جلسه سوم: ارتباط بین محصول و تولید

Product/Production Relationships

- Total number of product units = $Q_f = \sum_{j=1}^{P} Q_j$
- Product variety
  - Hard product variety = differences between products
  - Soft product variety = differences between models of products
- Product and part complexity
  - Product complexity n_p = number of parts in product
  - Part complexity n_o = number of operations per part

Product/Production Relationships - Product and Part Complexity

For a fabricated component, a possible measure of part complexity is the **number of processing steps** required to produce it.

An integrated circuit, which is technically a monolithic silicon chip with localized alterations in its surface chemistry, requires hundreds of processing steps in its fabrication.

Although it may measure only 9 mm (318 inch) on a side and is 0.5 mm (0.020 inch) thick, its complexity is orders of magnitude greater than a round washer of 9 mm (318 inch) outside diameter, stamped out of 0.8 mm (1132 inch) thick stainless steel in one step.

Product/Production Relationships - Product and Part Complexity

Complexity of an assembled product can be defined as the **number of distinct components**;

n_p = the number of parts per product.

Processing complexity of a part can be defined as the number of operations required to make it;

n_o = the number of operations or processing steps to make a part.

Some distinctions can be drawn among production plants on the basis of n_p and n_o by considering the three different types of plants: parts producers, pure assembly plants and vertically integrated plants .

n_p: Number of parts per product

Product (Approx. Date or Circa)	*Approx. Number of Components*
Mechanical pencil (modern)	10
Ball bearing (modern)	20
Rifle (1800)	50
Sewing machine (1875)	150
Bicycle chain	300
Bicycle (modern)	750
Early automobile (1910)	2000
Automobile (modern)	20,000
Commercial airplane (1930)	100,000
Commercial airplane (modern)	1,000,000
Space shuttle (modern)	10,000,000

n_o = the number Processing operations to make a part

Part	Approx. Number of Processing Operations	Typical Processing Operations Used
Plastic molded part	1	Injection molding
Washer (stainless steel)	1	Stamping
Washer (plated steel)	2	Stamping, electroplating
Forged part	3	Heating, forging, trimming
Pump shaft	10	Machining (from bar stock)
Coated carbide cutting tool	15	Pressing, sintering, coating, grinding
Pump housing, machined	20	Casting, machining
V-6 engine block	50	Casting, machining
Integrated circuit chip	75	Photolithography, various thermal and chemical processes

Production Plants Distinguished by n_o and n_p Values

Type of Plant	$n_p - n_o$ Parameter Values	Description
Parts producer	$n_p = 1, n_o > 1$	This type of plant produces individual components, and each component requires multiple processing steps.
Assembly plant	$n_p > 1, n_o = 1$	A pure assembly plant produces no parts. Instead, it purchases all parts from suppliers. In this pure case, we assume that one operation is required to assemble each part to the product (thus, $n_o = 1$).
Vertically integrated plant	$n_p > 1, n_o > 1$	The pure plant of this type makes all its parts and assembles them into its final products. This plant type also includes intermediate suppliers that make assembled items such as ball bearings, car seats, and so on for final product assembly plants.

Factory Operations Model

Simplified for purposes of conceptualization:

- Total number of product units $Q_f = PQ$
- Total number of parts produced $n_{pf} = PQn_p$
- Total number of operations $n_{of} = PQn_pn_o$

Limitations and Capabilities of a Manufacturing Plant

Manufacturing capability - the technical and physical limitations of a manufacturing firm and each of its plants

- Three dimensions of manufacturing capability:
  1. Technological processing capability - the available set of manufacturing processes
  2. Physical size and weight of product
  3. Production capacity (plant capacity) - production quantity that can be made in a given time

Manufacturing Models and Metrics

Sections:

1. Mathematical Models of Production Performance
2. Manufacturing Costs

Production Concepts and Mathematical Models

- Production rate R_p
- Production capacity *PC*
- Utilization *U*
- Availability *A*
- Manufacturing lead time *MLT*
- Work-in-progress *WIP*

Operation Cycle Time

Typical cycle time for a production operation:

$$T_c = T_o + T_h + T_{th}$$

where

T_c = cycle time,

T_o = processing time for the operation,

T_h = handling time (e.g., loading and unloading the production machine), and

T_{th} = tool handling time (e.g., time to change tools)

Production Rate

Batch production: batch time $T_b = T_{su} + QT_c$

Average production time per work unit $T_p = T_b/Q$

Production rate $R_p = 60/T_p$

Job shop production:

For $Q = 1$, $T_p = T_{su} + T_c$

For quantity high production:

$R_p = R_c = 60/T_p$ since $T_{su}/Q \rightarrow 0$

For flow line production

$T_c = T_r + \text{Max } T_o$ and $R_c = 60/T_c$

Production Capacity

Plant capacity for facility in which parts are made in one operation ($n_o = 1$):

$$PC_w = n\, S_w\, H_s\, R_p$$

where PC_w = weekly plant capacity, units/wk

Plant capacity for facility in which parts require multiple operations ($n_o > 1$):

$$PC_w = \frac{nS_wH_sR_p}{n_o}$$

where n_o = number of operations in the routing

Utilization and Availability

Utilization: $U = \dfrac{Q}{PC}$

where Q = quantity actually produced, and

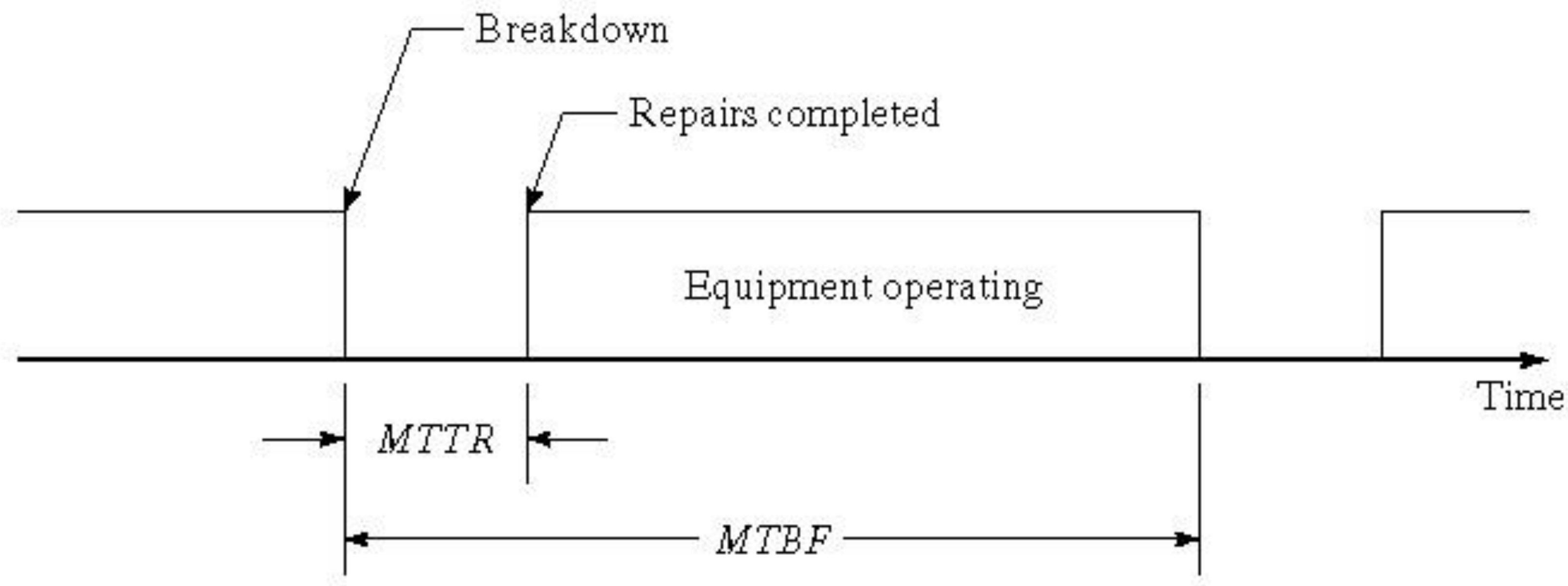
PC = plant capacity

Availability: $A = \dfrac{MTBF - MTTR}{MTBF}$

where $MTBF$ = mean time between failures, and

$MTTR$ = mean time to repair

Availability - *MTBF* and *MTTR* Defined



Manufacturing Lead Time

$$MLT = n_o\,(T_{su} + QT_c + T_{no})$$

where MLT = manufacturing lead time,

n_o = number of operations,

T_{su} = setup time,

Q = batch quantity,

T_c = cycle time per part, and

T_{no} = non-operation time

Work-In-Process

$$WIP = \frac{AU(PC)(MLT)}{S_w H_{sh}}$$

where WIP = work-in-process, pc;

A = availability, U = utilization,

PC = plant capacity, pc/wk;

MLT = manufacturing lead time, hr;

