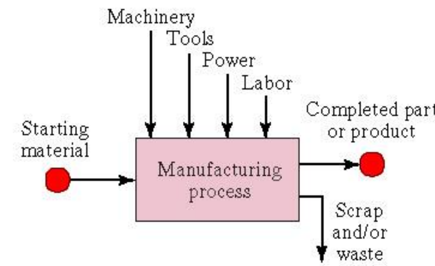
Sistem Produksi

Manufacturing Defined - Technological Definition

- Manufacturing is the application of physical and chemical processes to alter the geometry, properties, and/or appearance of a given starting material to make parts or products
  - Manufacturing includes the joining of multiple parts to make assembled products
  - The process that accomplish manufacturing involve a combination of machinery, tools, power, and manual labor
  - Manufacturing is almost always carried out as a sequence of operations

Manufacturing Defined - Technological Definition

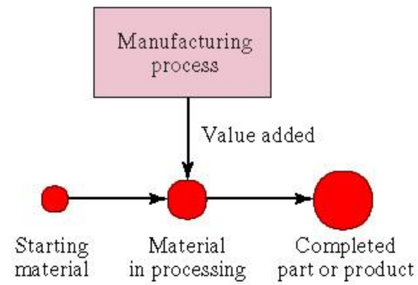


Manufacturing Defined - Economic Definition

Transformation of materials into items of greater value by means of one or more processing and/or assembly operations

- Manufacturing *adds value* to the material
- Examples:
  - Converting iron ore to steel adds value
  - Transforming sand into glass adds value
  - Refining petroleum into plastic adds value

Manufacturing Defined - Economic Definition



Manufacturing Industries

- Industry consists of enterprises and organizations that produce and/or supply goods and/or services
- Industries can be classified as
  - Primary Industries → cultivate and exploit natural sources
    - Examples: agriculture, mining
  - Secondary Industries → convert the output of the primary industries into products, include construction and power utilities
    - Examples: manufacturing, power generation, construction
  - Tertiary industries – service sector
    - Examples: banking, education, government, legal services, retail trade, transportation

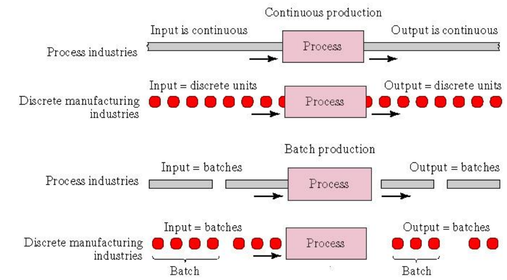
Manufacturing Industries

- Industries can be distinguished as
  - Process industries → chemicals, pharmaceuticals, petroleum, basic metals, food, beverages, and electric power generation
    - Continuous production
    - Batch production
  - Discrete parts and products industries → automobiles, aircraft, appliances, computers, machinery, and the component parts that these products are assembled from
    - Continuous production
    - Batch production

Manufacturing Industries

- Production operation in the process industries and the discrete product industries can be divided into:
  - Continuous Production → occurs when the production equipment is used exclusively for the given product, and the output of the product is uninterrupted
  - Batch Production → occurs when the materials are processed in finite amounts or quantities

Process Industries and Discrete Manufacturing Industries



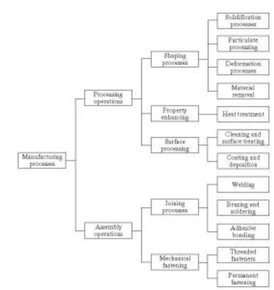
Manufactured Products

- Final products made by industries can be divided into two major classes
  - Consumer goods → products purchased directly by consumers
  - Capital goods → products purchased by other companies to produce goods and supply services
- (+) There are companies in industry whose business primarily to produce materials, components, and supplies for the company that make the final products

Manufacturing Operations

- Processing and assembly operations
- Material handling and storage
- Inspection and testing
- Coordination and control

