Chapter 6
Lecture # 1-3

- **Overview of Chapter 6.**
- **Factors Affecting the Cost of Manufacturing A Chemical Product COM.**
- **Labor Cost**

Overview of Chapter 6

Title: **Estimation of Manufacturing Cost**

Topics:

Methods to relate the total cost of manufacturing to five elements: 1) fixed capital investment, 2) cost of operating labor, 3) cost of raw materials, 4) cost of utilities, and 5) cost of waste treatment .

Factors Affecting the COM

- Direct Costs
  - Vary with production rate
- Fixed Costs
  - Do not vary with production rate
- General Expenses
  - Costs associated with management levels not directly related to the manufacturing process – overhead burden

Factors Affecting the COM

Table 6.1 Factors Affecting the Cost of Manufacturing (COM), for a Chemical Product (from references [1, 2 and 3])

Factor	Description of Factor
1. Direct costs	**Factors that vary with the rate of production**
A. Raw materials	Costs of chemical feed stocks required by the process. Flowrates obtained from the PFD.
B. Waste treatment	Costs of waste treatment to protect environment.
C. Utilities	Costs of utility streams required by process. Includes but not limited to: a. Fuel gas, oil, and/or coal b. Electric power c. Steam (all pressures) d. Cooling water e. Process water f. Boiler feed water g. Instrument air h. Inert gas (nitrogen) etc. i. Refrigeration Flowrates for utilities found on the PFD/PIDs
D. Operating labor	Costs of personnel required for plant operations.
E. Direct supervisory and clerical labor	Cost of administrative/engineering and support personnel.
F. Maintenance and repairs	Costs of labor and materials associated with the maintenance.
G. Operating supplies	Costs of miscellaneous supplies that support daily operation not considered to be raw materials. Examples include chart paper, lubricants, miscellaneous chemicals, filters, respirators and protective clothing for operators, etc.
H. Laboratory charges	Costs of routine and special laboratory tests required for product quality control and troubleshooting.
I. Patents and royalties	Cost of using patented or licensed technology.

Factors Affecting the COM

Table 6.1 Factors Affecting the Cost of Manufacturing (COM), for a Chemical Product (from references [1, 2 and 3])

Factor	Description of Factor
2. Fixed costs	**Factors not affected by the level of production**
A. Depreciation	Costs associated with the physical plant (buildings, equipment, etc.). Legal operating expense for tax purposes.
B. Local taxes and insurance	Costs associated with property taxes and liability insurance. Based on plant location and severity of the process.
C. Plant overhead costs (sometimes referred to as factory expenses)	Catch-all costs associated with operations of auxiliary facilities supporting the manufacturing process. Costs involve payroll and accounting services, fire protection and safety services, medical services, cafeteria and any recreation facilities, payroll overhead and employee benefits, general engineering, etc.

Factors Affecting the COM

Table 6.1 Factors Affecting the Cost of Manufacturing (COM), for a Chemical Product (from references [1, 2 and 3])

Factor	Description of Factor
3. General expenses	**Costs associated with management level and administrative activities not directly related to the manufacturing process**
A. Administration costs	Costs for administration. Includes salaries, other administration, buildings, and other related activities.
B. Distribution and selling costs	Costs of sales and marketing required to sell chemical products. Includes salaries and other miscellaneous costs.
C. Research and development	Costs of research activities related to the process and product. Includes salaries and funds for research-related equipment and supplies, etc.

Factors Affecting the COM

Cost of Manufacture (COM)	=
Direct Manufacture Costs (DMC)	+
Fixed Manufacturing Costs (FMC)	+
General Expenses (GE)	

Factors Affecting the COM

The cost of manufacturing, *COM*, can be determined when the following costs are known or can be estimated:

1. Fixed capital investment (*FCI*): (C_{TM} or C_{GR})
2. Cost of operating labor (C_{OL})
3. Cost of utilities (C_{UT})
4. Cost of waste treatment (C_{WT})
5. Cost of raw materials (C_{RM})

