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Modern Logistics & Supply Chain Management

ML & SCM

Inventory Systems
Part I

*As gold which he cannot spend
will make no man rich,
so knowledge which he cannot apply
will make no man wise.*
Samuel Johnson: The Idler No. 84

Dr. Wolfgang Garn
Winter, 2016

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Some Inventory Examples

- Oil tanker - "Moving" Inventory
- Ikea - Warehouse



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Why is Inventory Management important?

- Finance
 - 10% to 40% of product price is due to inventory costs
 - Up to 50% of assets in a company's inventory
- Production continuity
 - Decoupling in production process



Role of Inventory (1 of 2)

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- **Inventory** is a stock of items kept on hand used to meet customer demand.
- A level of inventory is maintained that will **meet anticipated demand**.
- If demand is *not* known with *certainty*, **safety (buffer) stocks** are kept on hand.
- Additional stocks are sometimes built up to meet **seasonal or cyclical** demand.
- **Large amounts** of inventory are sometimes purchased to take advantage of **discounts**.

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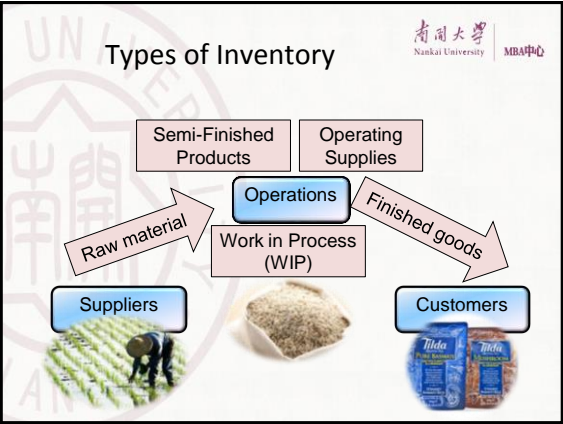
Role of Inventory (2 of 2)

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- **Raw materials inventory** kept to avoid delays in case of supplier problems.
- **(Work) In-process inventories** maintained to provide independence between operations.
- Stock of **finished parts** kept to meet customer demand in event of work stoppage.
- In general inventory serves to **decouple** consecutive steps.

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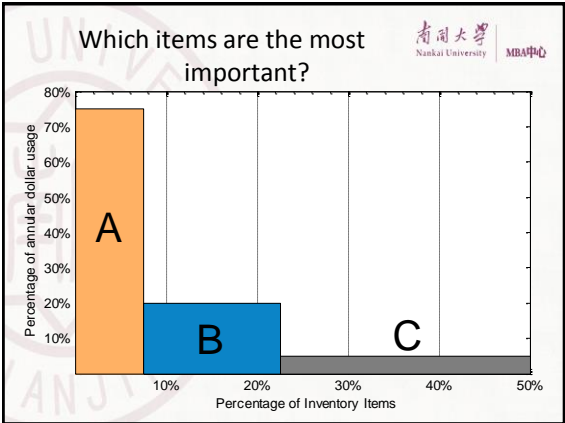
Inventory Management



- Inventory
 - is any quantifiable item that is stored and used in an operation
- Inventory management
 - is the planning and controlling of activities both within and outside of an organisation to ensure that the correct quantity and type of inventory is delivered to the correct place at the right time and at the right cost.

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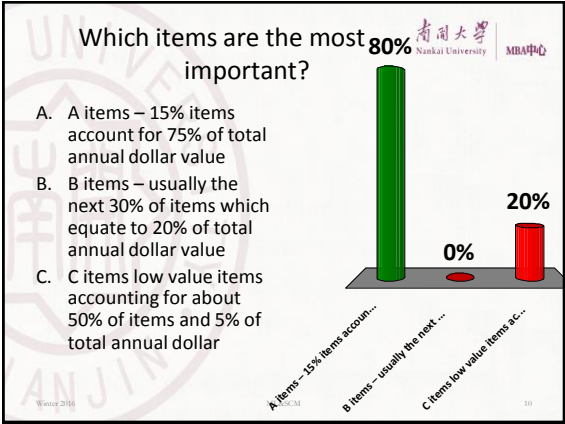


ABC classification system

- Inventory is grouped according to its importance (value)
 - Normally this is the annual expenditure
 - Each group obtains a letter
 - Usually follows a Pareto distribution

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Role play

- You are inventory managers for a large supermarket! You want to ...
 - Identify three fundamental cost categories
 - for the most important product
 - How could you determine the cost elements for each category?

Elements of Inventory Management

Inventory Costs (1 of 3)

Carrying cost = Holding cost Costs of holding items in storage.

- Direct storage cost ("Warehousing")
 - Facility costs, rent, heating, cooling (refrigeration), lighting
 - Hygiene, security, protective packaging, record keeping
 - Spoilage, breakage, pilferage
- Indirect storage cost
 - Tight up funds (loans, interests, taxes and money depreciation)
 - Obsolescence (markets diminish), Product deterioration
- Characteristics
 - Vary with level of inventory and sometimes with length of time held.
 - Assigned on a per unit basis per time period, or as percentage of average inventory value (usually estimated as 10% to 40%).