Classification of manufacturing processes



Processing Operations

- Transform a work material from one state of completion to a more advanced state that is closer to the final desired part or product
- Add value by changing the geometry, properties, or appearance of the starting material
- Are performed on discrete workparts, but some are also applicable to assembled items
- Use energy to alter a workpart's shape, physical properties, or appearance → mechanical, thermal, electrical, chemical

Processing Operations

- Categories of processing operations:
  - Shaping operations
    - Apply mechanical force or heat or other forms and combination of energy to effect a change in geometry of the work material.
    - Classification based on the state of the starting material:
      - Solidification processes: casting, molding
      - Particulate processing: pressing
      - Deformation processes: forging, extrusion, rolling, drawing, forming, bending
      - Material removal processes: turning, drilling, milling, grinding, non-traditional processes
  - Property-enhancing operations
    - Are designed to improve mechanical or physical properties of the work material
    - Classification: heat treatments, sintering
  - Surface processing operations
    - Cleaning, surface treatments, coating and thin film deposition processes

Assembly Operations

- Join two or more components to create a new entity, which is called assembly, subassembly, or some other term that refers to the specific joining process
- Classification:
  - Permanent joining processes: welding, brazing, soldering, adhesive bonding, rivets, fitting, expansion fits
  - Semi-permanent joining process: mechanical assembly
    - threaded fasteners – screws, bolts, nuts
    - Rivets
    - Interference fits (e.g., press fitting, shrink fits)
    - Other

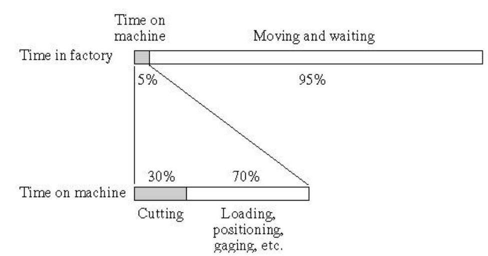
Material Handling and Storage

- A means of moving and storing materials between processing and/or assembly is usually required
- In most manufacturing plants, materials spend more time being moved and stored than being processed
- In some cases, the majority of the labor cost in the factory is consumed in handling, moving, and storing materials
- It is important that this function be carried out as efficiently as possible

Material Handling

- Material transport
  - Vehicles, e.g., forklift trucks, AGVs, monorails
  - Conveyors
  - Hoists and cranes
- Storage systems
- Unitizing equipment
- Automatic identification and data capture (AIDC)
  - Bar codes
  - RFID
  - Other AIDC equipment

Time Spent in Material Handling



Inspection and Test

- Are quality control activities
- The purpose of inspection is to determine whether the manufactured product meets the established design standards and specifications
  - Inspection for variables - measuring
  - Inspection of attributes – gaging
- Testing is generally concerned with the functional specifications of the final product rather than with the individual parts that go into the product
  - observing the product (or part, material, subassembly) during actual operation or under conditions that might occur during operation

Coordination and Control

Includes:

- Regulation of the individual processing and assembly operations (Control at the process level involves the achievement of certain performance objective by properly manipulating the inputs and other parameters of the process)
  - Process control
  - Quality control
- Management of plant level activities (Control at the plant level includes effective use of labor, maintenance of the equipment, moving materials in the factory, controlling inventory, shipping products of good quality on schedule, and keeping plant operating costs at a minimum possible level)
  - Production planning and control
  - Quality control

PRODUCT/PRODUCTION RELATIONSHIPS

Product/Production Relationships

- Product parameters that are influential in determining how the products are manufactured:
  - Production Quantity
  - Product Variety
  - Complexity of Assembled Products
  - Complexity of Individual Parts

Production Quantity and Product Variety

- Q = production quantity
- P = product variety
- QP = product variety and product quantity relationships

Production Quantity and Product Variety

- Q = the number of units of a given part or product that are produced annually by a plant
- Q_j = annual quantity of style j
- Q_f = total quantity of all parts or products made in the factory
- P = total number of different part or product styles
- j = subscript to identify each part or product style; j = 1, 2, …, P

$$Q_f = \sum_{j=1}^{P} Q_j$$

Production Quantity and Product Variety

- P = the different product designs or types that are produced in a plant
- P1 = the number of distinct product lines produced by the factory (hard product variety)
- P2 = the number of models in a product line (soft variety)

$$P = \sum_{j=1}^{P1} P2_j$$

Product and Part Complexity

- Indicator of product complexity: Its number of components
- Indicator part complexity: The number processing steps required to produce it
- n_p = the number of parts per product
- n_o = the number of operations or processing steps to make a part

Product and Part Complexity

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 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.

