

production management مدیریت عملیات

Operations Management

Inventory Management

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Outline

- **GLOBAL COMPANY PROFILE: AMAZON.COM**
- **FUNCTIONS OF INVENTORY**
 - Types of Inventory
- **INVENTORY MANAGEMENT**
 - ABC Analysis
 - Record Accuracy
 - Cycle Counting
 - Control of Service Inventories

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Outline Continued

- **INVENTORY MODELS**
 - Independent versus Dependent Demand
 - Holding, Ordering, and Setup Costs
- **INVENTORY MODELS FOR INDEPENDENT DEMAND**
 - Basic Economic Order Quantity (EOQ) Model
 - Minimizing Costs
 - Reorder Points
 - Production Order Quantity Model

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Outline Continued

- **PROBABILISTIC MODELS WITH CONSTANT LEAD TIME**
- **FIXED PERIOD (P) SYSTEMS**

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Learning Objectives

When you complete this chapter, you should be able to :

Identify or Define:

- ABC analysis
- Record accuracy
- Cycle counting
- Independent and dependent demand
- Holding, Ordering, and Setup Costs

Describe or Explain:

- The functions of inventory and basic inventory models

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AMAZON.com

- Jeff Bezos, in 1995, started AMAZON.com as a “virtual” retailer – no inventory, no warehouses, no overhead; just a bunch of computers.
- Growth forced AMAZON.com to excel in inventory management!
- AMAZON is now a worldwide leader in warehouse management and automation.

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Order Fulfillment at AMAZON

1. You order items;, computer assigns your order to distribution center [closest facility that has the product(s)]
2. Lights indicate products ordered to workers who retrieve product and reset light.
3. Items placed in crate with items from other orders, and crate is placed on conveyor. Bar code on item is scanned 15 times – virtually eliminating error.

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Order Fulfillment at AMAZON Continued

4. Crates arrive at central point where items are boxed and labeled with new bar code.
5. Gift wrapping done by hand (30 packages per hour)
6. Box is packed, taped, weighed and labeled before leaving warehouse in a truck.
7. Order appears on your doorstep within a week

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What is Inventory?

- Stock of materials
- Stored capacity
- Examples

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The Functions of Inventory

- To "decouple" or separate various parts of the production process
- To provide a stock of goods that will provide a "selection" for customers
- To take advantage of quantity discounts
- To hedge against inflation and upward price changes

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Types of Inventory

- Raw material
- Work-in-progress
- Maintenance/repair/operating supply
- Finished goods

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The Material Flow Cycle

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Disadvantages of Inventory

- **Higher costs**
 - Item cost (if purchased)
 - Ordering (or setup) cost
 - Costs of forms, clerks' wages etc.
 - Holding (or carrying) cost
 - Building lease, insurance, taxes etc.
- **Difficult to control**
- **Hides production problems**

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Inventory Classifications

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The Material Flow Cycle

- 1 **Run time:** Job is at machine and being worked on
- 2 **Setup time:** Job is at the work station, and the work station is being "setup"
- 3 **Queue time:** Job is where it should be, but is not being processed because other work precedes it.
- 4 **Move time:** The time a job spends in transit
- 5 **Wait time:** When one process is finished, but the job is waiting to be moved to the next work area.
- 6 **Other:** "Just-in-case" inventory

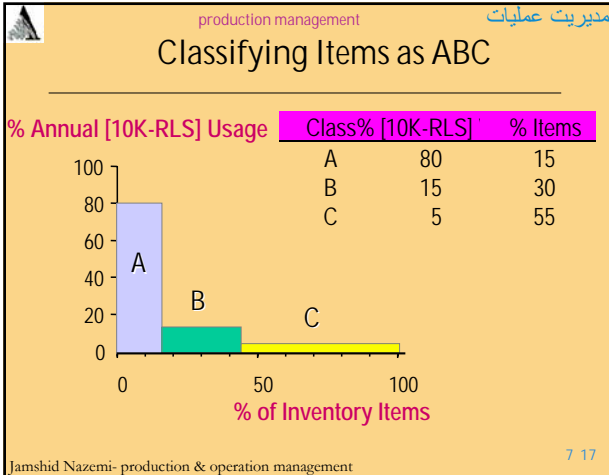
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ABC Analysis

