# Process Improvement

## *Operations management*

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# Introduction

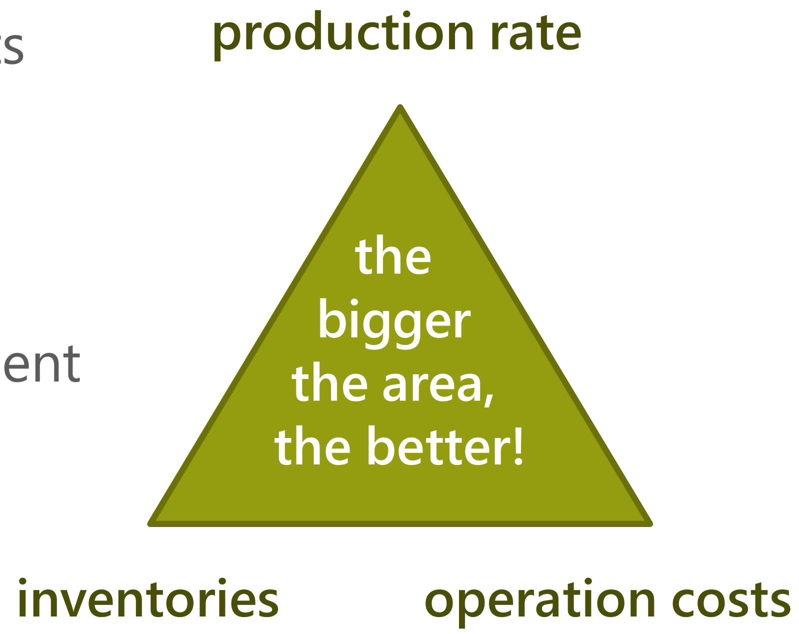
- **Management**: planning, organizing, controlling and leading resources for gaining company targets efficiently and effectively

- **Operations management**: efficient operation of resources directly related to production → functional area based on analytical methods, operations research

- **Production systems**: convert input resources into products/services, using different components and tools

# Operation measures

- For evaluating decisions related to production management
- **1. Production rate:**
  - number of products made in a period
- **2. Amount of inventories**
  - raw materials, components, products
  - costs!
- **3. Direct operation costs**
  - influenced by production management
  - no marketing cost



## Why do we have to determine the amount of capacity available?

To decide about:

- which orders to accept? (*production planning*)
- when to raise or lower inventory levels? (*inventory management*)
- where to increase or reduce capacity? (*investment decisions, resource allocation*)

**Resource capacity:** the *amount* of products or services that can be produced *in a given time*.

Measures: units per month, tonnes per year, customers per day, etc.

# I.a. Capacity indices

**1. Design capacity**: the maximum output of a resource *under ideal conditions* in a given period.

$$\text{Design capacity (DC)} = \frac{\text{total available time}}{\text{unit production time}} = \frac{NDSH}{M}$$

$$M = 1/P$$

*N* – number of parallel *resources* having equivalent properties

*D* – number of *days* available

*S* – number of *shifts* per day

*H* – number of *hours* worked during one shift

*M* – *time* to make one unit of product or service (hours/unit)

*P* – production rate (units/hour)

# I.a. Capacity indices

**2. Effective capacity**: the maximum output that a resource can be expected to produce in a given period when it works in an *actual operating schedule* (actual working hours).

$$\text{Effective capacity (EC)} = \frac{\text{real available time}}{\text{unit production time}} = \frac{NDSH(1-\xi)}{M}$$

- $0 \leq \xi \leq 1$ when expressed in percentages
- can be expressed in hours also (see Bottling line example)
- represents the *expected time loss* → time lost due to maintenance, scheduled rest periods, setup times

design capacity & effective capacity → **absolute indices**

# I.a. Capacity indices

3. **Capacity utilization** refers to the proportion of the design capacity that is actually used.

$$\text{Capacity utilization (CU)} = \frac{\text{Actual output}}{\text{Design capacity}}$$

4. **Efficiency** refers to the proportion of the capacity actually used under normal operating conditions.

$$\text{Efficiency (EF)} = \frac{\text{Actual output}}{\text{Effective capacity}}$$

capacity utilization & efficiency → **relative indices**

(actual output produced compared to the maximum values)

# Example 1.

*A* machine works for *one* *eight-hour* shift on *five days* a week. When working, it can produce *100 units an hour*. *10%* of its time is needed for maintenance and setups. The output of the machine was *3,000 units* in a particular week.