Product and Part Complexity

- n_{pf} = total number of parts made in the factory (pc/yr)
- Q_j = annual quantity of product style j (products/yr)
- n_{pj} = number of parts in product j (pc/product)

$$n_{pf} = \sum_{j=1}^{P} Q_j n_{pj}$$

Product and Part Complexity

- n_{of} = total number of operation cycles performed in the factory (ops/yr)
- n_{ojk} = number of processing operations for each part k, summed over the number of parts in product j, n_{pj}

$$n_{of} = \sum_{j=1}^{P} Q_j \sum_{k=1}^{n_{pj}} n_{ojk}$$

Product and Part Complexity

- Assuming that the number of product designs P are produced in equal quantities Q, all products have the same number of components n_p, and all components require an equal number of processing steps n_s
- The total number of product units produced by the factory is given by

$$Q_f = PQ$$

Product and Part Complexity

- The total number of parts produced by the factory is given by

$$n_{pf} = PQn_p$$

- The total number of manufacturing operation cycles performed by the factory is given by

$$n_{of} = PQn_p n_o$$

Limitations and Capabilities of a Manufacturing Plant

- Manufacturing capability refers to the technical and physical limitations of a manufacturing firm and each of its plants
- Dimensions:
  - Technological processing capability
  - Physical size and weight of product
  - Production capacity

Examples (1)

- A company specializes in consumer photographic products. It produces only cameras and projectors. In its camera line it offers 15 different models, and in its projector line it offers five models. The totality of product models offered is given by ….

Examples (2)

- Suppose a company has designed a new product line and is planning to build a new plant to manufacture this product line. The new line consists of 100 different product types, and for each product type the company wants to produce 10,000 units annually. The products average 1,000 components each ,and the average number of processing steps required for each component is 10. All parts will be made in the factory. Each processing step takes an average of 1 min. Determine:
  - How many products;
  - How many parts;
  - How many production operations will be required each year; and
  - How many workers will be needed for the plant, if it operates one shift for 250 day/yr?

PRODUCTION CONCEPTS AND MATHEMATICAL MODELS

Production Concepts And Mathematical Models

- A number of production concepts are quantitative, or they require quantitative approach to measure them
- The models developed in this section are ideal in the sense that they neglect some of the realities and complications that are present in the factory
  - Ours models do not include the effect of scrap rates

Production Concepts And Mathematical Models

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

Production Rate

- The production rate for an individual processing or assembly operation is usually expressed as an hourly rate, that is parts or products per hour
- Three types of production:
  - Job shop production
  - Batch production
  - Mass production

Production Rate

- T_c = the operation cycle time
  - The time that one work unit spends being processed or assembled/the time between when one work unit begins processing (or assembly) and when the next unit begins)
  - The time an individual part spends at the machine, but not all of this time is productive
  - In a typical processing operation, such as machining, Tc consists of:
    - Actual machining operation time
    - Workpart handling time
    - Tool handling time per workpiece
      - Time changing from one tool to the next, tool indexing time for indexable inserts or for tools on a turret lathe or turret drill, tool repositioning for a next pass, and so on → some activities do not occur every cycle; they must be spread over the number of parts between their occurences to obtain an average time per workpiece

Production Rate

- T_c = operation cycle time (min/pc)
- T_o = time of the actual processing or assembly operation (min/pc)
- T_h = handling time (min/pc)
  - e.g., loading and unloading the production machine
- T_{th} = tool handling time (min/pc)
  - e.g., time to change tools