- **Divides on-hand inventory into 3 classes**
 - A class, B class, C class
- **Basis is usually annual [10K-RLS] volume**
 - $[10K-RLS] \text{ volume} = \text{Annual demand} \times \text{Unit cost}$
- **Policies based on ABC analysis**
 - Develop class A suppliers more
 - Give tighter physical control of A items
 - Forecast A items more carefully

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- ### Cycle Counting
- Physically counting a sample of total inventory on a regular basis
 - Used often with ABC classification
 - A items counted most often (e.g., daily)
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- ### Advantages of Cycle Counting
- Eliminates shutdown and interruption of production necessary for annual physical inventories
 - Eliminates annual inventory adjustments
 - Provides trained personnel to audit the accuracy of inventory
 - Allows the cause of errors to be identified and remedial action to be taken
 - Maintains accurate inventory records
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- ### Techniques for Controlling Service Inventory Include:
- Good personnel selection, training, and discipline
 - Tight control of incoming shipments
 - Effective control of all goods leaving the facility
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Independent versus Dependent Demand

- **Independent demand** - demand for item is independent of demand for any other item
- **Dependent demand** - demand for item is dependent upon the demand for some other item

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Inventory Costs

- **Holding costs** - associated with holding or "carrying" inventory over time
- **Ordering costs** - associated with costs of placing order and receiving goods
- **Setup costs** - cost to prepare a machine or process for manufacturing an order

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Holding (Carrying) Costs

- Obsolescence
- Insurance
- Extra staffing
- Interest
- Pilferage
- Damage
- Warehousing
- Etc.

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Inventory Holding Costs (Approximate Ranges)

Category	Cost as a % of Inventory Value
Housing costs (building rent, depreciation, operating cost, taxes, insurance)	6% (3 - 10%)
Material handling costs (equipment, lease or depreciation, power, operating cost)	3% (1 - 3.5%)
Labor cost from extra handling	3% (3 - 5%)
Investment costs (borrowing costs, taxes, and insurance on inventory)	11% (6 - 24%)
Pilferage, scrap, and obsolescence	3% (2 - 5%)
Overall carrying cost	26%

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Ordering Costs

- Supplies
- Forms
- Order processing
- Clerical support
- Etc.

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Setup Costs

- Clean-up costs
- Re-tooling costs
- Adjustment costs
- Etc.

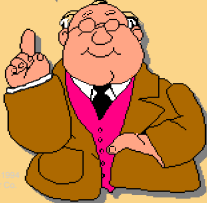
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Inventory Models

- Fixed order-quantity models
 - Economic order quantity
 - Production order quantity
 - Quantity discount
- Probabilistic models
- Fixed order-period models

Help answer the inventory planning questions!