**TASK** Determine absolute and relative capacity indices!

$N=1$, $S=1$, $H=8$, $D=5$, $P=100\ u/h$, $\xi=0.1$

$AO=3000$

$\rightarrow M=1/P=1/100\ h/u$

# Example 1.

1. Design capacity = $\dfrac{NDSH}{M} = \dfrac{1\times5\times1\times8}{\dfrac{1}{100}} = 5\times8\times100 = 4000$

2. Effective capacity = $\dfrac{NDSH(1-\xi)}{M} = \dfrac{1\times5\times1\times8\times(1-0.1)}{\dfrac{1}{100}} = 5\times8\times100\times0.9 = 3600$

3. Capacity utilization = $\dfrac{\text{Actual output}}{\text{Design capacity}} = \dfrac{3000}{4000} = 0.75 \rightarrow 75\%$

4. Efficiency = $\dfrac{\text{Actual output}}{\text{Effective capacity}} = \dfrac{3000}{3600} = 0.833 \rightarrow 83.3\%$

# Demand management

The aim of demand management is to redirect demand from periods of capacity shortage to periods of spare capacity.

Typical ways:

- Changing the price: price reductions, ”happy hour”
- Producing for stock in periods of spare capacity
- Changing the order lead time
  - Lead time: the time passing between placing and receiving an order
- Taking orders: customers are asked to place an order or to make an appointment in advance

# Capacity management

Changing the data used in the formula for calculating effective capacity:

$$\frac{NDSH(1-\xi)}{M}$$

Typical ways:

- Hiring sub-contractors, leasing equipment (N)
- Increasing the number of shifts (S)
- Working overtime (D, H)
- Rescheduling maintenance ($\xi$)
- Making the customer perform certain operations (M)

# Formula used in short-term capacity planning

$$Q \leq \frac{NDSH(1-\xi)}{M}$$

This formula expresses that the effective capacity must be sufficient to perform the required task (*Q*).

# Example

A bank has forecasted that an average of 500 customers a week will want to open a newly introduced type of account in a given period. One front-office employee can deal on average with three customers an hour, but the associated back-office paperwork takes an average of 40 minutes per customer. Employees spend 20% of their time on other activities, such as meetings. A standard working day is from 9 am to 4 pm, on five days a week, with a one-hour lunch break at noon.

**TASKS** How many employees are needed on average (in a week) to perform the task?

Calculate absolute capacity indices and relative capacity indices on a day when 90 customers are dealt with.

We need to determine the number of employees (N). Using the above inequality, the following condition must be met:

$$N \geq \frac{QM}{DSH(1-\xi)}$$

- $Q$ = 500 customers/week
- $M$ = 60/3 + 40 minutes → 1 hour
- $\xi$ = 20% = 0.2
- $S$ = 1
- $D$ = 5
- $H$ = 16-9 = 7 hours (with 1 hour lunch break!)

- $N \rightarrow \quad N \geq \dfrac{500 \times 1}{5 \times 1 \times (7-1) \times (1-0.2)} = 20.83$

  *21 employees are needed* to perform the task!

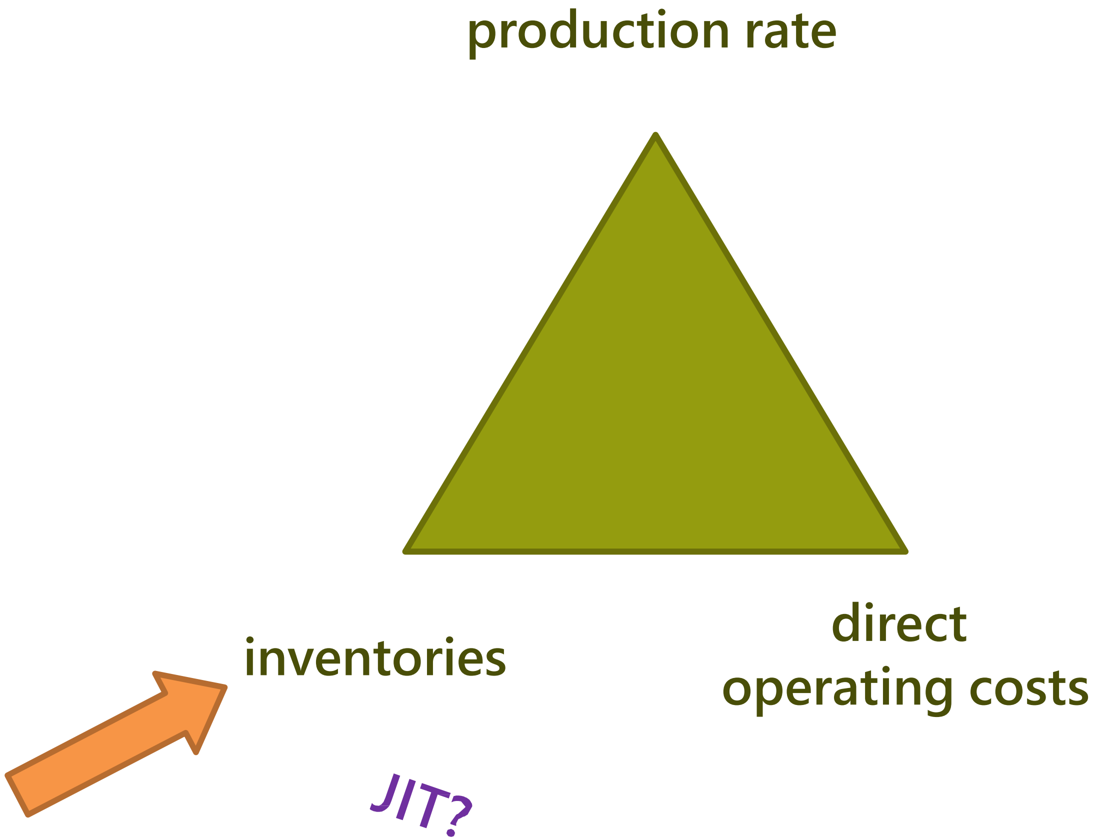
**Absolute capacity indices** of the system:

- Design capacity = $\dfrac{21 \times 5 \times 1 \times 7}{1} = 735 \text{ customers/week}$
- Effective capacity = $\dfrac{21 \times 5 \times 1 \times (7-1) \times (1-0.2)}{1} = 504 \text{ customers/week}$

**Relative indices** on a day when *90 customers* are dealt with:

- Capacity utilization = $\dfrac{90}{735/5} = 0.6122 \rightarrow 61.22\%$
- Efficiency = $\dfrac{90}{504/5} = 0.8928 \rightarrow 89.28\%$

# Operation measures



# Inventories

- Supplies of goods and materials that are held by an organization

- Types of inventories:
  - Raw materials,
  - Work-in-progress → semi-finished goods
  - Finished goods
  - Spare parts
  - Consumables
    - oil, fuel, paper, etc.

# Inventories

- Benefits of holding inventories:
  - Stabil and smooth workflows within the production system
  - Protection against
    - shutdowns (long blackout)
    - delivery delays of suppliers,
    - uncertain demand
  - Taking advantage of low prices – price discounts on large orders

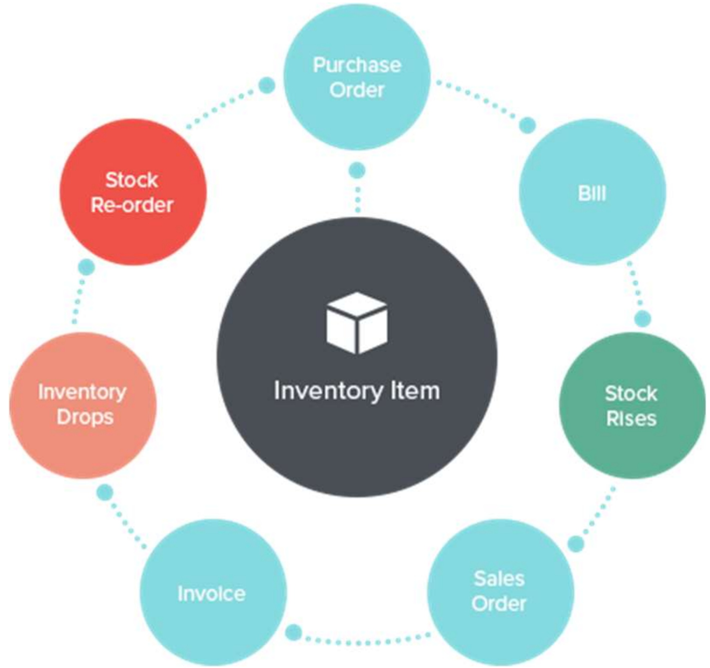
- Drawback of holding inventories:

COSTS!

# Inventory Control

- Inventory control is the effort to maintain inventory levels and costs within acceptable limits.

- Decisions related to the operation of inventory systems:
  1. How should the inventory be operated? (*inventory mechanism*)
  2. How much should be ordered? (*economic order quantity*)
  3. When should an order be placed? (*reorder level, lead time*)



# Classic inventory control mechanisms

- Q1: **how to order?**

- Define two things: ***a)*** the *event* or events that must occur for an order to be placed ***b)*** and the *principles* for calculating the amount to be ordered.

