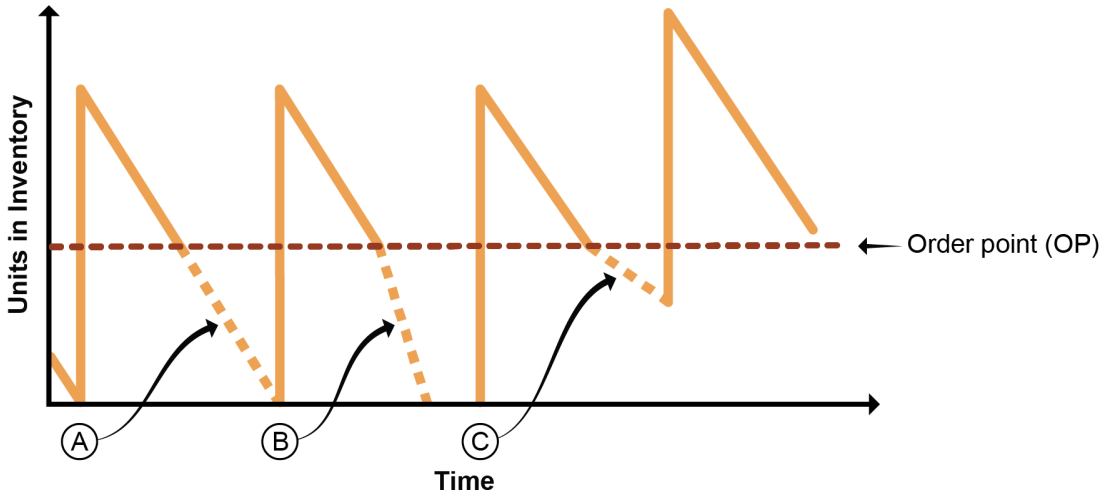
Push or Pull Replenishment

Order Point System

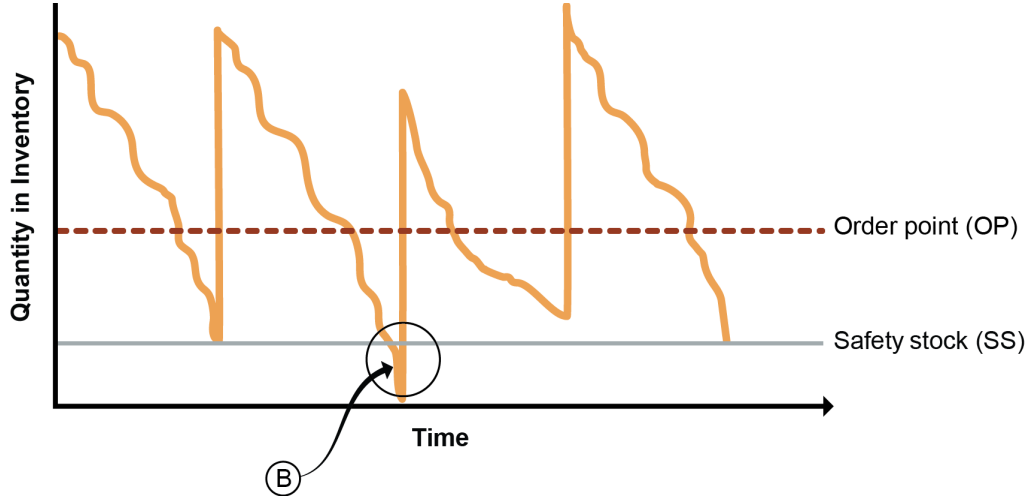


Push or Pull Replenishment

Effect of Uncertainty



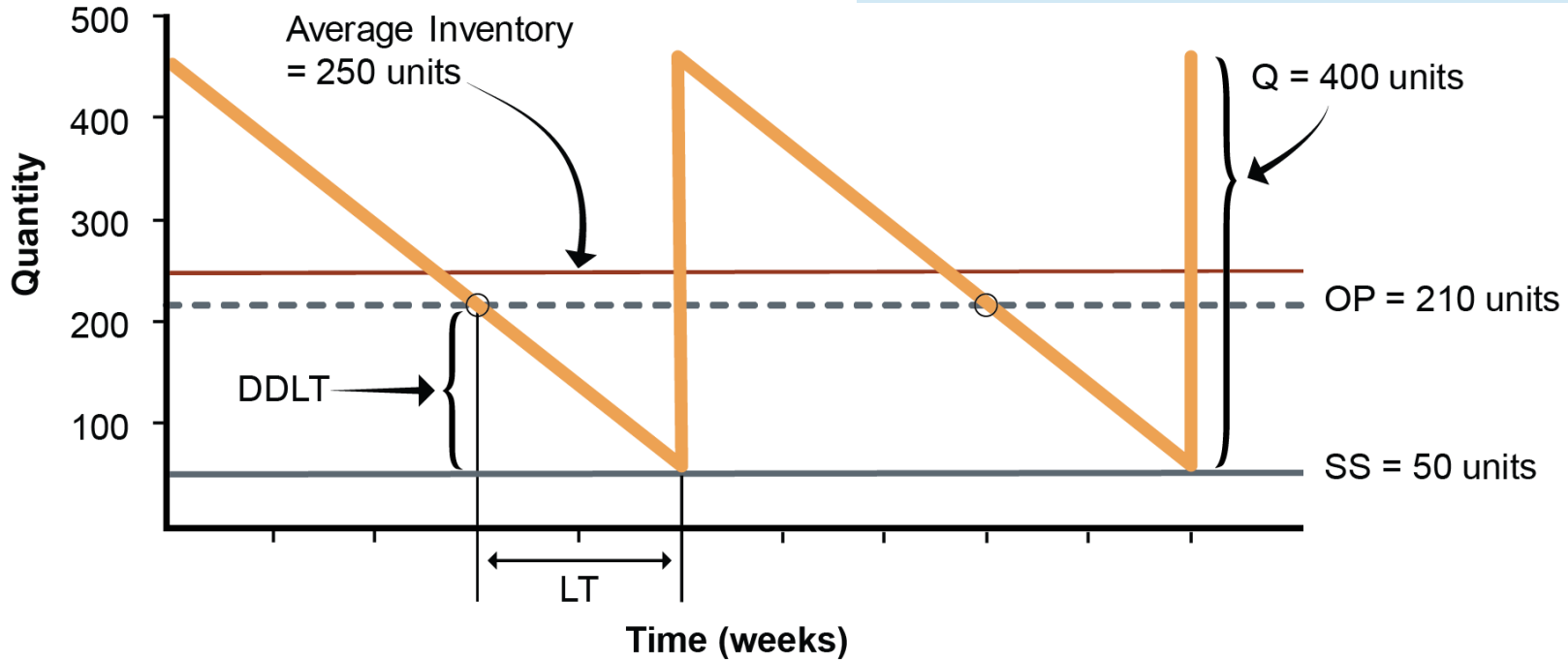
Safety stock is needed to address demand and resupply uncertainty.



Push or Pull Replenishment

Order Point Systems

Units per period = 80/week
LT = Lead time (2 weeks)
DDLT = Demand during lead time (80 x 2)
SS = Safety stock (50 units)
Q = Lot size quantity (400) units
OP = Order point = DDLT + SS = 210 units



Order Point Systems

Assumptions

- Demand relatively stable with random variation
- Order point sooner if demand above average, later if demand below average
- Fixed order quantities (possibly set using EOQ)

Demand During Lead Time = Units per Period × Lead Time

= 80 Units per Week × 2 Weeks = 160 Units

Order Point = Demand During Lead Time + Safety Stock

210 Units = 160 Units + 50 Units

When Order Point Is Reached: Perpetual Inventory

- Current transactions record (e.g., ERP)
- Record inaccurate? Shrinkage, errors

Scenario: Demand averages 80 units/week

– Allocated (to orders) reduces available but not on hand

Part: 682 Name: Hydraulic door closer, silver
Lead Time : 1 week Order Point: 210 Quantity: 400

Week	Ordered	Issued	Received	On Hand	Allocated	Available
0				350		350
1				350	70	280
2				350	80	200
3	400	70		280	90	110
4		80	400	600	85	425
5		90		510	75	350

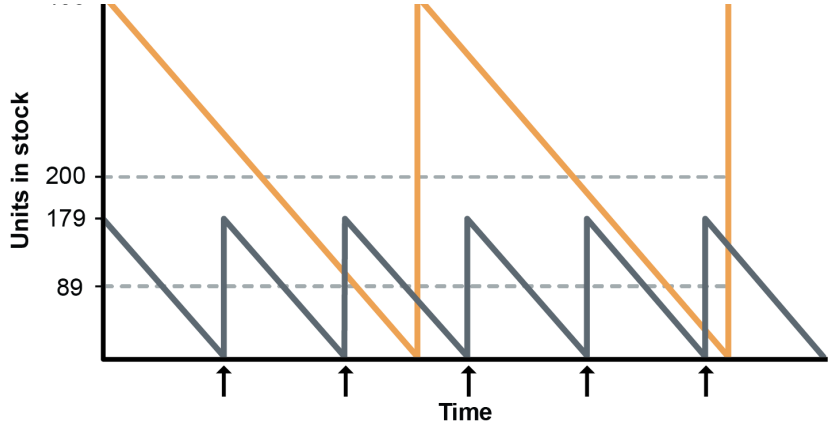
When Order Point Is Reached: Two-Bin, Kanban

Two-bin systems

- Fixed-order system
- Reorder when first bin empty
- On receipt, put excess in working bin
- Useful for C items