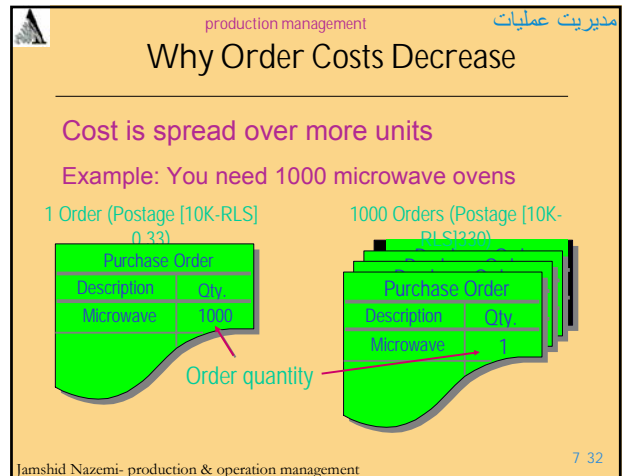
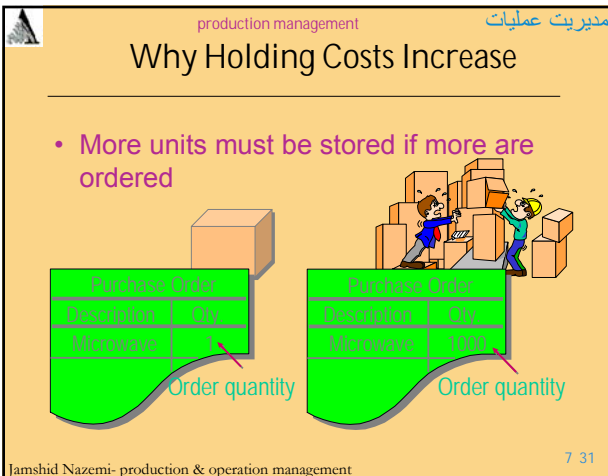
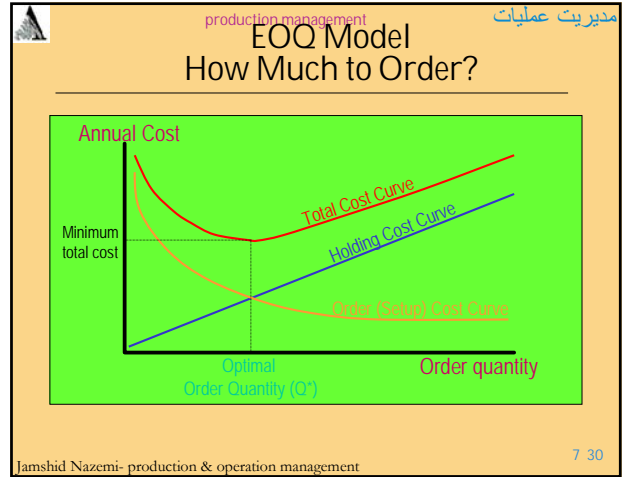
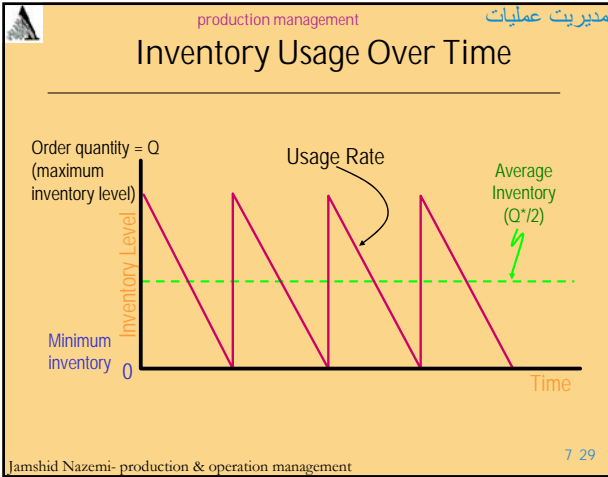
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EOQ Assumptions

- Known and constant **demand**
- Known and constant **lead time**
- **Instantaneous receipt** of material
- **No quantity discounts**
- Only order (setup) cost and holding cost
- No **stockouts**

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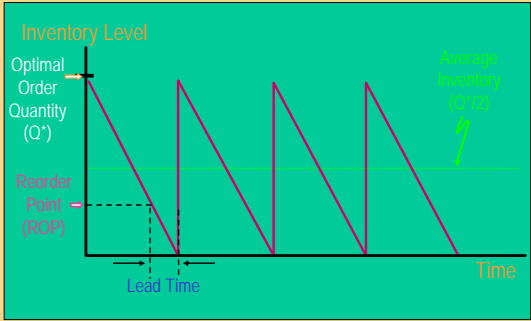
Deriving an EOQ

1. Develop an expression for setup or ordering costs
2. Develop an expression for holding cost
3. Set setup cost equal to holding cost
4. Solve the resulting equation for the best order quantity