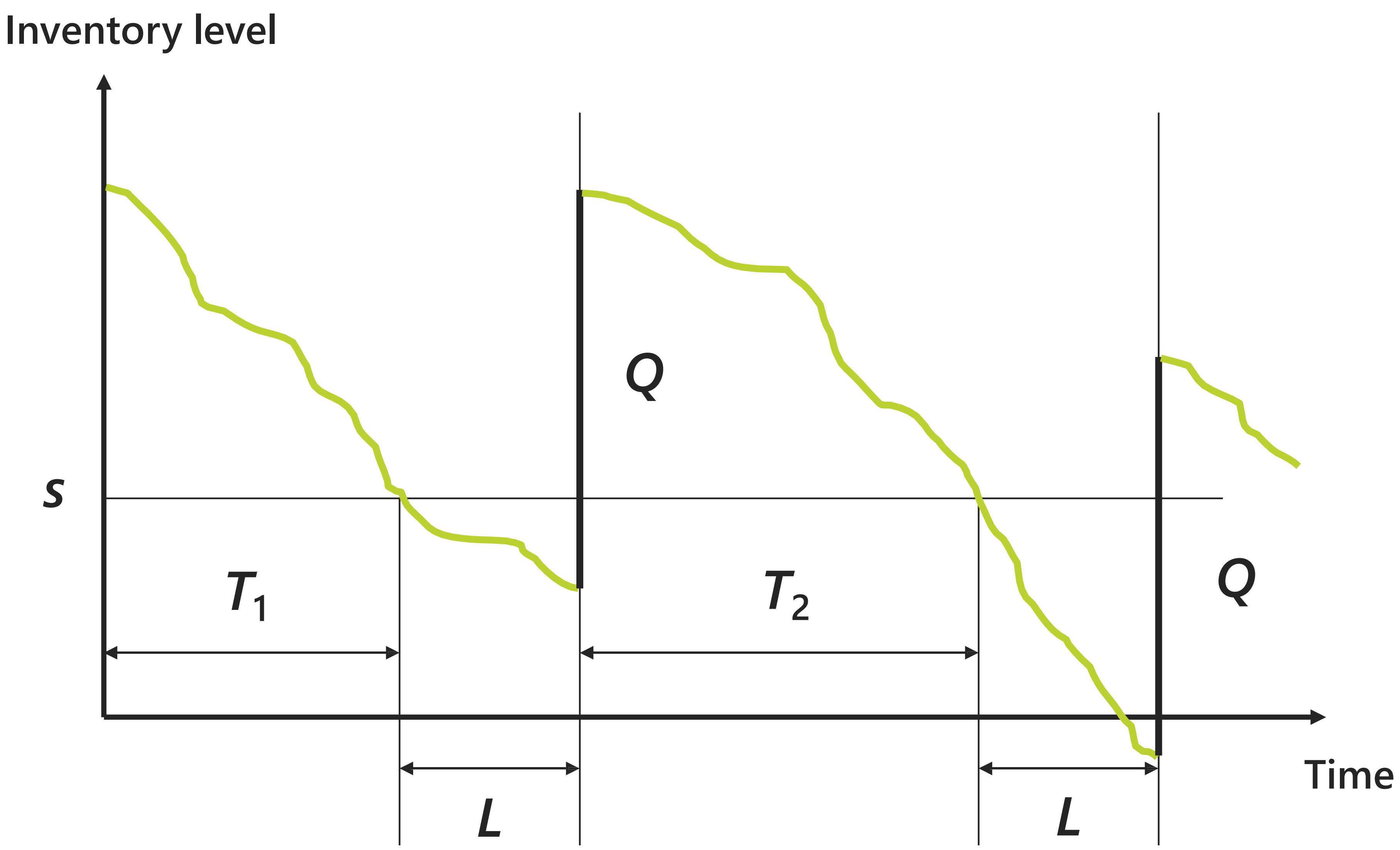
- There are essentially two groups according to the type of inventory review: *continuous* or *periodic*.

# Continuous Review System I.

- The inventory level is monitored *continuously* and an order is placed when it drops to a specified value.
- Also called *fix ordered quantity system* or *(s;Q) system*

- **Ordering policy:** placing an order for *Q* whenever the inventory level reaches *s*.
  - when the inventory level reaches the reorder level (*s*), an order for quantity *Q* is placed.
  - when the order lead time (*L*) ends, the ordered amount arrives, raising the inventory level that has dropped below *s* in the meantime.