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

Production Rate: Batch Production

- The time to process one batch consisting of Q work units is the sum of the setup time and processing time

$$T_b = T_{su} + QT_c$$

- T_b = batch processing time (min)
- T_{su} = setup time to prepare for the batch (min)
- Q = batch quantity (pc)
- T_c = operation cycle time per work unit (min/pc)

Production Rate: Batch Production

- We assume that one work unit is completed each cycle and so T_c also has units of min/pc
- If more than one part is produced each cycle, then the equation must be adjusted accordingly
- Dividing batch time by batch quantity, we have the average production time per work unit T_p for the given machine:

$$T_p = \frac{T_b}{Q}$$

Production Rate: Batch Production

- The average production rate for the machine is simply the reciprocal of production time
- It is usually expressed as an hourly rate

$$R_p = \frac{60}{T_p}$$

- R_p = hourly production rate (pc/hr)
- T_p = average production time per minute (min/pc)
- The constant 60 converts minutes to hours

Production Rate: Job Shop Production

- When quantity **Q = 1**, the production time per work unit is the sum of setup and operation cycle times

$$T_p = T_{su} + T_c$$

- When the quantity is greater than one, then this reverts to the batch production case

Production Rate: Mass Production

- For quantity type mass production, we can say that the production rate equals the cycle rate of the machine (reciprocal of operation time) after production is underway and the effects of setup time become insignificant
- That is, as Q becomes very large (T_{su}/Q) → 0 and

$$R_p \to R_c = \frac{60}{T_c}$$

- R_c = operation cycle rate of the machine (pc/hr)
- T_c = operation cycle time (min/pc)

Production Rate: Flow line mass Production

- The production rate approximates the cycle rate of the production line, again neglecting setup time
- The cycle time of a production line is the sum of the longest processing (or assembly) time plus the time to transfer work units between stations

$$T_c = T_r + \max T_o$$

- T_c = cycle time of the production line (min/cycle)
- T_r = time to transfer work units between stations each cycle (min/pc)
- Max T_o = operation time at the bottleneck station (the maximum of the operation times for all stations on the line, min/cycle)

Production Rate: Flow line mass Production

- Theoretically, the production rate can be determined by taking the reciprocal of T_c

$$R_c = \frac{60}{T_c}$$

- R_c = theoretical or ideal production rate or the cycle rate (cycles/hr)
- T_c = ideal cycle time

Production Capacity

- Is defined as the maximum rate of output that a production facility (or production line, work center, or group of work centers) is able to produce under a given set of assumed operating conditions
- The production facility refers to a plant or factory, and so term plant capacity is often used for this measure
- The assumed operating conditions refer to the number of shifts per day (one, two, or three), number of days in the week (or month) that the plant operates, employment levels, and so forth

Production Capacity

- Quantitative measures of plant capacity can be developed based on production rate models derived earlier
- PC = the production capacity of a given facility under consideration
- The measure of capacity = the number of units produced per week
- n = the number of machines or work centers in the facility
- The machine or work center capable of producing at a rate R_p unit/hr
- Each work center operates for H hr/shift
- Provision for setup time is included in R_p
- S = the number of shifts per week

Production Capacity

- PC = production capacity of the facility (output units/wk)
- n = number of work centers producing in the facility
- S = number of shifts per period (shift/wk)
- H = hr/shift
- R_p = hourly production rate of each work center (output units/hr)

$$PC = nSHR_p$$

Example 3

- The turret lathe section has six machines, all devoted to the production of the same part. The section operates 10 shift/wk. The number of hours per shift averages 8.0. Average production rate of each machines is 17 unit/hr. Determine the weekly production capacity of the turret lathe section

Production Capacity

- If we include the possibility that each work unit is routed through no operations, with each operation requiring a new setup on either the same or a different machine, than the plant capacity equation must be amended as follows

$$PC = \frac{nSHR_p}{n_o}$$

- n_o = number of distinct operations through which work units are routed

Production Capacity

- Changes that can be made to increase or decrease plant capacity over the short term
  - Change the number of shifts per week
  - Change the number of hours worked per shift
- Over the intermediate or longer term, the following changes can be made to increase plant capacity
  - Increase the number of work centers, n, in the shop by using the equipment that was formerly not in use and hiring new workers
  - Increase the production rate, R_p, by making improvement in methods or process technology
  - Reduce the number of operations no required per work unit by using combined operations, simultaneous operations, or integrations of operations