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EOQ Model When To Order



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EOQ Model Equations

Optimal Order Quantity $= Q^* = \sqrt{\frac{2 \times D \times S}{H}}$

Expected Number of Orders $= N = \frac{D}{Q^*}$

Expected Time Between Orders $= T = \frac{\text{Working Days / Year}}{N}$

$d = \frac{D}{\text{Working Days / Year}}$

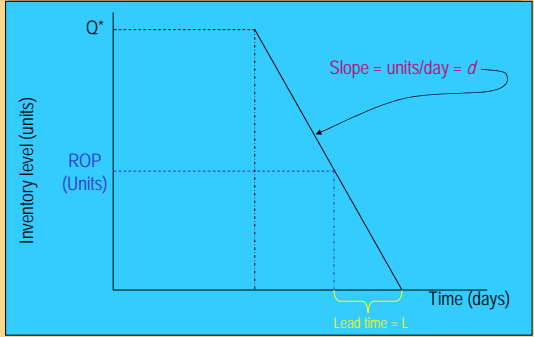
$ROP = d \times L$

$D =$ Demand per year
 $S =$ Setup (order) cost per order
 $H =$ Holding (carrying) cost
 $d =$ Demand per day
 $L =$ Lead time in days

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The Reorder Point (ROP) Curve



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Production Order Quantity Model

- Answers how much to order and when to order
- Allows partial receipt of material
 - Other EOQ assumptions apply
- Suited for production environment
 - Material produced, used immediately
 - Provides production lot size
- Lower holding cost than EOQ model

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EOQ POQ Model When To Order

The graph shows Inventory Level on the y-axis and Time on the x-axis. It features two sawtooth inventory patterns. The first pattern has a yellow triangle for production and a pink triangle for usage. The second pattern has a yellow triangle for production and a pink triangle for usage. A horizontal line indicates the Maximum inventory level. Labels indicate 'Both production and usage take place' for the first cycle and 'Usage only takes place' for the second cycle.

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EOQ POQ Model When To Order

The graph shows Inventory Level on the y-axis and Time on the x-axis. It features a sawtooth inventory pattern with a yellow triangle for production and a pink triangle for usage. A horizontal line indicates the Optimal Order Quantity (Q*). A horizontal line below Q* indicates the Reorder Point (ROP). A horizontal line at the top indicates the Average Inventory. A horizontal line at the bottom indicates the Lead Time.

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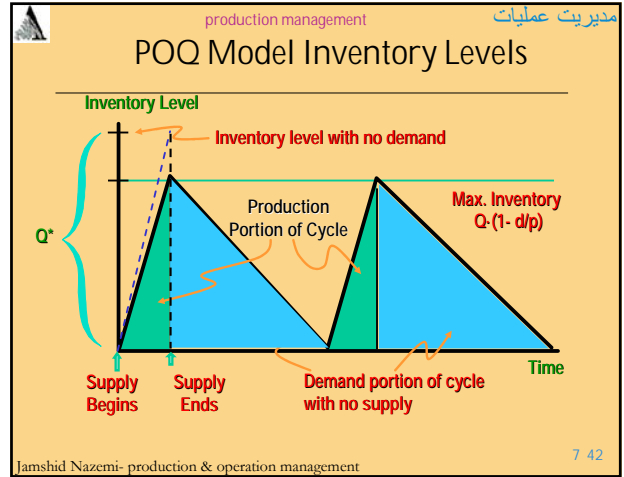
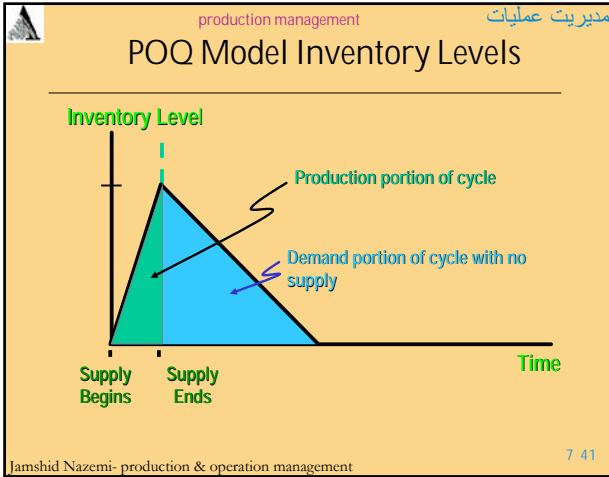
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Reasons for Variability in Production