S_w = shifts per week,

H_{sh} = hours per shift, hr/shift

Costs of Manufacturing Operations

- Two major categories of manufacturing costs:
  1. Fixed costs - remain constant for any output level
  2. Variable costs - vary in proportion to production output level
- Adding fixed and variable costs

$$TC = FC + VC(Q)$$

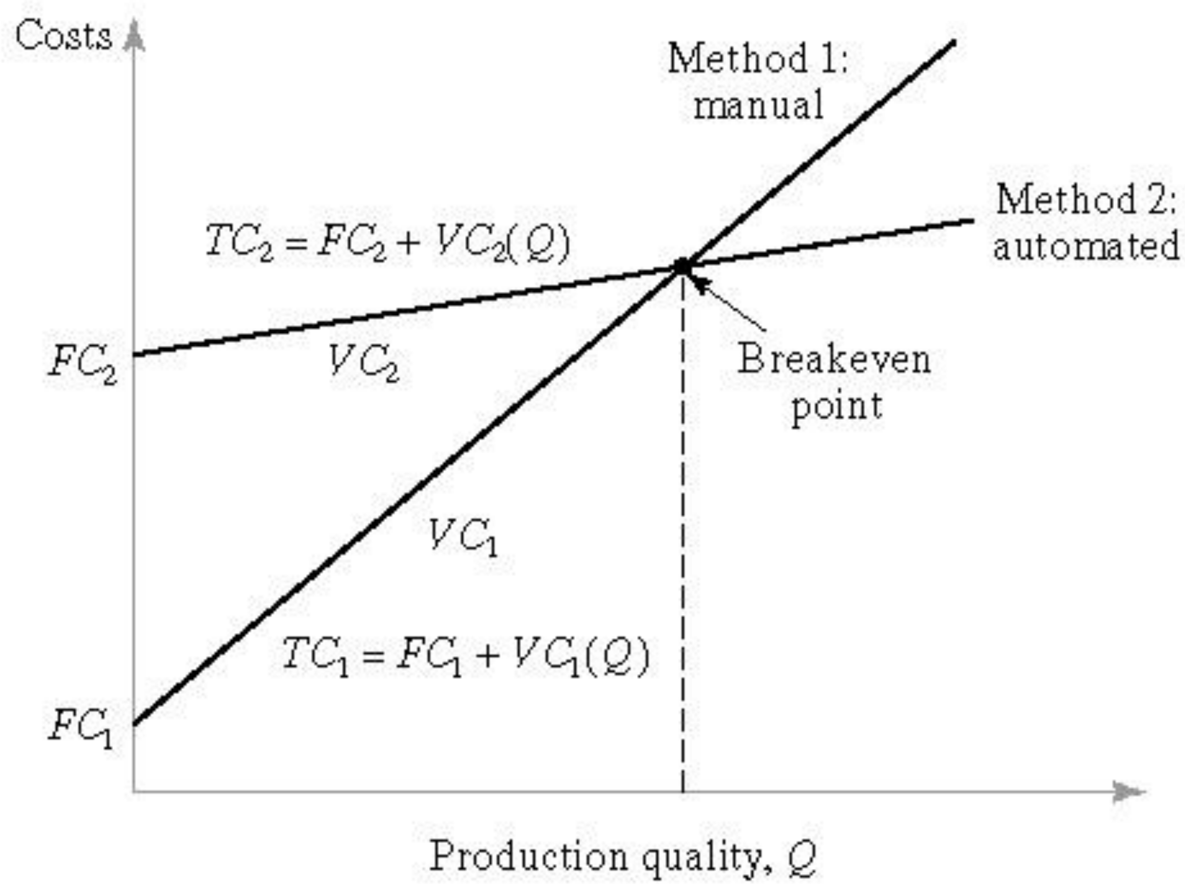
where TC = total costs,

FC = fixed costs (e.g., building, equipment, taxes),

VC = variable costs (e.g., labor, materials, utilities),

Q = output level.

Fixed and Variable Costs



Manufacturing Costs

- Alternative classification of manufacturing costs:
    1. Direct labor - wages and benefits paid to workers
    2. Materials - costs of raw materials
    3. Overhead - all of the other expenses associated with running the manufacturing firm
        - Factory overhead
        - Corporate overhead