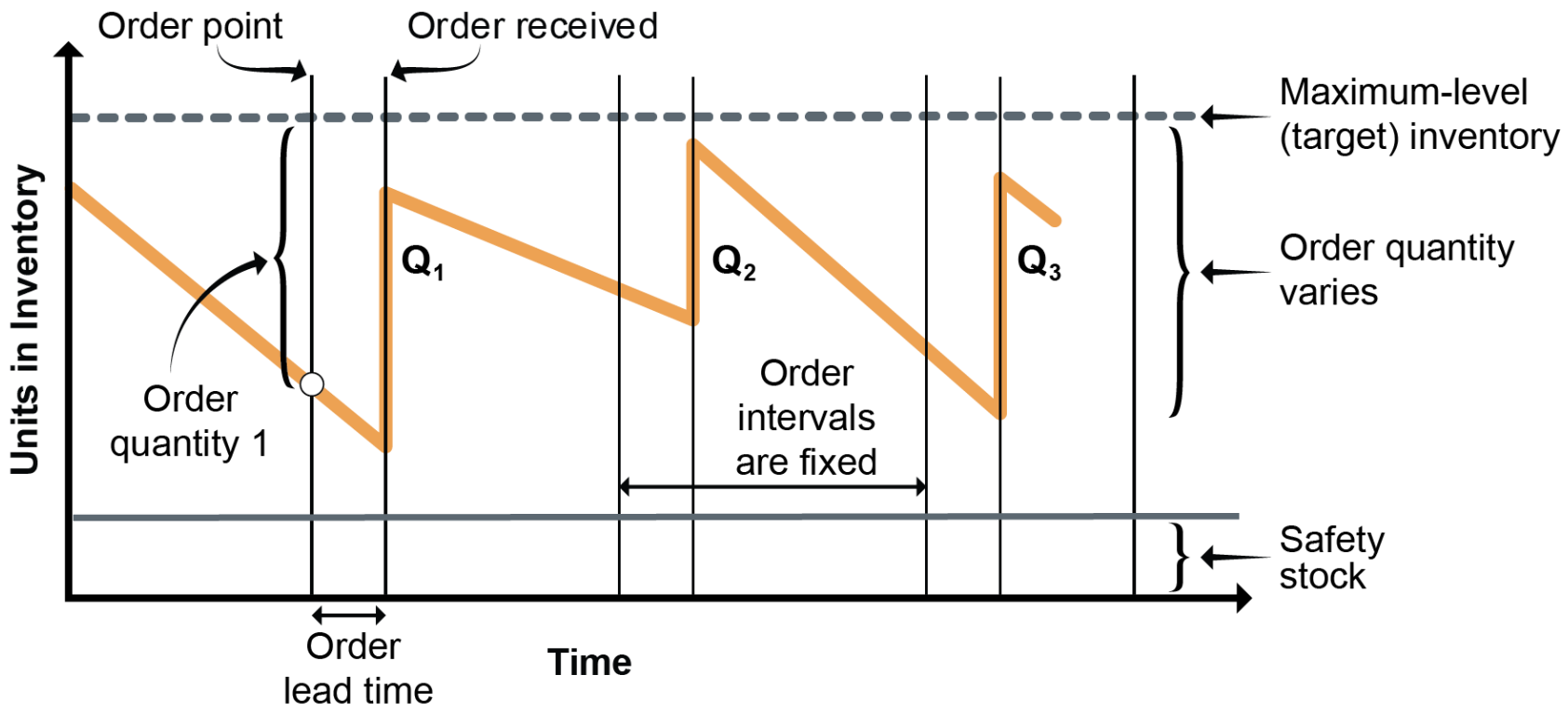
Kanban systems

- Visual signals
  - Card, light, empty container
- Visual demand-pull system so less record keeping
- Lower EOQ, more stockout risk



Push or Pull Replenishment

Periodic Review or Fixed Reorder Interval



Periodic Review Systems

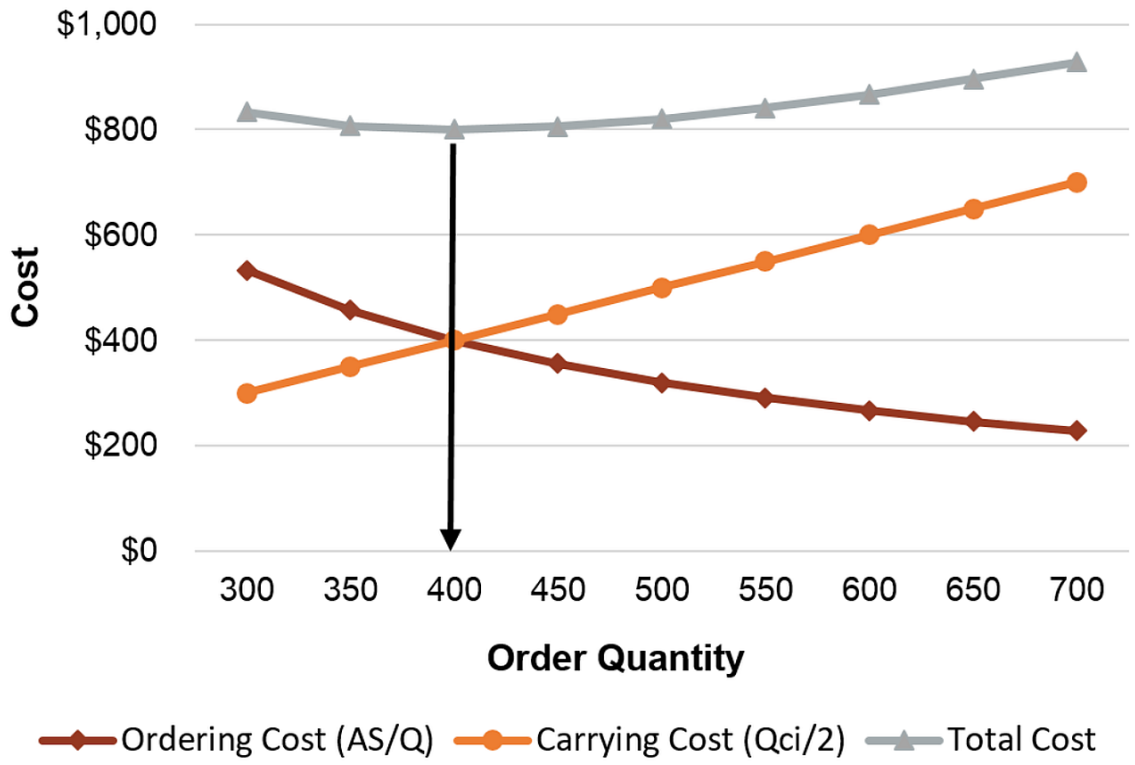
- Review periods and lead times are constant.
- Orders placed at start of review period.
- Order size based on demand during review period.
- Scenario: 50 units per day average demand (D), 100 units safety stock (SS), 7-day review period (R), 2-day lead time (L), 150 units on-hand inventory (I)

$$\text{Target Level (T)} = D \times (R + L) + SS$$

$$= 50 \text{ Units per Day} \times (7 \text{ Days} + 2 \text{ Days}) + 100 \text{ Units} = 550 \text{ Units}$$

$$\text{Order Quantity (Q)} = T - I = 550 \text{ Units} - 150 \text{ Units} = 400 \text{ Units}$$

Economic Order Quantity



A guiding concept built on simplifying assumptions

- Demand is known and constant.
- Lot and batch production.
- Inventory costs are known and constant.
- Replenishment all at once.

EOQ Process, Step 1 (Annual Ordering Cost)

Scenario: DC annual demand of 8,000 units, current lot size of 500, cost per order of $20

$$\text{Number of Orders} = \frac{\text{Annual Demand (A)}}{\text{Lot-Size Quantity (Q)}}$$

$$= \frac{8{,}000}{500} = 16 \text{ Orders per Year}$$

$$\text{Annual Ordering Cost} = \text{Number of Orders} \times \text{Cost per Order (S)}$$

$$= 16 \text{ Orders} \times \$20 \text{ per Order} = \$320$$

$$\text{Annual Ordering Cost} = \frac{A \times S}{Q} = \frac{8{,}000 \times \$20}{500} = \$320$$

EOQ Process, Steps 2 (Annual Carrying Cost) and 3 (Total Inventory)

Scenario: Cost/unit (c): $10, carrying cost rate (i): 20% or 0.2

$$\text{Average Inventory} = \frac{Q}{2} = \frac{500}{2} = 250 \text{ Units}$$

$$\text{Annual Carrying Cost} = \frac{Qci}{2}$$

$$= \frac{Q}{2} \times c \times i$$

Another way to show formula

$$= \frac{500}{2} \times \$10 \text{ per Unit} \times 0.2 = \$500$$

Total Inventory Cost = Annual Ordering Cost + Annual Carrying Cost

= $320 + $500 = $820

EOQ is when ordering cost = carrying cost (not there yet)

EOQ Process, Step 5: Find EOQ using Trial and Error or Formula

Only Q changes

Annual Demand (A)	Order Costs (S)	Order Quantity (Q)	Cost per Unit (c)	Carrying Cost Rate (i)	Ordering Cost (AS/Q)	Carrying Cost (Qci/2)	Total Cost
8,000	$20	300	$10	0.2	$533	$300	$833
8,000	$20	350	$10	0.2	$457	$350	$807
8,000	$20	400	$10	0.2	$400 =	$400	$800
8,000	$20	450	$10	0.2	$356	$450	$806
8,000	$20	500	$10	0.2	$320	$500	$820

Trial and error

Where

- EOQ replaces Q (quantity)
- Annual demand (A) = 8,000 units
- Order costs (S) = $20 per order
- Cost per unit (c) = $10 per unit
- Carrying cost rate (i) = 20% = 0.2