Utilization and Availability

- Utilization refers to the amount of output of a production facility relative to its capacity

$$U = \frac{Q}{PC}$$

- U = utilization of the facility
- Q = actual quantity produced by the facility during a given time period (pc/wk)
- PC = production capacity from the same period (pc/wk)

Utilization and Availability

- Utilization can be accessed for an entire plant, a single machine in the plant, or any productive resource (i.e., labor)
- For convenience, it is often defined as the proportion of time that the facility operating relative to the time available under the definition of capacity
- Utilization is usually expressed as a percentage

Example 4

- A production machine operates 80 hr/wk (two shift, 5 days) at full capacity. Its production rate is 20 unit/hr. during a certain week, the machine produced 1000 parts and was idle the remaining time.
- (a) determine the production capacity of the machine
- (b) what was the utilization of the machine during the week under consideration?

Utilization and Availability

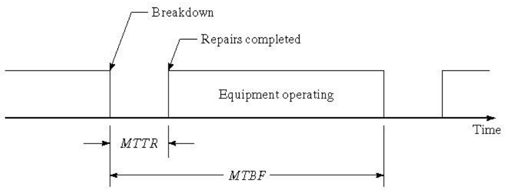
- Availability is a common measure of reliability for equipment
- It is especially appropriate for automated production equipment
- Availability is defined using two other reliability terms
  - Mean time between failure (MTBF): indicates the average length of time the piece of equipment runs between breakdowns
  - Mean time to repair (MTTR): indicates the average time required to service the equipment and put it back into operation when a breakdown occurs
- Availability is typically expressed as a percentage
- When a piece of equipment is brand new (and being debugged), and later when it begins to age, its availability tends to be lower

Utilization and Availability

- A = availability
- MTBF = mean time between failure (hr)
- MTTR = mean time to repair (hr)

$$A = \frac{MTBF - MTTR}{MTBF}$$

Availability - *MTBF* and *MTTR* Defined



Example 5

- Consider previous Example 3. Suppose the same data from that example were applicable, but that the availability of the machines A = 90%, and the utilization of the machines U = 80%. Given this additional data, compute the expected plant output.

Manufacturing Lead Time

- Manufacturing lead time (MLT) is defined as the total time required to process a given part or product through the plant
- Production usually consists of a series of individual processing and assembly operations
- Between the operations are material handling, storage, inspections, and other nonproductive activities
- The activities of production:
  - An operation: is performed on a work unit when it is in the production machine
  - The nonoperation elements include handling, temporary storage, inspections, and other sources of delay when the work unit is not in the machine

Manufacturing Lead Time

- T_c = the operation cycle time at a given machine or workstation
- T_{no} = the nonoperation time associated with the same machine
- n_o = the number of separate operations (machines) through which the work unit must be routed to be completely processed
- T_{su} = the setup time required to prepare each production machine for particular product

Manufacturing Lead Time

- MLT_j = manufacturing lead time for part or product j (min)
- T_{suji} = setup time for operation i (min)
- Q_j = quantity of part or product j in the batch being processed (pc)
- T_{cji} = operation cycle time for operation i (min/pc)
- T_{noji} = nonoperation time associated with operation i (min)
- i = the operation sequences in the processing; i = 1, 2, …, n_{oj}

$$MLT_j = \sum_{i=1}^{n_{oj}} \left(T_{suji} + Q_j T_{cji} + T_{noji}\right)$$

Manufacturing Lead Time

- Assume that all setup times, operation cycle times, and nonoperation times are equal for the n_{oj} machines
- Suppose that the batch quantities of all parts or products processed through the plant are equal and that they are all processed through the same number of machines, so that n_{oj} = n_o

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

Example 6

- A certain part is produced in a batch size of 100 units. The batch must be routed through five operations to complete the processing of the parts. Average setup time is 3 hr/operation, and average operation time is 6 min (0.1 hr). Average nonoperation time due to handling, delays, inspections, etc., is 7 hours for each operation. Determine how many days it will take to complete the batch, assuming the plant runs one 8-hr shift/day.