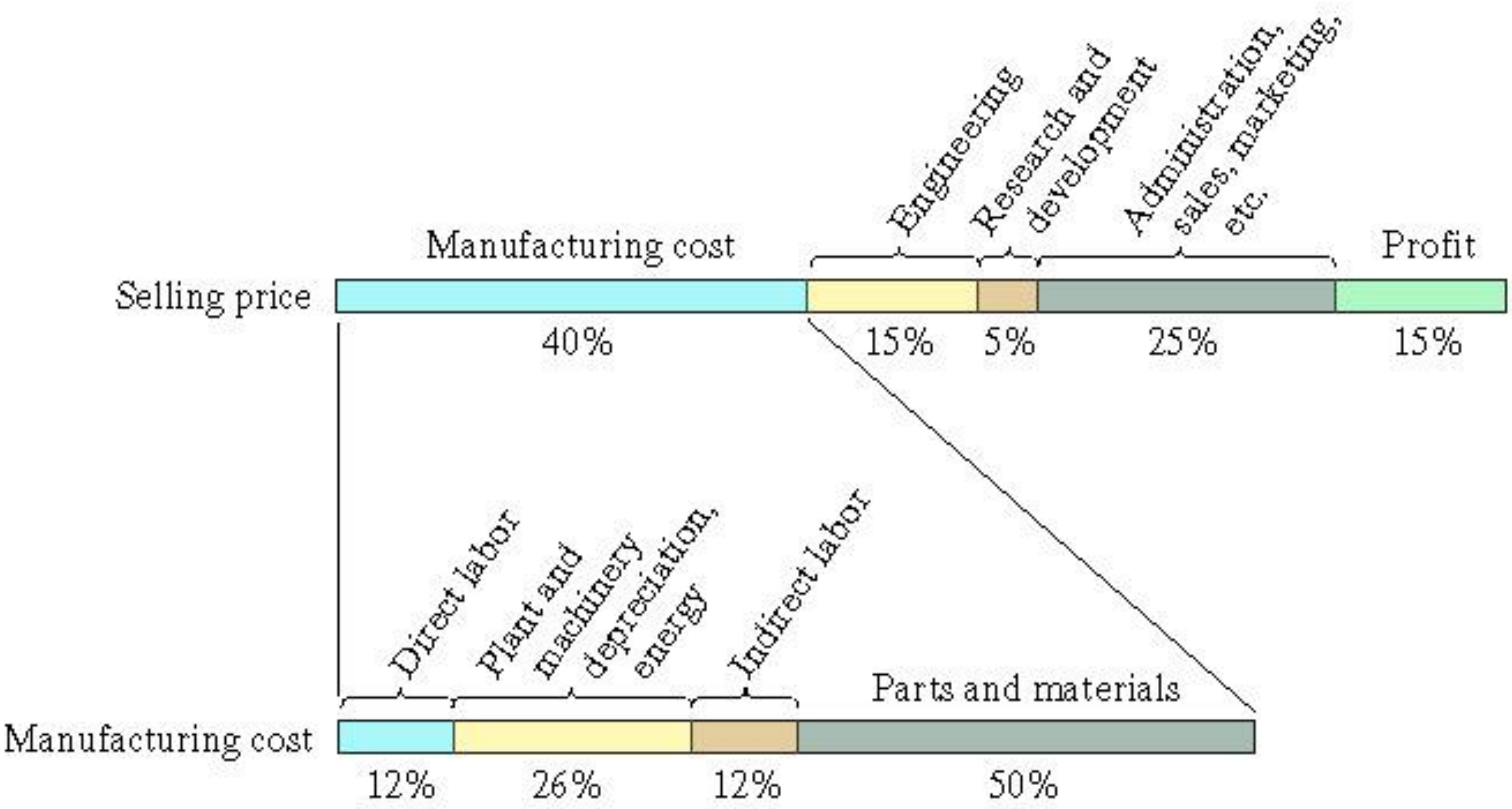
TABLE 2.7 Typical Factory Overhead Expenses

Plant supervision	Applicable taxes
Line foreman	Insurance
Maintenance crew	Heat and air conditioning
Custodial services	Light
Security personnel	Power for machinery
Tool crib attendant	Factory depreciation
Material handling	Equipment depreciation
Shipping and receiving	Fringe benefits

TABLE 2.8 Typical Corporate Overhead Expenses

Corporate executives	Applicable taxes
Sales and marketing	Cost of office space
Accounting department	Security personnel
Finance department	Heat and air conditioning
Legal counsel	Light
Engineering	Insurance
Research and development	Fringe benefits
Other support personnel	Other office costs

Typical Manufacturing Costs



Overhead Rates

Factory overhead rate:

$$FOHR = \frac{FOHC}{DLC}$$

Corporate overhead rate:

$$COHR = \frac{COHC}{DLC}$$

where DLC = direct labor costs

Cost of Equipment Usage

Hourly cost of worker-machine system:

$$C_o = C_L(1 + FOHR_L) + C_m(1 + FOHR_m)$$

where C_o = hourly rate, \$/hr;

C_L = labor rate, \$/hr;

$FOHR_L$ = labor factory overhead rate,

C_m = machine rate, \$/hr;

$FOHR_m$ = machine factory overhead rate