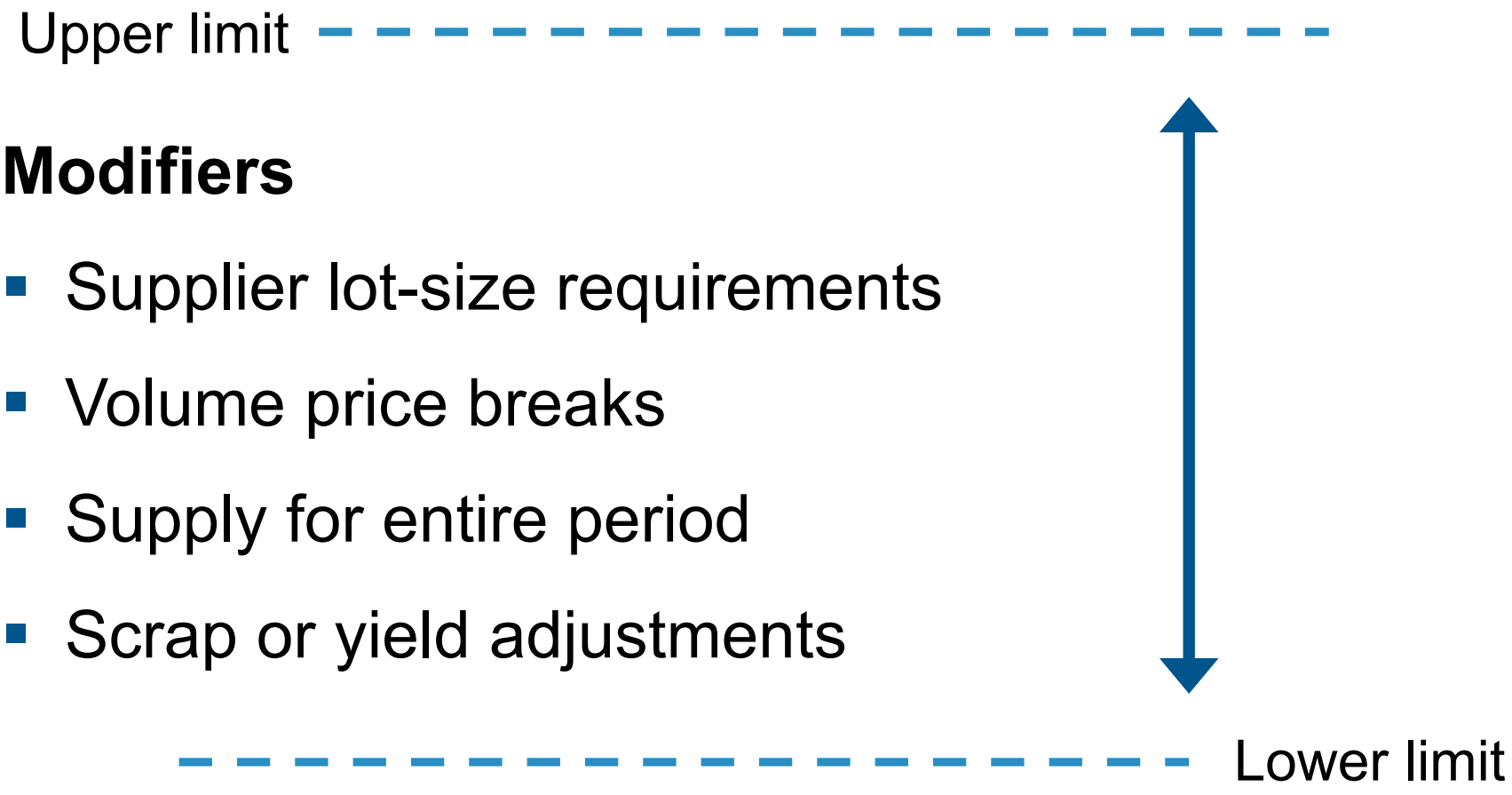
$$EOQ = \sqrt{\frac{2AS}{ci}}$$

Formula

$$= \sqrt{\frac{2 \times 8{,}000 \text{ Units} \times \$20 \text{ per Order}}{0.2 \times \$10 \text{ per Unit}}}$$

= 400 Units

EOQ Constraints and Their Modifiers



Using Continuous Improvement to Change EOQ

- Reduce costs: shift curves and where they intersect.
- Partly controllable (not all by manufacturing).
  - Annual demand (market forces, marketing)
  - Unit cost (purchasing or manufacturing, but takes time)
  - Carrying cost (market rates, risks, warehouse costs)
- Shorter time horizon: reduce annual ordering cost.
  - Fewer or faster setups
  - More contract buying (fewer POs)
  - Automate purchasing cycle

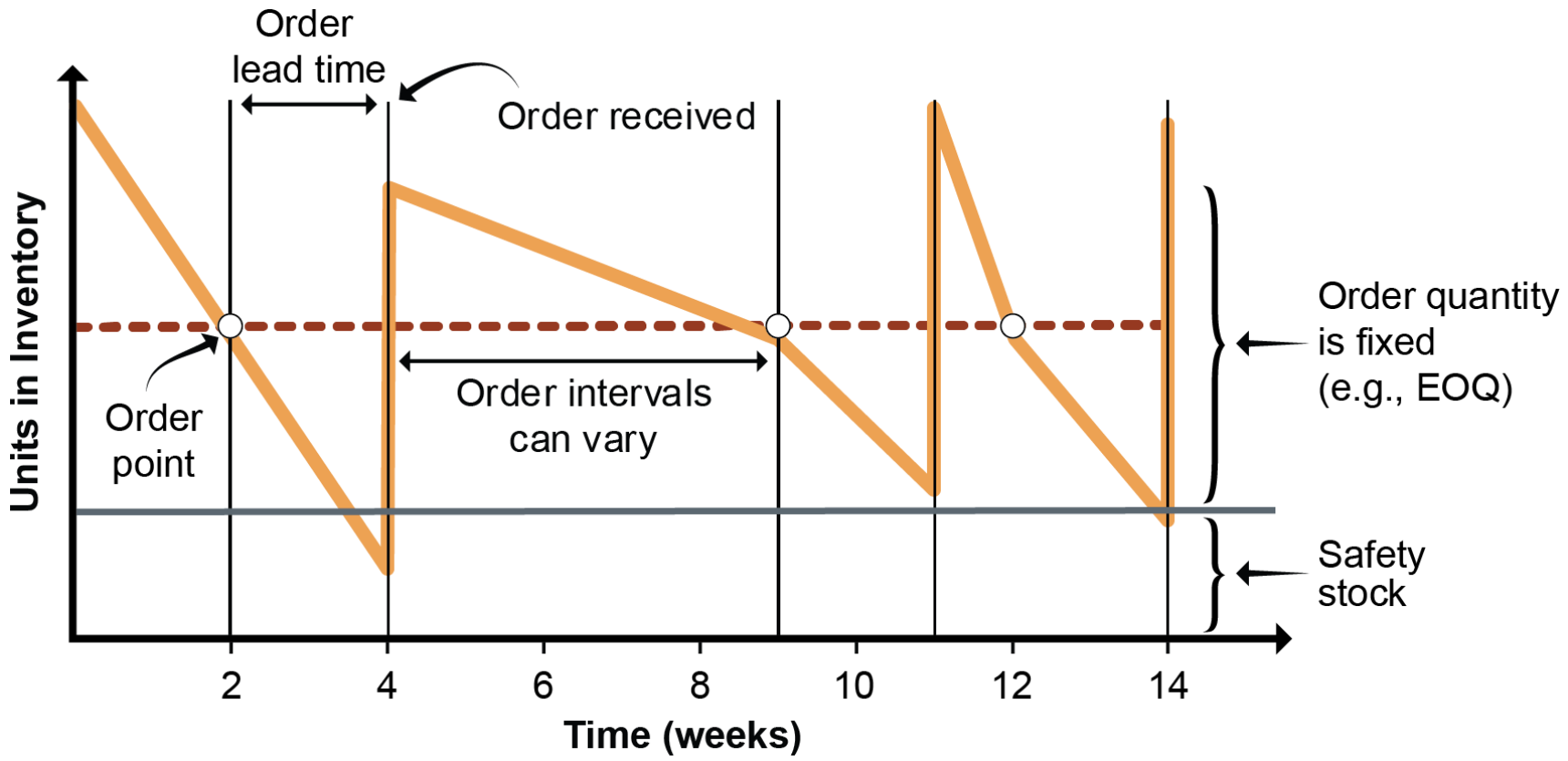
Economic Order Quantity and Lot-Size Rules

Lot for Lot (L4L)

- Order quantity is directly related to demand. There is no unused lot-size inventory.
- Used to
  - Plan and fulfill time-phased requirements for dependent and independent demand items
  - Control investments in expensive, infrequently used, and/or perishable inventory
  - Control waste in lean environments.

Economic Order Quantity and Lot-Size Rules

Fixed Order Quantity (FOQ)



Order *n* Periods

- Planners order enough inventory to meet needs for a specific number—*n*—of periods.
- The most cost-effective number of periods is the period order quantity.