Most variability is caused by waste or by poor management. Specific causes include:

- ❑ employees, machines, and suppliers produce units that do not conform to standards, are late or are not the proper quantity
- ❑ inaccurate engineering drawings or specifications
- ❑ production personnel try to produce before drawings or specifications are complete
- ❑ customer demands are unknown

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POQ Model Equations

Optimal Order Quantity $= Q^*_p = \sqrt{\frac{2 \cdot D \cdot S}{H \cdot \left(1 - \frac{d}{p}\right)}}$

Maximum inventory level $= Q^* \left(1 - \frac{d}{p}\right)$

Setup Cost $= \frac{D}{Q} \cdot S$

Holding Cost $= 0.5 \cdot H \cdot Q \left(1 - \frac{d}{p}\right)$

D = Demand per year
 S = Setup cost
 H = Holding cost
 d = Demand per day
 p = Production per day

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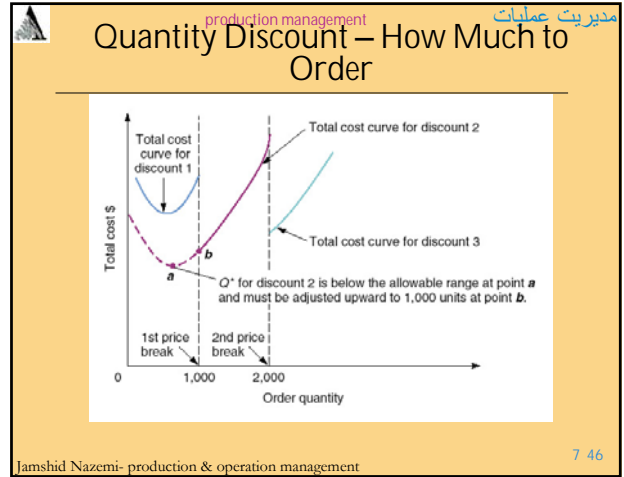
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- ### Quantity Discount Model
- Answers how much to order & when to order
 - Allows quantity discounts
 - Reduced price when item is purchased in larger quantities
 - Other EOQ assumptions apply
 - Trade-off is between lower price & increased holding cost
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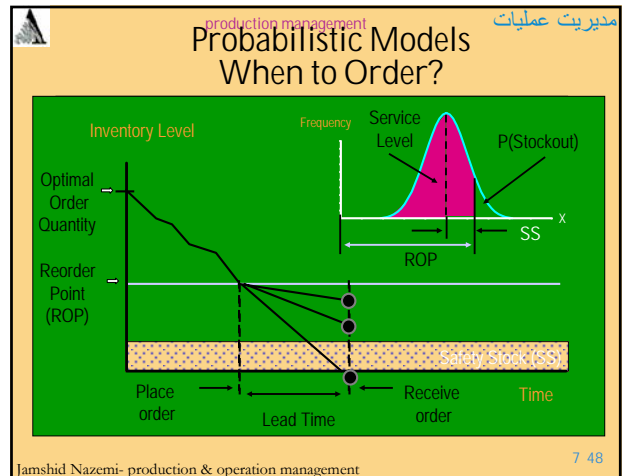
Quantity Discount Schedule

Discount Number	Discount Quantity	Discount (%)	Discount Price (P)
1	0 to 999	No discount	[10K-RLS]5.00
2	1,000 to 1,999	4	[10K-RLS]4.80
3	2,000 and over	5	[10K-RLS]4.75