# Continuous Review System II.



https://youtu.be/rPZdWuOPaHY

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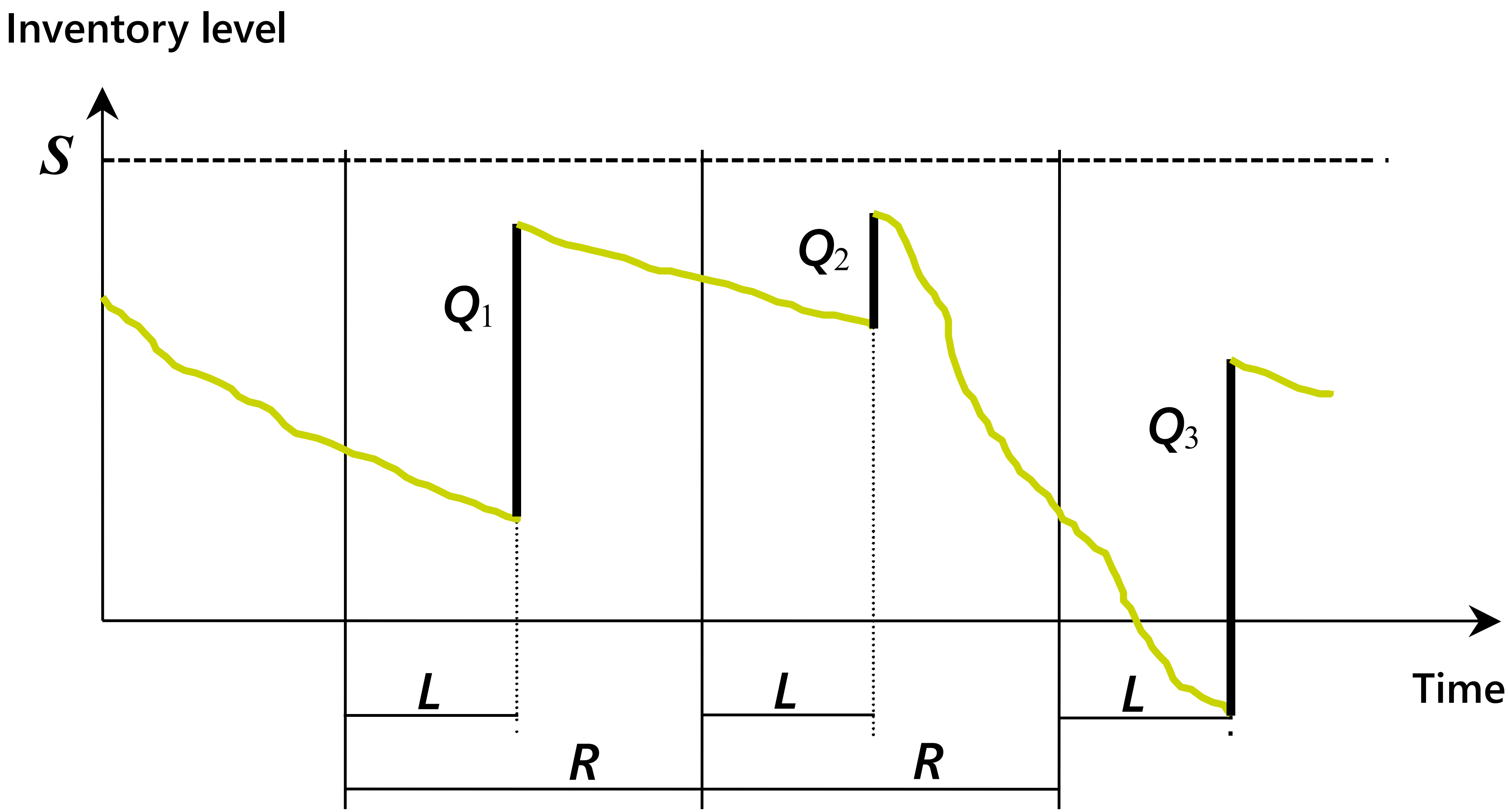
# Periodic Review System I.

- Orders are placed at regular intervals to raise the inventory level to a specified value.
- Also called *fix ordering period system* or *(R;S) system*

- **Ordering policy:** placing orders at regular intervals $R$ for amounts that bring up the inventory level to $S$.
  - when it is time to review the inventory level, an order is placed for the amount that brings the inventory on hand up to the target inventory level ($S$).
  - the ordered amount ($Q_i$) arrives at the end of the order lead time ($L$).
  - since the inventory level continues to fall during this time, the ordered amount will bring the inventory level up to a value that is less than $S$.

# Periodic Review System II.



# Differences between inventory review systems

- Continuous review systems are able to respond more flexibly to changes in demand → lower risk of stocking out.
- Periodic review systems are exposed to shortages during the order interval as well as during the lead time (R + L) → the probability of stocking out is greater.
- Periodic inventory reviews are easier to organize, continuous review requires checking if the inventory level has already dropped to *s* each time an item is removed from inventory.