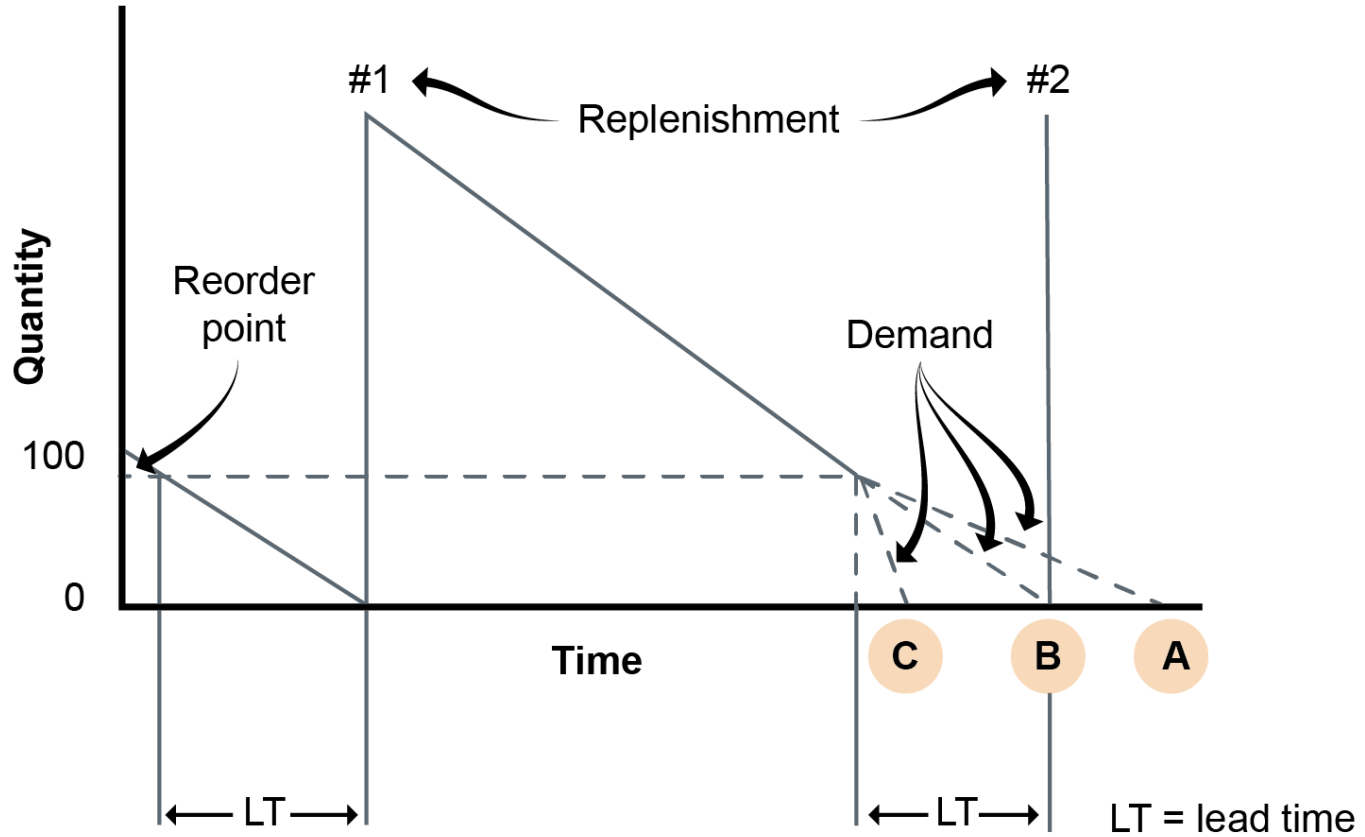
$$\text{Period Order Quantity} = \frac{\text{EOQ}}{\text{Average Weekly Usage}}$$

Lot-Size Techniques Exercise

Technique	Efficient response to discrete period demand	Impact on inventory investment
Lot-for-lot	High	Low
POQ	Medium	Medium
Order *n*	Medium	Medium
EOQ	Low	High
FOQ	Low	High

Safety Stock and Safety Lead Time

Safety Stock Function



Point A: Zero inventory level is not reached before replenishment occurs; no stockout.

Point B: Zero inventory level is reached at replenishment; no stockout.

Point C: Zero inventory level is reached before replenishment; stockout.

Safety Stock and Safety Lead Time

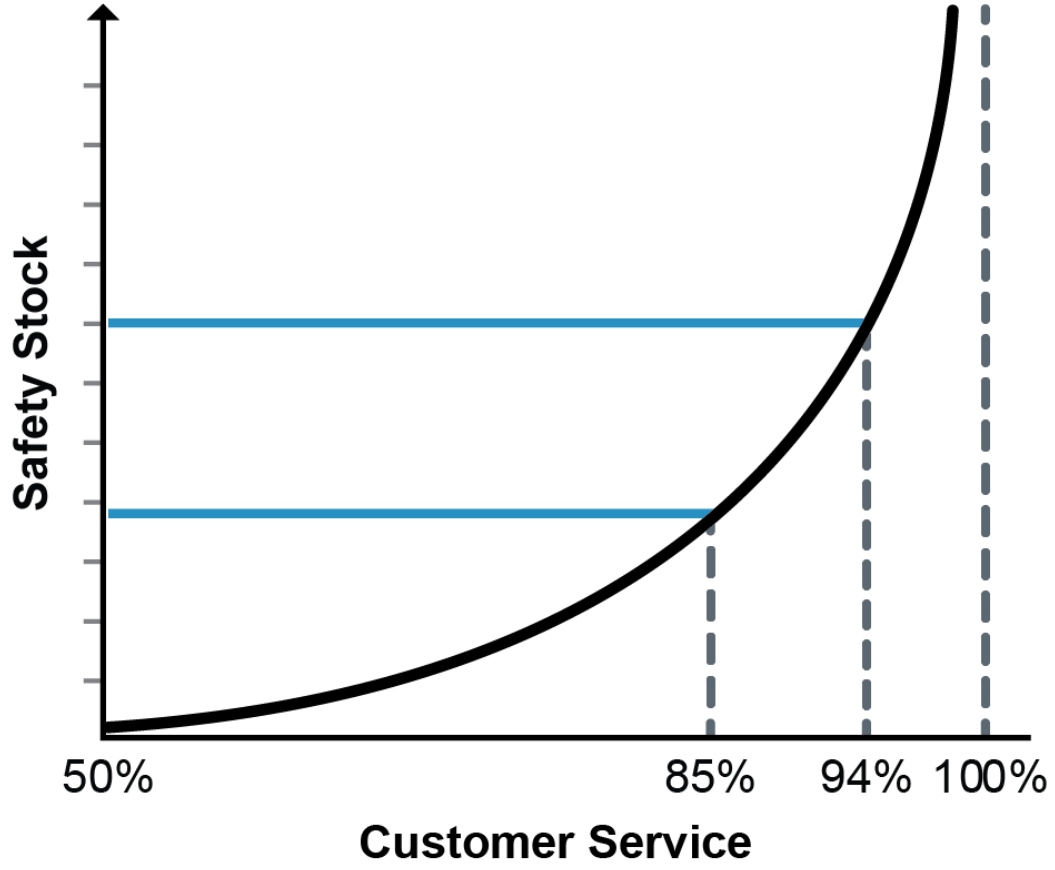
Factors for Determining Safety Stock

- Targeted customer service level
- Importance to customer
- Demand variability during lead time
- Forecast error
- Order frequency
- Duration of lead time

Safety Stock and Safety Lead Time

Establishing Appropriate Customer Service Levels

- Level of service (customer service ratio or number of allowed stockouts per period)
  - For example, 95% service level is 5% stockout percentage.
- Safety stock is one way to improve customer service.



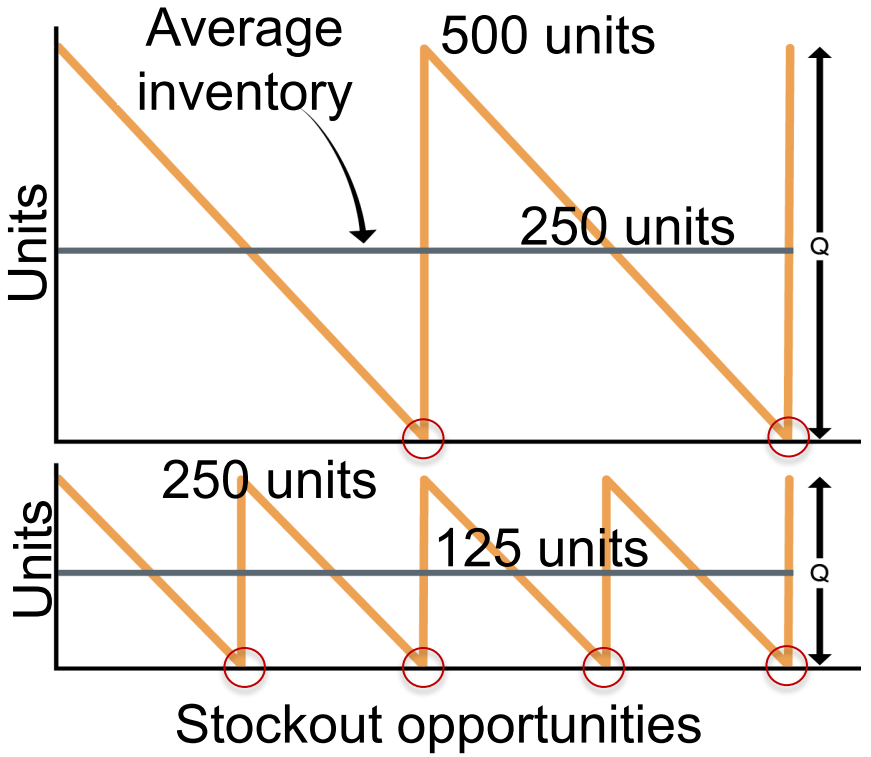
Safety Stock Based on Acceptable Stockouts/Period

$$\text{Orders per Period} = \frac{\text{Period Demand}}{\text{Order Quantity}}$$

$$= \frac{8{,}000}{400} = 20 \text{ Orders per Year}$$

$$\text{Customer Service Level} = \frac{\text{Orders per Period} - \text{Stockouts}}{\text{Orders per Period}}$$

$$= \frac{20 - 2}{20} = 0.9 = 90\%$$



Customer Service Level	Safety Factor Table	
	With SD or RMSE	With MAD
90.00	1.28	1.60
95.00	1.65	2.06