Elements of Inventory Management

Inventory Costs (2 of 3)

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Ordering cost

costs of replenishing stock of inventory.

- Purchase negotiations (e.g. RFQ) and orders,
- Shipping (transportation), handling & placing
- Quality & Quantity inspection, Accounting (audit)
- Characteristics
 - Expressed as **dollar amount per order**, in some models independent of order size.
 - Vary with the **number of orders** made.
- Ordering cost are substituted by “**setup cost**”, if it’s a production scenario!

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Elements of Inventory Management

Inventory Costs (3 of 3)

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Shortage (stockout)

costs - Associated with insufficient inventory.

- Result in permanent **loss of sales** and profits for items not on hand.
- Sometimes **penalties** involved; if customer is internal, *work delays* could result.

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Inventory decisions

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- How much to order?
- When to order?
- Which items are the most important?

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Economic Order Quantity Model

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- Purpose
 - Determine order quantity that minimises the total annual ordering and holding costs
- Assumptions
 - Annual and stable (constant) demand
 - Linear quantity cost relationship
 - Constant delivery lead time
 - Fixed ordering costs

Basic EOQ Model

Carrying Cost (1 of 2)

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- **Carrying cost** = **Holding costs** usually expressed on a *per unit basis of time*, traditionally one year.
- Annual carrying cost equals carrying cost per unit per year times average inventory level:
 - Carrying cost per unit per year = c_c
 - Average inventory = $Q/2$
 - **Annual carrying cost** = $c_c Q/2$.

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Basic EOQ Model

Carrying Cost (2 of 2)

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Figure 16.4 Average Inventory

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Basic EOQ Model

Ordering Cost

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■ Total annual **ordering cost** equals *cost per order* (c_o) times number of orders per year.

■ What is the number of orders per year?

■ Demand D is constant and known

■ Order quantity Q can be derived

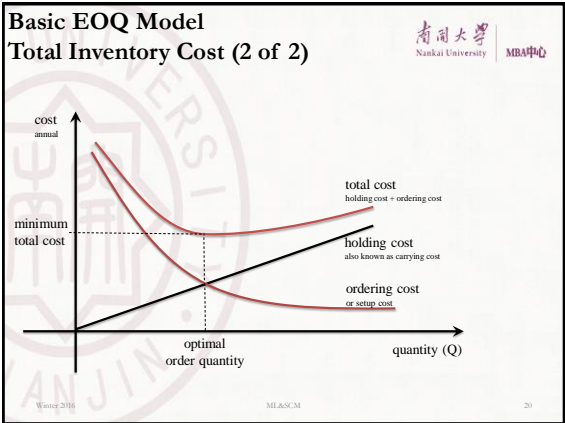
■ Thus number of orders per year is $\frac{D}{Q}$

■ Annual ordering cost $c_o \frac{D}{Q}$

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Basic EOQ Model

Total Inventory Cost (1 of 2)

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Total annual inventory cost is sum of ordering and carrying cost:

$TC = c_o \frac{D}{Q} + c_c \frac{Q}{2}$

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Basic EOQ Model

EOQ and Minimum Total Cost

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EOQ occurs where total cost curve is at minimum value and carrying cost equals ordering cost:

$$TC_{\min} = \frac{c_o D}{Q_{opt}} + c_c \frac{Q_{opt}}{2}$$
$$Q_{opt} = \sqrt{\frac{2C_o D}{C_c}}$$

The EOQ model is robust because Q is a square root and errors in the estimation of D, C_c and C_o are dampened.

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Basic EOQ Model

Example (1 of 2)


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A supermarket wants to order pallets of a certain rice product, so that it can fulfill its customer demand.

D = 10,000 pallets



You have determined the annual carrying cost per item. c_c = £0.75
You have found out that the ordering cost are: c_o = £150 per order (without discounts)

What is the optimal order quantity?

$$Q_{opt} = \sqrt{2D \frac{c_o}{c_c}} = \sqrt{\frac{2 \cdot 150 \cdot 10,000}{0.75}} = 2,000 \text{ pallets}$$

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Basic EOQ Model

Example (2 of 2)

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What is the total annual inventory cost?

$$TC_{\min} = c_o \frac{D}{Q_{opt}} + c_c \frac{Q_{opt}}{2} = 150 \frac{10,000}{2,000} + 0.75 \frac{2000}{2} = £1,500$$

How many orders have to be done per year?

$$\frac{D}{Q_{opt}} = \frac{10,000}{2,000} = 5$$

When do you have to order?
(assuming the supermarket has 350 working days)

$$\frac{350 \text{ days}}{5 \text{ orders}} = 70 \frac{\text{days}}{\text{order}} \quad \text{every 70 working days}$$

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When purchasing any typical item, what fraction is caused by Inventory costs typically*?

1. 10 to 40%

2. 0 to 20%

3. 20 to 50%

67%

0%

33%

*according to Taylor p763

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1.

2.

3.

What for do we use Inventory Models?

1. To count the stock

2. To determine the order quantity and when to order

3. To visualise the demand

0%

17%

83%

图 1. 图 2. 图 3.