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- ### Probabilistic Models
- Answer how much & when to order
 - Allow demand to vary
 - Follows normal distribution
 - Other EOQ assumptions apply
 - Consider service level & safety stock
 - Service level = $1 - \text{Probability of stockout}$
 - Higher service level means more safety stock
 - More safety stock means higher ROP
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Fixed Period Model

- Answers how much to order
- Orders placed at fixed intervals
 - Inventory brought up to target amount
 - Amount ordered varies
- No continuous inventory count
 - Possibility of stockout between intervals
- Useful when vendors visit routinely
 - Example: P&G representative calls every 2 weeks

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Inventory Level in a Fixed Period System

Various amounts (Q_i) are ordered at regular time intervals (p) based on the quantity necessary to bring inventory up to target maximum

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Fixed Period Model When to Order?

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Example

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Tire order problem

- A local distributor for a national tire company expects to sell approximately 9,600 steel belted radial tires of a certain size and tread design next year. Annual carrying cost is [10K-RLS]16 per tire, and ordering cost is [10K-RLS]75. The distributor operates 288 days a year.
- What is the EOQ?
- How many times per year does the store reorder?
- What is the length of an order cycle?
- What is the total annual cost if the EOQ quantity is ordered?

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Solution

D = 9,600 tires per year
H = [10K-RLS]16 per unit per year
S = [10K-RLS]75

a. $Q_0 = \sqrt{\frac{2DS}{H}} = \sqrt{\frac{2(9,600)75}{16}} = 300$ tires

b. Number of orders per year $\frac{D}{Q_0} = \frac{9,600 \text{ tires}}{300 \text{ tires}} = 32$

c. Length of order cycle: $\frac{Q_0}{D} = \frac{300 \text{ tires}}{9,600 \text{ tires}} = \frac{1}{32}$ of a year $\Rightarrow \frac{1}{32} \times 288 = 9$ workdays

d. $TC = \text{carrying cost} + \text{ordering cost}$
 $= \frac{Q_0}{2} H + \frac{D}{Q_0} S$
 $= \frac{300}{2} \times 16 + \frac{9,600}{300} \times 75$
 $= \$2,400 + \$2,400$
 $= \$4,800$

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POQ

- A toy manufacturer uses 48,000 rubber wheels per year for its popular dump truck series. The firm makes its own wheels, which it can produce at a rate of 800 per day. The toy trucks are assembled uniformly over the entire year. Carrying cost is [10K RLS]1 per wheel a year. Setup cost for a production run of wheels is [10K RLS]45. The firm operates 240 days per year. Determine the:
- Optimal run size
- Minimum total annual cost for carrying and setup
- Cycle time for the optimal run size
- Run time

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Solution

D = 48,000 wheels per year
S = [10K-RLS]45
H = [10K-RLS]1 per wheel per year
p = 800 wheels per day
u = 48,000 wheels per 240 days, or 200 wheels per day

a. $Q_0 = \sqrt{\frac{2DS}{H} \frac{p}{p-u}} = \sqrt{\frac{2(48,000)45}{1} \frac{800}{800-200}} = 2,400$ wheels

$TC_{min} = \text{carrying cost} + \text{setup cost} = \frac{I_{min}}{2} H + \frac{D}{Q_0} S$
 $I_{min} = \frac{Q_0}{p} (p - u) = \frac{2,400}{800} (800 - 200) = 1,800$ wheels
 $TC = \frac{1,800}{2} \times 1 + \frac{48,000}{2,400} \times 45 = \$900 + \$900 = \$1,800$

b. $I_{min} = 1,800$ wheels

c. Cycle time = $\frac{Q_0}{u} = \frac{2,400 \text{ wheels}}{200 \text{ wheels per day}} = 12$ days
Thus, a run of wheels will be made every 12 days.

d. Run time = $\frac{Q_0}{p} = \frac{2,400 \text{ wheels}}{800 \text{ wheels per day}} = 3$ days
Thus, each run will require 3 days to complete.

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