Safety Stock at 90% =

28 Units × 1.60 = 45 Units

Calculating Safety Stock

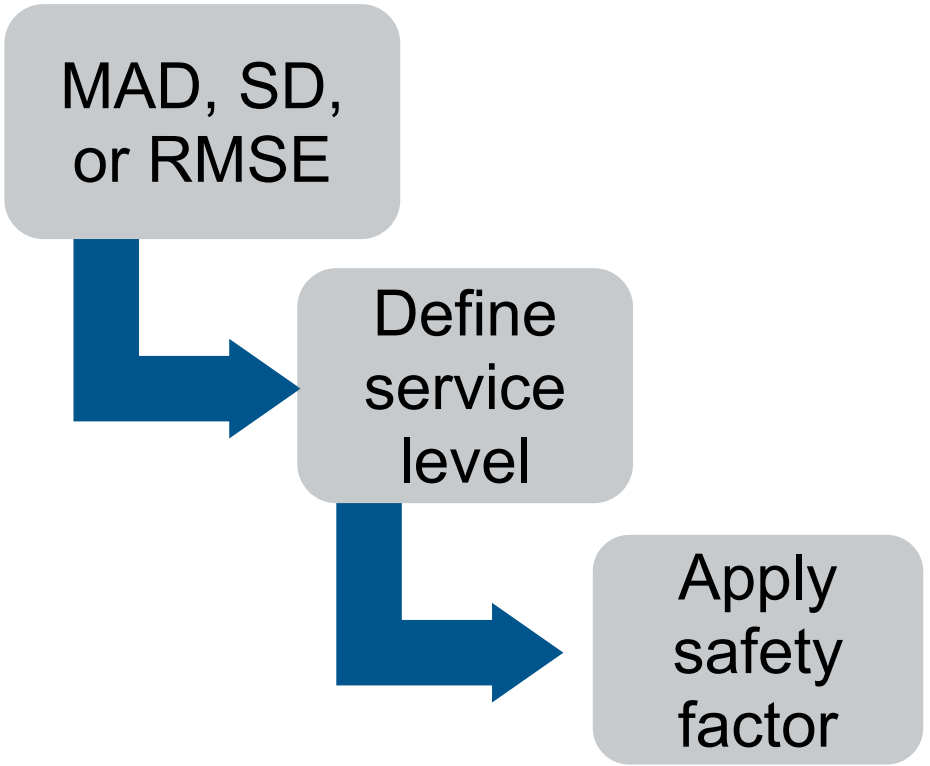
Overview of methods

Statistical

Time period

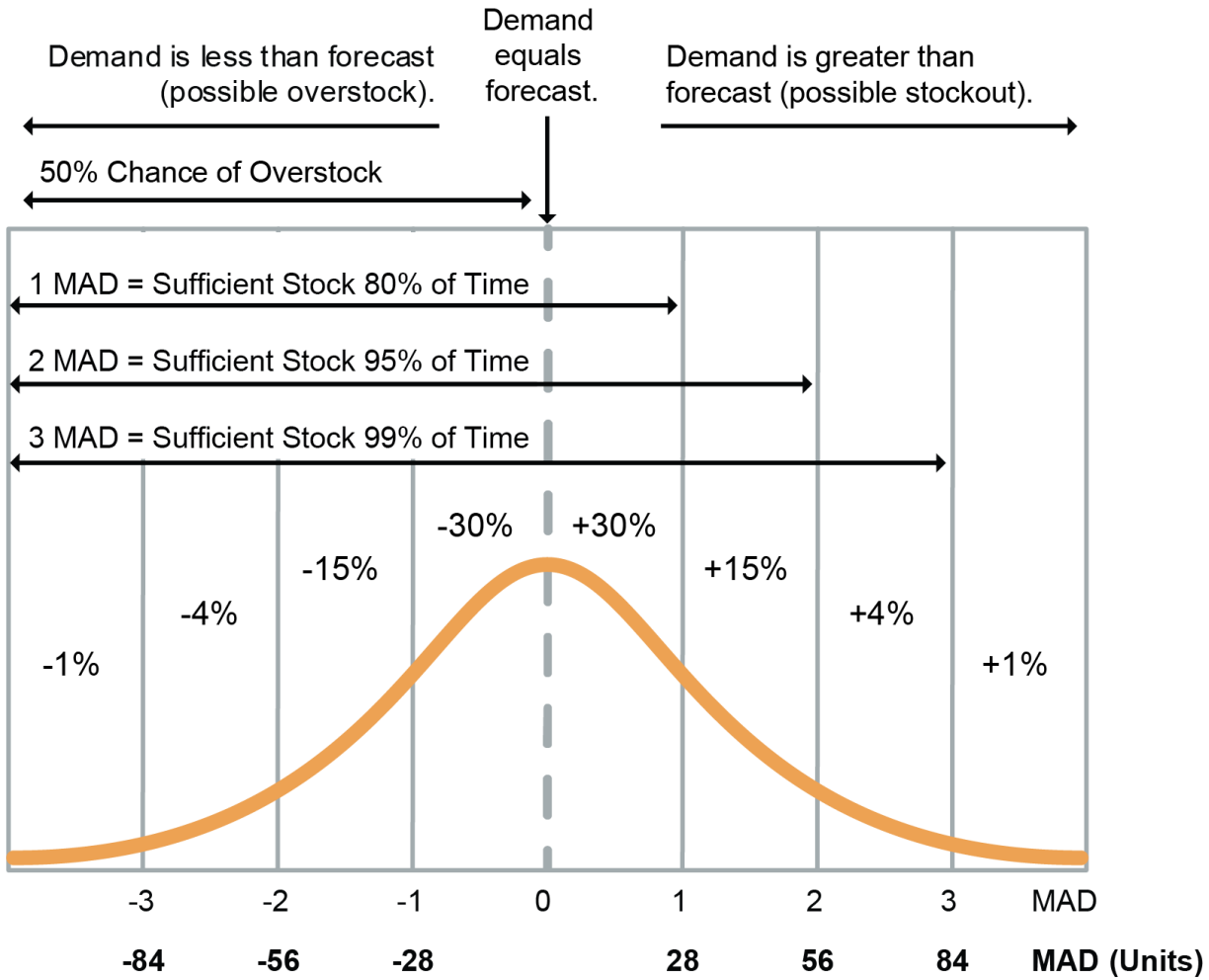
Fixed order

Statistical methods

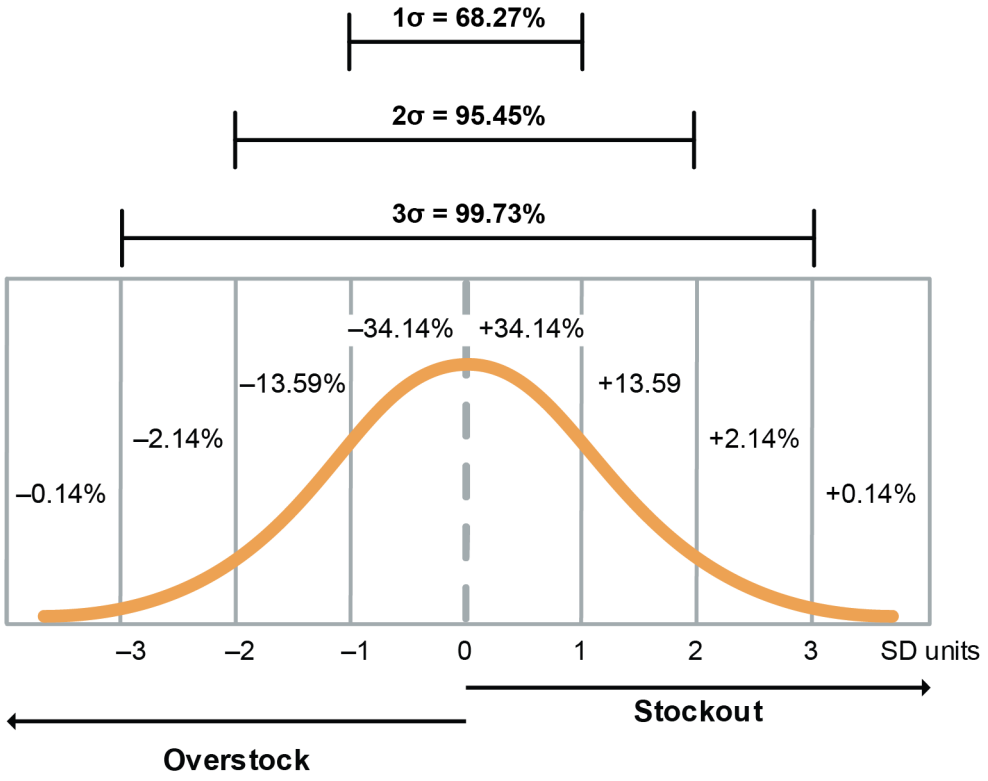


Safety Stock and Safety Lead Time

Mean Absolute Deviation



Standard Deviations (σ) in a Normal Distribution



Given 50% probability of overstock:

- 1 SD: Sufficient stock 84.14% of time
- 2 SD: Sufficient stock 97.73% of time
- 3 SD: Sufficient stock 99.87% of time

Calculate Standard Deviation

- Sum and average demand for *n* periods.
- Subtract average from actual demand and square.
- Sum squared deviations and divide by *n* – 1.
- Calculate square root.