# Costs of keeping inventory I.

- Unit purchasing cost
  - The price of a product (charged by the supplier)
  - OR the cost of manufacturing one
- Order cost
  - The cost of placing an order
  - Setup cost, resetting cost, cost of administration/ transportation, etc.

# Costs of keeping inventory II.

- Unit holding cost
  - The cost of holding one unit of an item in stock for a unit period of time
  - Generally is calculated as percentages of unit cost → holding cost rate
  - Damages, amortization, opportunity cost, etc.

- Shortage cost
  - Occurs when an item is needed but cannot be supplied
  - Cost of customer lost, loss of goodwill, loss of future sales, etc.

# Economic Order Quantity (EOQ)

- Q2: **how much to order** at a time?
- Optimizing method used for determining order quantity and reorder points and minimizing inventory costs.

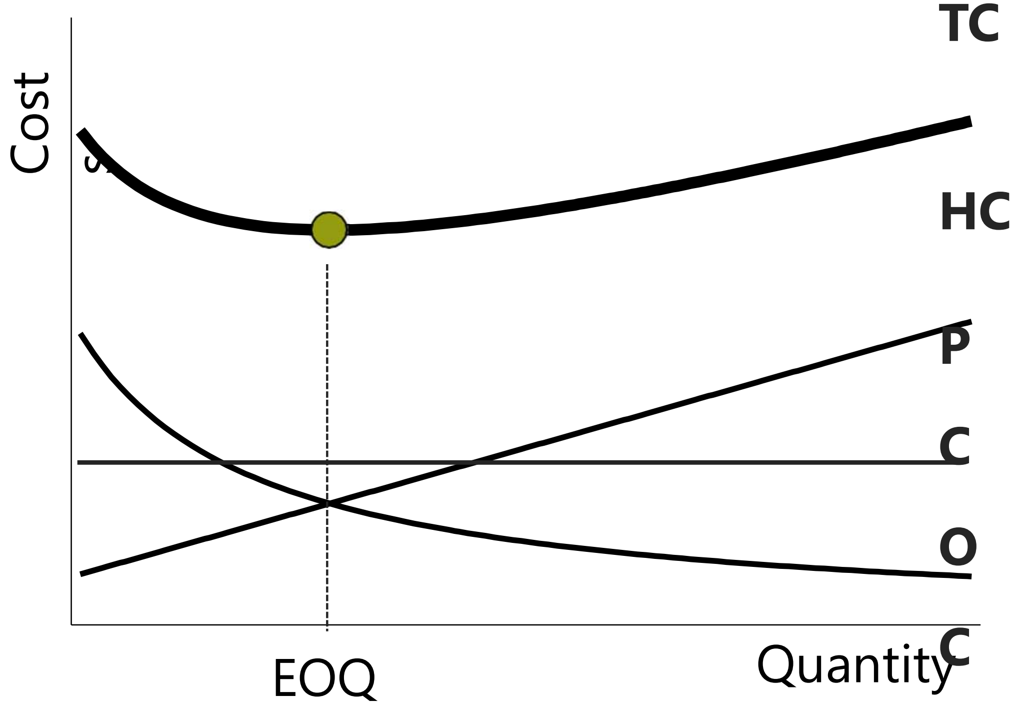
**Six assumptions**:

1. Demand is known and constant over a given period.
2. Lead time is zero.
3. The quantity ordered arrives at once.
4. All demand is met, shortages are not allowed.
5. Ordering and setup costs are fixed and constant (independent of the order size).
6. Holding costs are proportional to unit (item) costs.

# Relation between EOQ and total cost

- Large infrequent orders give high holding cost and low order cost; small frequent orders give low holding cost and high order cost

- Sum of these costs gives a U-shaped curve. The minimum of this curve shows the optimal order size



# Nomination in the model

- *D* – demand (known and constant)
- *v* – unit cost or value of an item
- *A* – ordering cost or ″administration cost″
- *r* – holding cost rate (percentage - %)
- *Q* – ordered quantity
- *EOQ* – economic order quantity
- $I_{avg}$ – average inventory level

# Calculating total costs of a period

- Total costs = purchasing costs + ordering costs + holding costs

$$TK\{Q\} = Dv + A\frac{D}{Q} + I_{Avg}vr$$

- At some points an order of size *Q* arrives, which is used at a constant rate until no stock is left → the inventory level varies between *Q* and 0, so the average level is

$$I_{Avg} = \frac{Q}{2}$$

- So the formula of total costs is

$$TK\{Q\} = Dv + A\frac{D}{Q} + \frac{Q}{2}vr$$

# Calculating the EOQ

- The minimum of the total cost curve is the optimal lot size

- So we derivate total cost with respect to *Q*, equate it with 0 and after some transformations we get the economic order quantity (EOQ)

$$Q_{OPT} = EOQ = \sqrt{\frac{2AD}{vr}}$$

- Principle of equilibrium: holding cost and ordering cost are equal

$$A\frac{D}{Q} = \frac{Q}{2}vr$$

# Cycle time and order numbers

- How long will the ordered quantity last? → cycle time

$$T = \frac{Q}{D}$$

If EOQ is ordered:

$$T_{EOQ} = \frac{EOQ}{D}$$

- *Q* and *D* are given in years, but we usually need *T* in days → conversion!