Manufacturing Lead Time

- For a job shop in which the batch size is one (Q = 1)

$$MLT = n_o\left(T_{su} + T_c + T_{no}\right)$$

Manufacturing Lead Time

- For mass production, the term Q is very large and dominates the other terms
- In the case of quantity type mass production in which a large number of units are made on a single machine (n_o = 1), the MLT simply becomes the operation cycle time for the machine after the setup has been completed and productions begins

Manufacturing Lead Time

- For flow line mass production, the entire production line is set up in advance
- The nonoperation time between processing steps is simply the transfer time T_r to move the part or product from one workstation to the next
- The station with the longest operation time sets the pace for all stations

Manufacturing Lead Time

- For flow line mass production
- MLT = time between start and completion of a given work unit on the line (min)
- n_o = number of operations on the line
- T_r = transfer time (min)
- Max T_o = operation time at the bottleneck station (min)
- T_c = cycle time of the production line (min/pc)

$$MLT = n_o(T_r + \max T_o) = n_o T_c$$

Manufacturing Lead Time

- Since the number of station is equal to the number of operations (n = n_o)

$$MLT = n(T_r + \max T_o) = nT_c$$

Work-in-Process

- Is the quantity of parts or products currently located in the factory that are either being processed or are between processing operations
- Is inventory that is in the state of being transformed from raw material to finished product
- Represents an investment by the firm, but one that cannot be turned into revenue until all processing has been completed

Work-in-Process

- WIP = work-in-process in the facility (pc)
- A = availability
- U = utilization
- PC = production capacity of the facility (pc/wk)
- MLT = manufacturing lead time (wk)
- S = number of shifts per week (shift/wk)
- H = hours per shift (hr/shift)

$$WIP = \frac{AU(PC)(MLT)}{SH}$$

Example 7

- Part rata-rata yang dibuat pada pabrik manufaktur batch tertentu harus diproses rata-rata melalui 4 (empat) mesin (1 mesin = 1 operasi). Dua puluh lima batch part baru dikeluarkan setiap minggu. Waktu rata-rata operasi = 9 menit. Waktu rata-rata persiapan (setup) = 6 jam. Ukuran rata-rata batch = 40 part. Dan waktu rata-rata non-operasi tiap batch = 8 jam/mesin. Terdapat 16 mesin di dalam pabrik. Pabrik beroperasi rata-rata 80 jam per minggu. Laju pembuangan material (scrap) diabaikan. Availability = 90%. Tentukan besarnya Work-In-Process!

Costs of Manufacturing Operations

Costs of Manufacturing Operations

- Fixed and variable costs
- Direct labor, material, and overhead
- Cost of equipment usage

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:

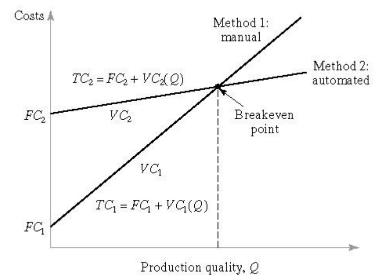
TC = total costs,

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

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

Q = output level

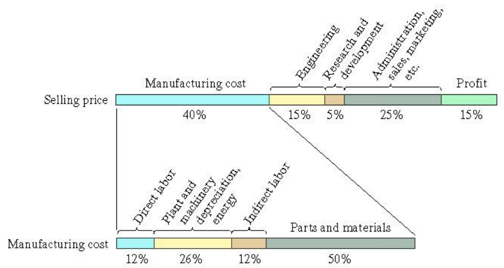
Fixed and Variable Costs



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

Typical Manufacturing Costs



Overhead Rates

- Factory Overhead

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

- Corporate Overhead

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

- Where DLC = direct labor cost

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

End of This Chapter