Week	Actual	Average (Sum of Actuals/10)	Actual – Average	(Actual – Average) Squared
1	1,100	1,076	24	576
2	950	1,076	-126	15,876
3	1,150	1,076	74	5,476
4	1,400	1,076	324	104,976
5	1,000	1,076	-76	5,776
6	900	1,076	-176	30,976
7	920	1,076	-156	24,336
8	1,300	1,076	224	50,176
9	990	1,076	-86	7,396
10	1,050	1,076	-26	676
Sum	10,760			246,240
Sum of (Actual – Average)^2 / *n* – *1*				27,360
Standard deviation (square root of prior sum)				165

Calculate Root Mean Squared Error

- Calculate error (Actual – Forecast).
- Square results.
- Sum squared errors and divide by *n* – 1.
- Calculate square root.

Week	Actual	Forecast	Actual – Forecast	(Actual – Forecast) Squared
1	1,100	1,050	50	2,500
2	950	1,000	-50	2,500
3	1,150	1,200	-50	2,500
4	1,400	1,320	80	6,400
5	1,000	1,025	-25	625
6	900	975	-75	5,625
7	920	900	20	400
8	1,300	1,125	175	30,625
9	990	1,000	-10	100
10	1,050	1,050	0	0
SUM	10,760	10,645		51,275
Average (SUM/*n* – *1*)				5,697
RMSE (square root of average)				75

Safety Stock and Safety Lead Time

Safety Factor Table (Abridged)

Customer Service Level	Safety Factor	
	With SD or RMSE	With MAD
50.00	0.00	0.00
90.00	1.28	1.60
95.00	1.65	2.06
97.00	1.88	2.35
99.00	2.33	2.91
99.50	2.57	3.20
99.90	3.09	3.85
Safety Stock = MAD, SD, or RMSE in Units × Appropriate Service Factor		
MAD 90% Service Level = 28 Units × 1.60 = 45 Units		
SD 90% Service Level = 165 Units × 1.28 = 211 Units		
RMSE 90% Service Level = 75 Units × 1.28 = 96 Units		

Source: www.supplychainchannel.org

Calculating Safety Stock: Time Period and Fixed Order

Time period method

- Time Period Safety Stock = Forecast Monthly Usage × Safety Stock Time Period
- Example: 50 Units × 0.5 Months = 25 Units

Fixed order method

- Used when parts are transitioning into or out of the system and special oversight is required

Adjusting Safety Stock Due to Lead Time Change

- More room for variability in longer lead times
- Approximation rather than recalculating MAD or SD for multiple products (e.g., 45 units for 90% service, 6-week lead time currently):

$$\text{New Safety Stock} = \text{Old Safety Stock} \times \sqrt{\frac{\text{New Lead Time}}{\text{Old Lead Time}}}$$

$$5 \text{ Weeks} = 45 \times \sqrt{\frac{5}{6}}$$

$$= 45 \times \sqrt{0.83}$$

$$= 45 \times 0.91 = 41 \text{ Units}$$

$$7 \text{ Weeks} = 45 \times \sqrt{\frac{7}{6}}$$

$$= 45 \times \sqrt{1.17}$$

$$= 45 \times 1.08 = 49 \text{ Units}$$

Safety Lead Time

- Protection from lead time fluctuations: order early
- MRP: firm planned order
- When used for independent demand ordering systems:
  - Temporary spike in inventory that resolves itself
  - Preferred over safety stock for sporadic demand items
  - If implemented incorrectly, supply partners see as regular ordering time and order early too (like bullwhip effect)

Safety Stock and Safety Lead Time

Calculation of Safety Stock for Target Service Level

Stockouts: 5 per 10-month period

10-month demand: 10,000 units Order quantity: 100 units MAD: 160 units

Step 1: Number of orders per 10-month period

$$\text{Number of orders per 10 months} = \frac{10{,}000}{100} = 100 \text{ orders}$$

Step 2: Target service level

5 stockouts per 100 orders = 95 orders with no stockouts

$$= \frac{100 - 5}{100} = .95 \text{ or } 95\%$$

Step 3: Safety stock level

$$= 2.06 \times 160 \text{ units} = 330 \text{ units}$$

Customer Service Level	Safety Factor	
	With SD or RMSE	With MAD
50.00	0.00	0.00
90.00	1.28	1.60
95.00	1.65	2.06
97.00	1.88	2.35

Source: www.supplychainchannel.org

Safety Stock Calculation Exercise

- Calculate the safety stock for a 95% service level. The standard deviation (σ) of the forecast interval distribution is 211 units.
- Safety stock = σ × SF

Safety stock = 211 × 1.65 = 348

Standard deviation (σ) safety factors		
Service level percent	Stockout probability percent	σ safety factors (Z value)
95	5	1.65
96	4	1.75
97	3	1.88
98	2	2.05
99	1	2.33
99.86	.14	3.0
99.99	.01	4.0

- What kinds of criteria would you use to consider moving to a 99% service level?

Special Inventory and Dangerous Goods

- High-security goods
- Perishable goods
- Temperature-controlled goods
- Hazardous or dangerous goods
- Remanufacturing industry inventories for maintenance, repair, and overhaul (MRO)
- Maintenance, repair, and operating (MRO) supplies

Class	Dangerous Goods
1	Explosives
2	Gases
3	Flammable liquids
4	Flammable solids
5	Oxidizing substances
6	Toxic substances
7	Radioactive material
8	Corrosive substances
9	Miscellaneous dangerous goods

Source: Adapted from the U.S. Federal Motor Carrier Safety Administration.

CPIM

CERTIFIED IN PLANNING
AND INVENTORY MANAGEMENT

SECTION D:
INVENTORY CONTROL

APICS

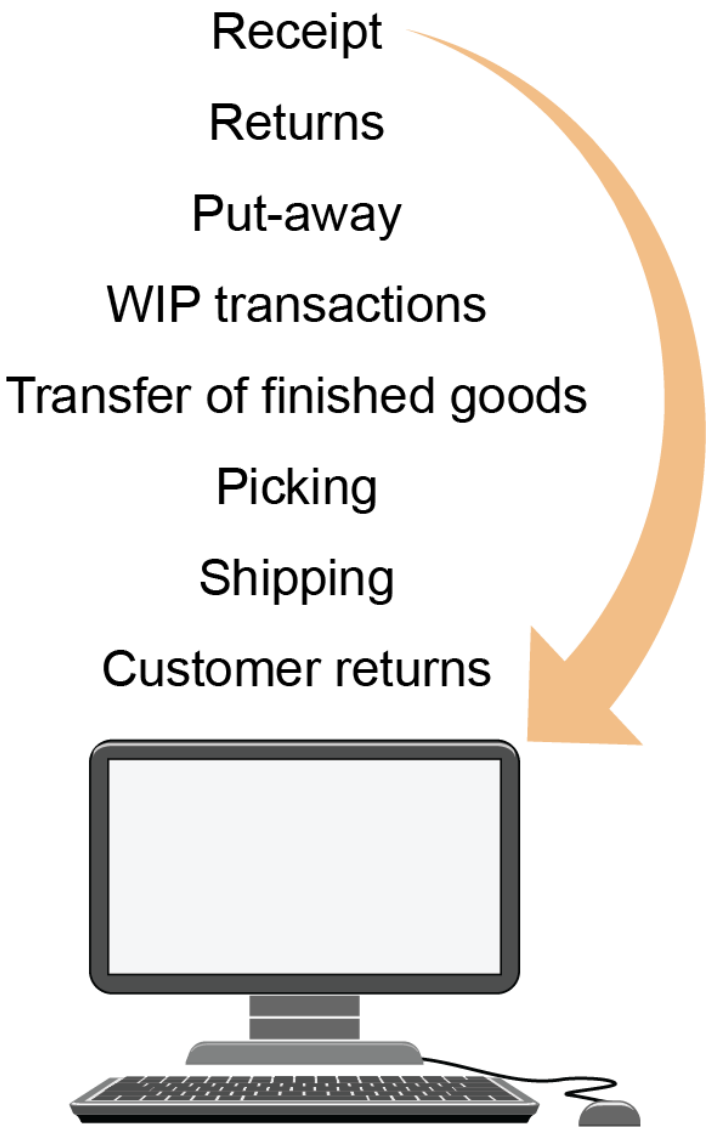
ASCM

Section D Learning Objectives

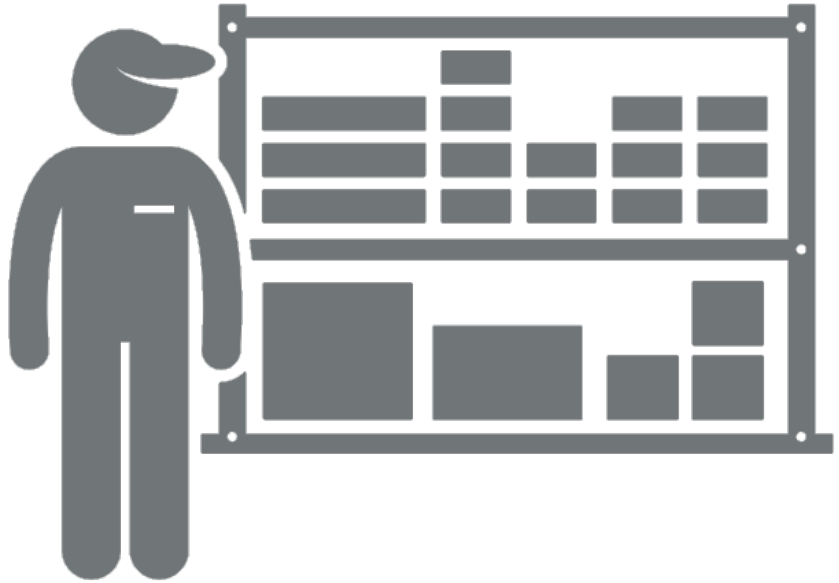
- Transaction management
- Storage layout and materials handling
- Inventory record inaccuracy and shrinkage
- Periodic and cycle counting approaches
- Methods of identifying and tracing inventory
- Product recall guidelines

Transaction Management

- Find all possible transaction points.
- Improve process design.
- Communicate goals and deliver training.
- Improve technology.