- How many times must orders be placed in a year?

$$N = \frac{D}{EOQ}$$

# Example

Let the demand for a product be an average of 3,600 units per year. The cost of one order is HUF 12,000. The purchase cost of one piece is HUF 2,500, and the annual inventory holding rate is 60%. Let's count on approximately 300 working days per year

a)How much the Economic order quantity?

b)How much is the cost of inventory politic?

c)How much time passes between two orders ?

d)What cost increase does ordering every six months cause?

# Example

$D$ = 3600 parts/year
$A$ = 12000 HUF
$v$ = 2500 HUF/parts

- r = 60% (0,6)
- 300 days

a)

b)

$$EOQ = \sqrt{\frac{2AD}{vr}} = \sqrt{\frac{2 \cdot 12\,000 \cdot 3\,600}{2\,500 \cdot 0{,}6}} = 240 \text{ parts}$$

$$TK\{240\} = 3\,600 \cdot 2\,500 + 12\,000 \cdot \frac{3\,600}{240} + \frac{240}{2} \cdot 2\,500 \cdot 0{,}6 =$$

c)

$$= 9\,000\,000 \text{ Ft} + 180\,000 \text{ Ft} + 180\,000 \text{ Ft} = 9\,360\,000 \text{ Ft.}$$

$$T_{\mathrm{EOQ}} = \frac{EOQ}{D} = \frac{240}{3600} = 0{,}0667 \text{ year} = 20 \text{ days}$$

# Example

d)

Ordered quantity:

$$Q = \frac{D}{2} = 1\,800 \text{ parts}$$

Cost:

$$TK(1800) = 3600 \cdot 2500 + 12\,000 \cdot \frac{3600}{1800} + \frac{1800}{2} \cdot 2500 \cdot 0,6 =$$

$$= 9\,000\,000 \text{ Ft} + 24\,000 \text{ Ft} + 1\,350\,000 \text{ Ft} = 10\,374\,000 \text{ Ft}$$

The cost change:

$$\Delta TK = \frac{TK(1800) - TK(240)}{TK(240)} = 0,1083 \quad \rightarrow \quad 10,83\%$$

# Calculation of the reorder level

- Q3: **When to place an order?** (if $L \neq 0$)
- Assumption: demand is still known and constant!

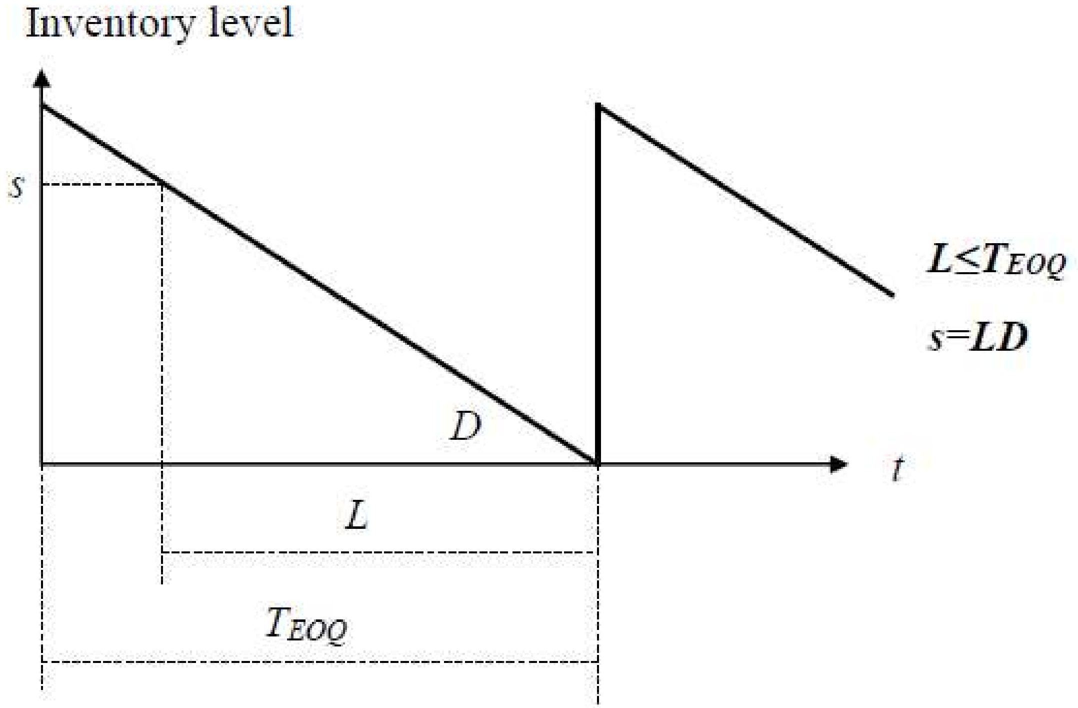
- **Objective**: order placements should be timed in such a way to ensure that the order is delivered when the inventory level hits zero