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1.

2.

3.

What are the most important cost factors in an Inventory model?

1. Rental cost, setup cost and sales cost

2. Holding cost, Ordering cost and Shortage cost

3. Sales costs, storage cost and carrying cost

4. Shortage costs, carrying and holding cost

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What is the Economic Order Quantity

1. A quantity that minimises the total costs

2. Although it is called quantity, it is actually the most economic time, when to order

3. A theoretical quantity, having far too many constraints.

86%

14%

0%

What are EOQ assumptions?

1. Data collected over a short period

2. Demand is known with certainty and is relatively constant over time.

3. Lead time for receipt of orders is constant

38%

50%

13%

What are the total costs in an EQO model

1. Ordering costs + Carrying costs + shortage costs

2. Holding costs + shipping costs

40%

60%

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Recap

- What do inventory systems minimise?
 - Total cost
- Simple inventory systems can be described by the
 - Economic order quantity model
- What for is inventory needed?
 - To meet customer demand; as safety buffer; or to decouple processes, ...

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The End

- Any questions?



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Appendix

- Dependent & independent demand
- Control systems
- EOQ supplemental
- Book contents

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Elements of Inventory Management

Demand

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- Inventory exists to **meet the demand** of customers.
- Customers can be **external** (purchasers of products) or **internal** (workers using material).
- Management needs an accurate **forecast** of demand.
- Items that are used internally to produce a final product are referred to as **dependent demand items**.
- Items that are final products demanded by an external customer are **independent demand** items.

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Inventory Control Systems

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- An inventory control system controls the level of inventory by determining **how much** (replenishment level) and **when** to order.
- Two basic types of systems - **continuous (fixed-order quantity)** and **periodic (fixed-time)**.
 - In a continuous system, an order is placed for the same constant amount when inventory decreases to a specified level.
 - In a periodic system, an order is placed for a variable amount after a specified period of time.

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Inventory Control Systems

Continuous Inventory Systems

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- A continual record of inventory level is maintained.
- Whenever inventory decreases to a predetermined level, the **reorder point**, an order is placed for a **fixed amount** to replenish the stock.
- The fixed amount is termed the **economic order quantity**, whose magnitude is set at a level that minimises the total inventory carrying, ordering, and shortage costs.
- Because of continual monitoring, management is always aware of status of inventory level and critical parts, but system is relatively expensive to maintain.

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Inventory Control Systems

Periodic Inventory Systems

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- Inventory on hand is **counted at specific time intervals** and an order placed that brings inventory *up to a specified level*.
- Inventory not monitored between counts and system is therefore less costly to track and keep account of.
- Results in less direct control by management and thus generally higher levels of inventory to guard against **stockouts**.
- System requires a **new order quantity** each time an order is placed.
- Used in smaller retail stores, drugstores, grocery stores and offices.

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Economic Order Quantity Models

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- **Economic order quantity**, or **economic lot size**, is the quantity ordered when inventory decreases to the **reorder point**.
- **Amount** is determined using the economic order quantity (EOQ) model.
- Purpose of the EOQ model is to determine the optimal order size that will **minimise total inventory costs**.
- Three model versions to be discussed:
 1. Basic EOQ model
 2. EOQ model without instantaneous receipt
 3. EOQ model with shortages

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Economic Order Quantity Models

Basic EOQ Model (1 of 2)

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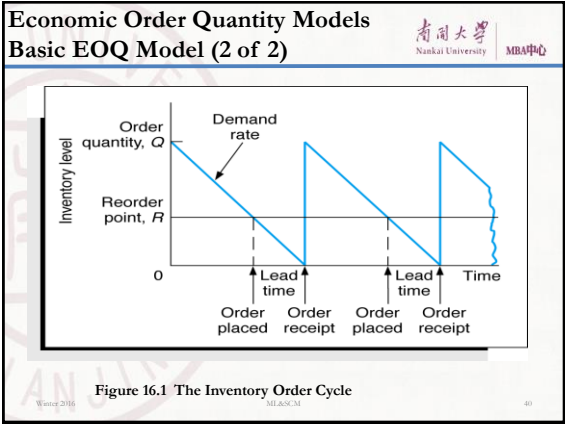
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- A **formula** for determining the optimal order size that *minimises the sum of carrying costs and ordering costs*.
- Simplifying assumptions and restrictions:
 - **Demand** is *known* with certainty and is relatively *constant* over time.
 - **No shortages** are allowed.
 - **Lead time** for the receipt of orders is **constant**.
 - The **order quantity** is *received all at once* and instantaneously.

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- Chapter Topics

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- Elements of Inventory Management
 - Inventory Control Systems
 - Economic Order Quantity Models
 - The Basic EOQ Model
 - The EOQ Model with Non-Instantaneous Receipt
 - The EOQ Model with Shortages
 - EOQ Analysis with QM for Windows
 - EOQ Analysis with Excel and Excel QM
 - Quantity Discounts
 - Reorder Point
 - Determining Safety Stocks Using Service Levels
 - Order Quantity for a Periodic Inventory System
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