Inventory Storage



Challenges

- Capacity utilization
  - Efficient rack and shelf systems
- Protection of inventory from damage or theft
  - Designated areas for vulnerable stock
- Balancing accessibility with control
  - Centralized or decentralized location

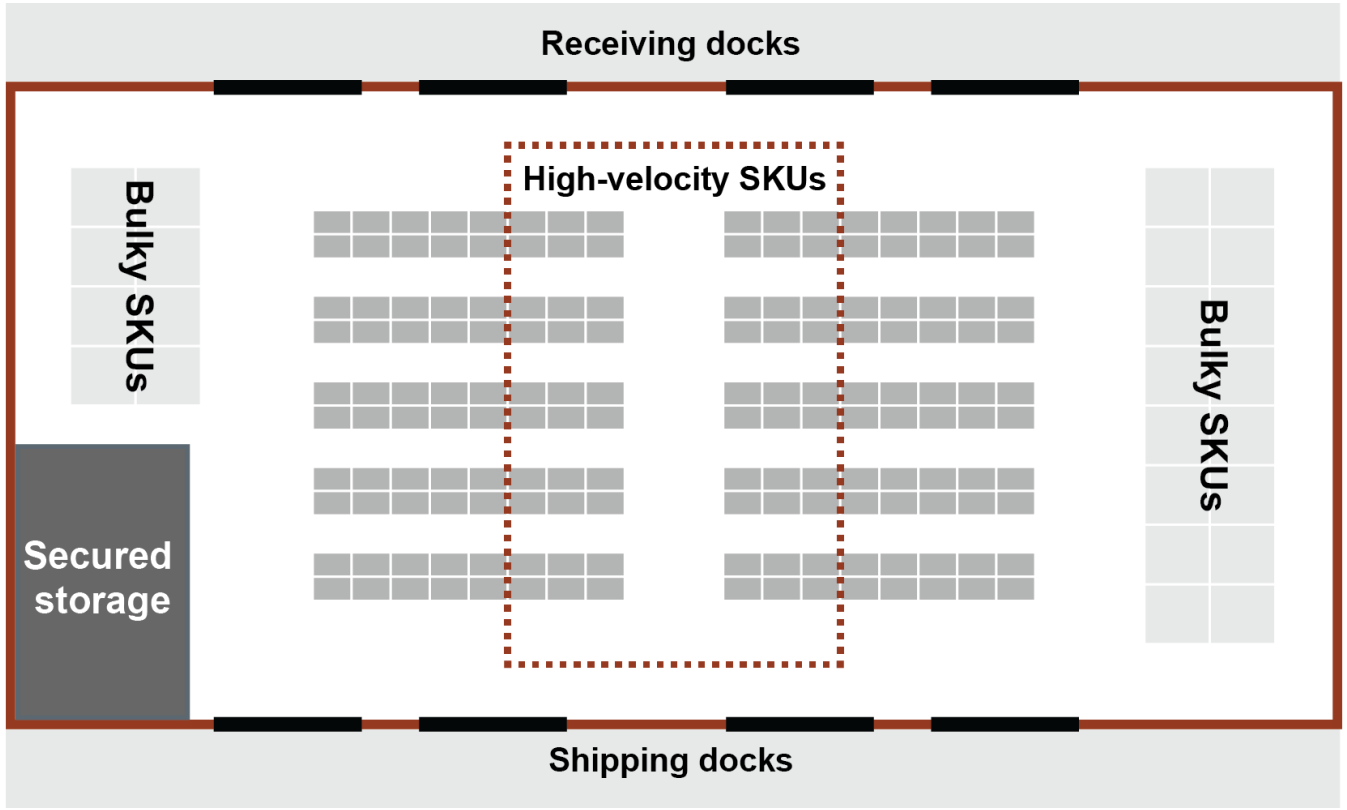
Warehouse Layout Principles

Items are grouped by

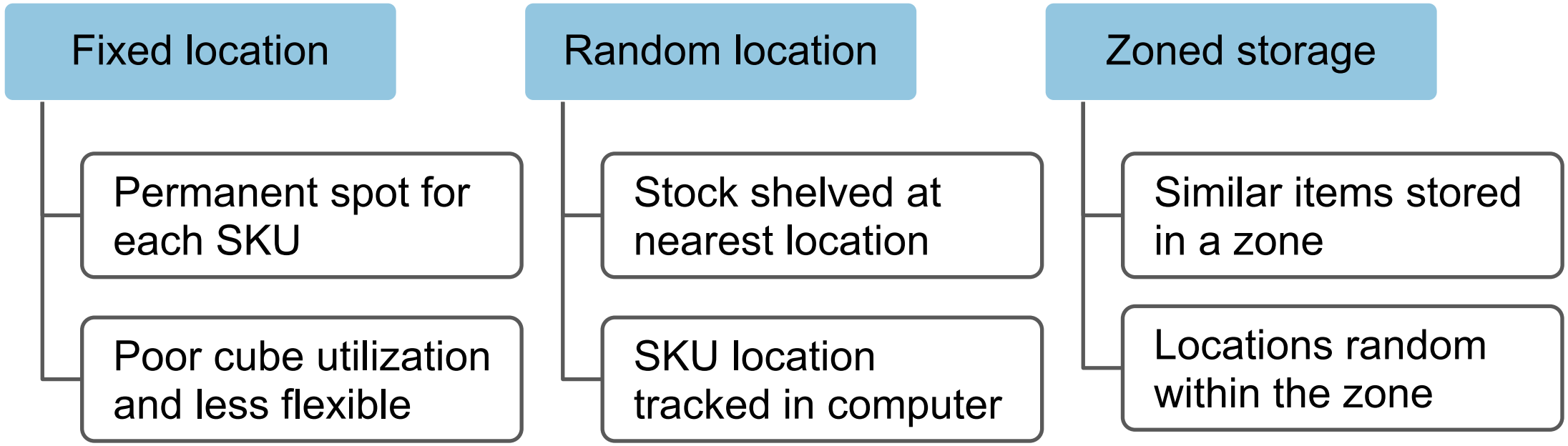
- Function
- Turnover rate
- Common storage needs
- Working vs. reserve stock