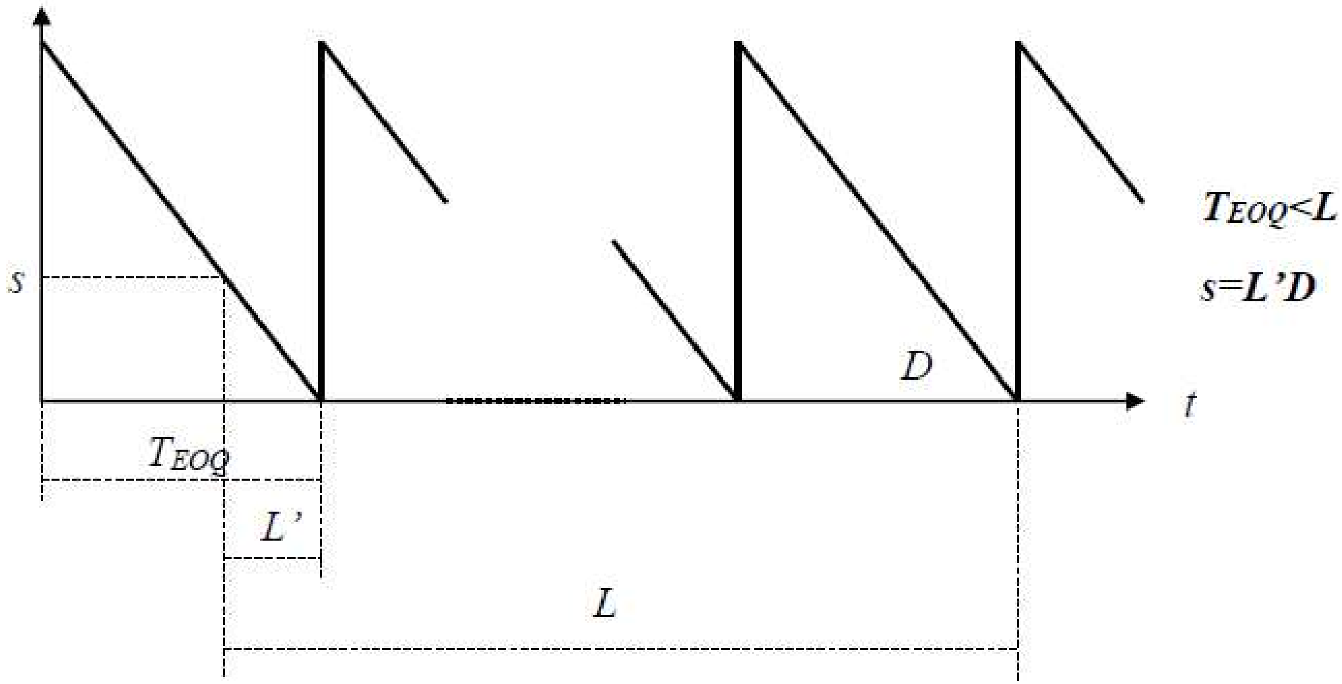
→ We have to determine *reorder inventory level* (and not the time!)

# The lead time

- How long will you have to wait before the new stock arrives? → lead time
- Two cases:

1. The order placed in a cycle arrives in *the same cycle* → the lead time is shorter than the cycle time
2. If the lead time is longer than the length of a cycle, then the ordered amount arrives in a *subsequent cycle*
   - full cycles don't affect the reorder level, we need to consider the remaining fraction of a cycle (modified lead time: $L'$)


Inventory level
s
D
t
L
$T_{EOQ}$
$L \leq T_{EOQ}$
$s = LD$


s
D
t
$T_{EOQ}$
L'
L
$T_{EOQ} < L$
$s = L'D$

# THANK YOU FOR YOUR ATTENTION!

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