Layouts

- Equipment requirements



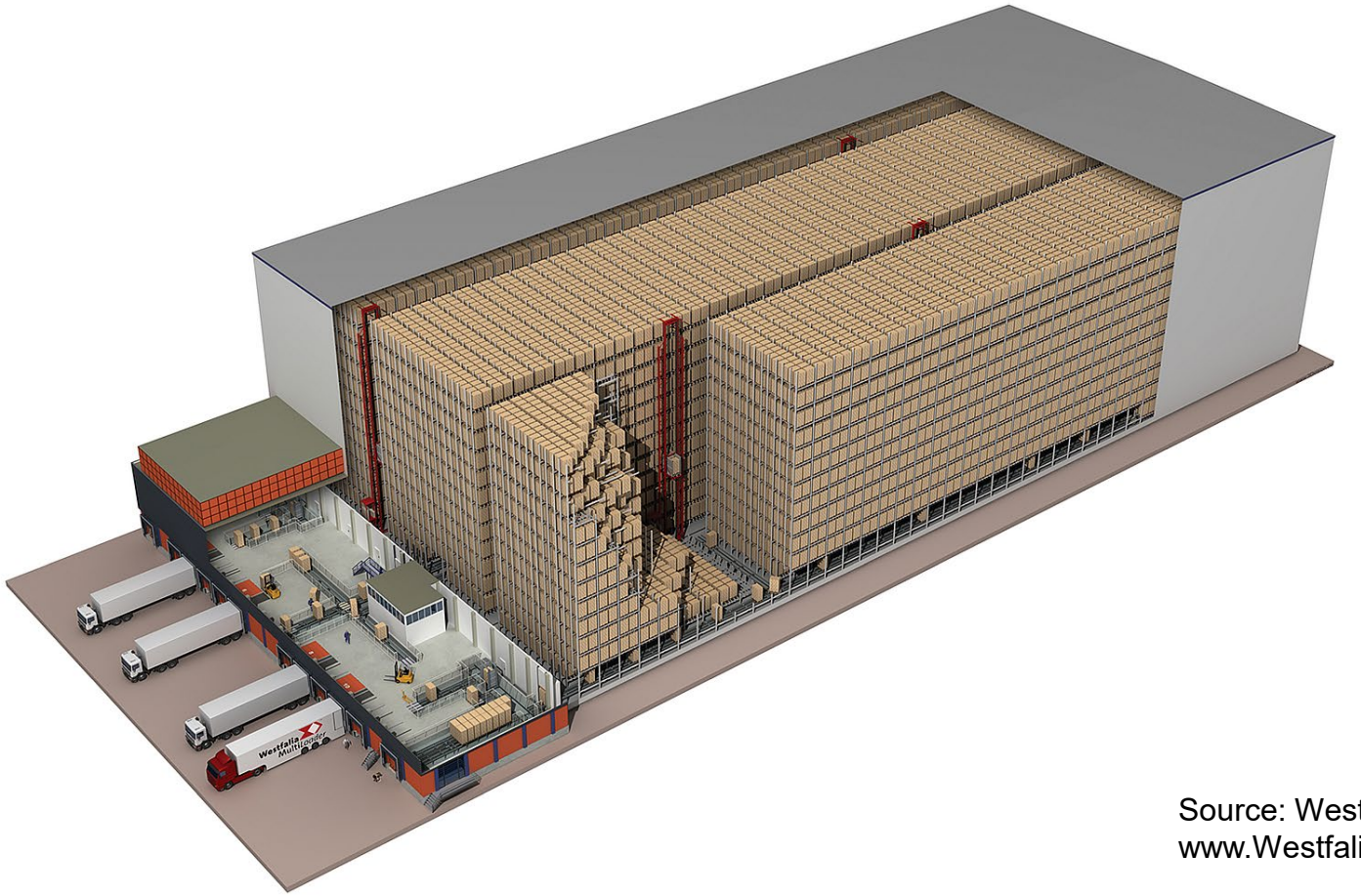
Warehouse Layout Principles



Inventory Location Analysis Exercise

Row #	Advantages and other important characteristics	Location type
1	Items always are in the same place; easy to learn locations.	F
2	Represents the most efficient use of storage space.	R
3	The location strategy is easy to grasp and understand.	F
4	Facilitates picking orders on a first-in, first-out basis as needed due to potential spoilage/corrosion.	R
5	Accommodates flammable or hazardous materials.	Z
6	Accommodates overflow materials easily.	R
7	Results in a high percentage of unused bin space.	F
8	Material does not have to fit in pre-assigned location.	R
9	Bin locations can be assigned to facilitate the picking of materials.	F
10	Quantity variations can be handled by storing material in more than one bin.	R
11	Allows for smaller bins and less wasted space.	R
12	Most-often-picked items can be stored where they are easiest to pick.	F
13	Changes to the variety of items being stocked can be readily accommodated.	R
14	Requires highest level of tracking and retrieval technology.	R
15	Accommodates outdoor storage.	Z
16	Lot or batch identity can be easily maintained.	R

Automated Storage and Retrieval Systems (AS/RS)



Source: Westfalia Technologies, Inc., www.WestfaliaUSA.com. Used with permission.

Alternative Approaches to Managing Inventory

Rapid replenishment	▪ Supplier uses customer point-of-sale data to align its own production schedule. ▪ Orders still used, but lead time decreases.
Continuous replenishment	▪ Supplier tracks and replenishes inventory to agreed level without orders. ▪ Supplier uses customer's demand patterns to lower its inventory level.
Vendor-managed inventory	▪ Vendor creates item inventory policy based on shared demand data. ▪ Vendor is responsible for tracking and replenishing stock without orders.
Consignment	▪ Vendor holds inventory at supplier and charges only at time of use/sale.

Alternative Inventory Management Requirements

- Trust between customer and vendor
- Aligned business processes
- Good communication policies
- Clear service level agreements
- E-commerce capability

Inventory Accuracy

Item Records

- Information that must be accurate
  - Part number and description
  - Quantity
  - Location
- Tolerance limits for accuracy

Causes for inaccurate records

- Employee and BOM errors
- Poorly designed forms and automated/manual tools
- Inadequate training on how to make and document withdrawals

Costs of Inaccuracy

Costs of inaccuracy

- Lost sales
- Excess production
- Low productivity
- Backorders
- Excessive expediting
- High inventory levels
- Shortages
- Missed schedules
- Late delivery
- Excess freight costs
- High levels of obsolescence

Identify Item Data Exercise

Part #	Description	Unit of measure	Order policy	Order quantity	Source code	ABC code	Lead time	Standard cost
10564	gear housing	EA	FOQ	50	M	B	3	108.44

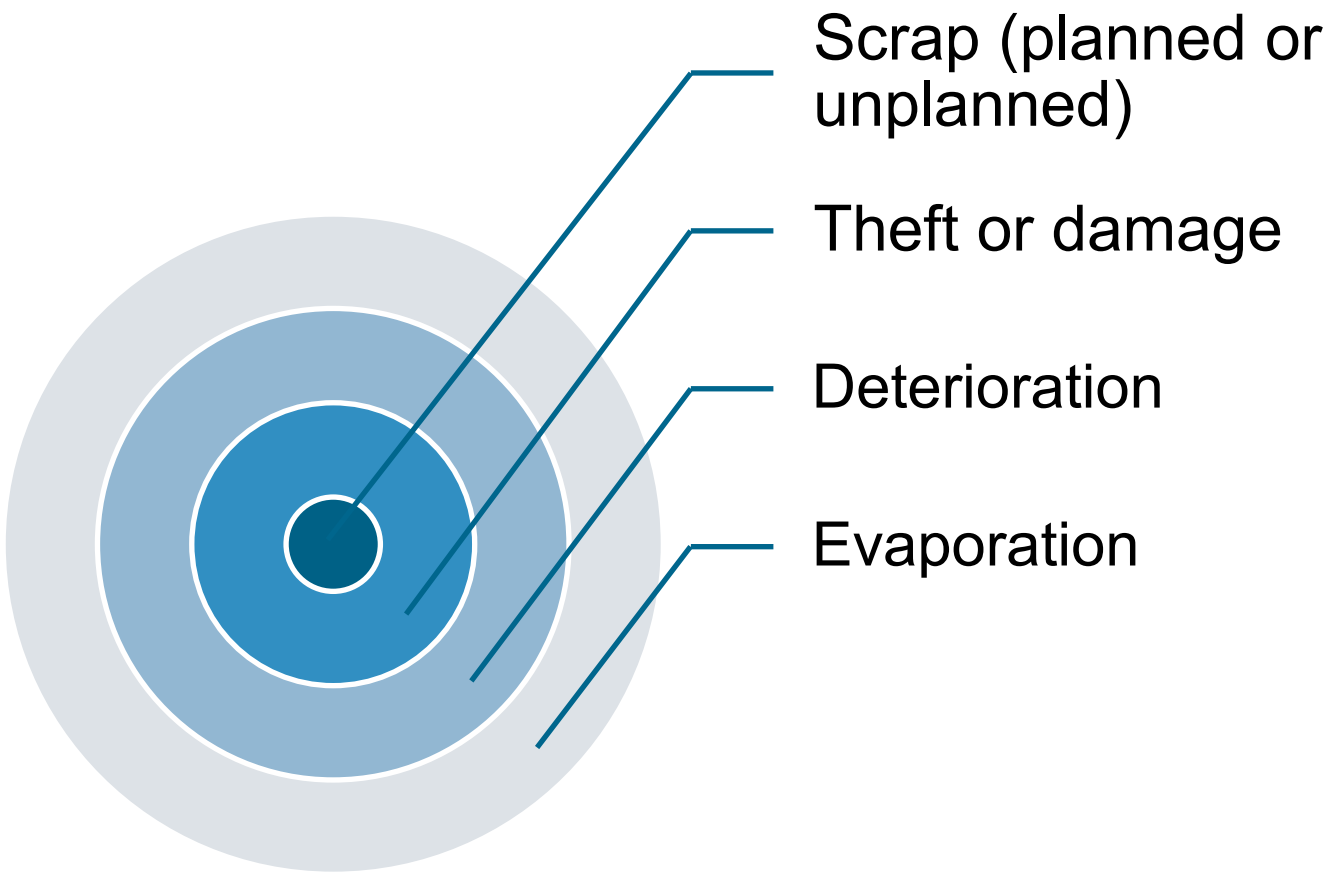
Prime location	Drawing	Revision	Planner/ buyer	Last cycle	Last receipt	Last issue	YTD usage	MTD usage
12C3	10564B	F1	D	03/22	04/01	04/06	190	23

On hand	Allocations	Available	On order	Safety stock	Scrap factor
17	7	10	22	0	.10

Transaction history:

Date	Reference	Initials	Receipts	Issues	Adjust	Stores	Location	Balance
03/13	M1056	VXS	49			S2	12C3	52
03/20	A357	MOM		15		S2	12C3	37
03/22	C87	REC			-1	S2	12C3	36
03/27	A412	MOM		22		S2	12C3	14
04/01	M1103	VXS	26			S2	12C3	40
04/06	A415	MOM		23		S2	12C3	17

Causes for Inventory Shrinkage



Inventory Audits

Periodic inventory

- All items are tagged and counted at one time.
- Requires many trained personnel.
- Requires shutting down operations for the duration.
- Needs a cutoff policy.

Cycle counting

- Items are counted on a predetermined schedule.
- Smaller auditing team.
- Less disruptive.
- Less subject to human error.
- Supports continuous improvement of process.
- Needs a cutoff policy.

Cycle Counting

- Count A items most times, B less, C least
- Category change: high street value; long lead time
- Fast- or slow-moving may be criteria for this ABC
- Count efficiently: at or near zero; as shipment arrives

ABC Class	Number of Items to Count	Annual Frequency	Number of Counts per Year	Percent of Total Counts	Daily Counts
A	800	12	9,600	42.5%	38
B	2,000	4	8,000	35.4%	32
C	5,000	1	5,000	22.1%	20
		SUM	22,600	100.0%	90
	Manufacturing Calendar Days		251		

Total Counts and Counts Per Day Exercise

Classification	Number of items	Count frequency	Number of counts
A	1,100	12	13,200
B	1,650	4	6,600
C	2,250	2	4,500
Total counts			24,300
Workdays per year			250
Counts per day			98

Traceability Requirements

Inventory ID and documentation

- Products, cartons, pallets, etc.
- Class, batch/lot, instance

Transportation documentation

- Certificate of origin/manufacture
- Shipper’s export declaration

Adherence to traceability standards

- Examples: ISO and GS1 standards

Adherence to product recall guidelines

- Specific to jurisdiction

Providing Order Visibility

Tracking in-transit inventory

- Track by purchase orders, SKUs, etc.
- Customize to need by specific role
- Access by buyers and suppliers via batch process or blockchain

Advance ship notice (ASN)

- Allows buyer time to prepare for receipt and plan deployment of contents
- Reduces uncertainty in order replenishments