Factors Affecting the COM

- *FCI* – Chapter 5 C_{TM} or C_{GR}
- C_{RM}
- C_{UT}
- C_{WT}
- C_{OL}

Factors Affecting the COM

Table 6.2 Multiplication Factors Estimating Manufacturing Cost† (See also Table 6.1)

Cost Item from Table 6.1	Typical Range of Multiplying Factors	Value Used in Text
1. Direct manufacturing costs		
a. Raw materials	C_{RM}*	
b. Waste treatment	C_{WT}*	
c. Utilities	C_{UT}*	
d. Operating labor	C_{OL}	C_{OL}
e. Direct supervisory and clerical labor	$(0.1 - 0.25)C_{OL}$	$0.18C_{OL}$
f. Maintenance and repairs	$(0.02 - 0.1)FCI$	$0.06FCI$
g. Operating supplies	(0.1 – 0.2)(Line 1.F.)	$0.009FCI$
h. Laboratory charges	$(0.1 - 0.2)C_{OL}$	$0.15C_{OL}$
i. Patents and royalties	$(0 - 0.06)COM$	$0.03COM$
Total direct manufacturing costs	$\boldsymbol{C_{RM} + C_{WT} + C_{UT} + 1.33C_{OL} + 0.03COM + 0.069FCI}$	

Factors Affecting the COM

Table 6.2 Multiplication Factors Estimating Manufacturing Cost† (See also Table 6.1)

Cost Item from Table 6.1	Typical Range of Multiplying Factors	Value Used in Text
2. Fixed manufacturing costs		
a. Depreciation	$0.1FCI$‡	$0.1FCI$‡
b. Local taxes and insurance	$(0.014 - 0.05)FCI$	$0.032FCI$
c. Plant overhead costs	$(0.50 - 0.7)$(Line 1.D. + Line 1.E. + Line 1.F.)	$0.708C_{OL} + 0.036FCI$
Total fixed manufacturing costs	$\mathbf{0.708C_{OL} + 0.068FCI}$ **+ depreciation**	
3. General manufacturing expenses		
a. Administration costs	0.15(Line 1.D. + Line 1.E.+ Line 1.F.)	$0.177C_{OL} + 0.009FCI$
b. Distribution and selling costs	$(0.02 - 0.2)COM$	$0.11COM$
c. Research and development	$0.05COM$	$0.05COM$
Total general manufacturing costs	$\mathbf{0.177C_{OL} + 0.009FCI + 0.16COM}$	
TOTAL COSTS	$\mathbf{C_{RM} + C_{WT} + C_{UT} + 2.215C_{OL} + 0.190COM + 0.146FCI}$ **+ depreciation**	

*Costs are evaluated from information given on the PFD and the unit cost
†Costs are given in dollars per unit time (usually per year)
‡Depreciation costs are covered separately in Chapter 7. The use of 10% of *FCI* is a crude approximation at best.
from references [1], [2], and [3]

Factors Affecting the COM

Manufacturing Costs

with depreciation as 10% FCI

$$COM = 0.280FCI + 2.73C_{OL} + 1.23\left(C_{UT} + C_{WT} + C_{RM}\right) \quad (6.1)$$

$$COM_d = 0.180FCI + 2.73C_{OL} + 1.23\left(C_{UT} + C_{WT} + C_{RM}\right) \quad (6.2)$$

COM without Depreciation –
Depreciation will be accurately estimated in Chapter 7

Factors Affecting the COM

Example 6.1

The following cost information was obtained from a design for a 92,000 tonne/year nitric acid plant.

Fixed Capital Investment:	$11,000,000
Raw Material Cost	$ 7,950,000/yr
Waste Treatment Cost	$ 1,000,000/yr
Utilities	$ 356,000/yr
Direct Labor Cost	$ 300,000/yr
Fixed Costs	$ 1,500,000/yr

Determine:

a. the manufacturing cost in $/yr and $/tonne of nitric acid,

b. the percentage of manufacturing costs resulting from each cost category given in Table 6.1 and 6.2.

Factors Affecting the COM

Using Equation 6.2:

$$COM_d = (0.180)(\$11{,}000{,}000) + (2.73)(\$300{,}000) + (1.23)(\$356{,}000 + \$1{,}000{,}000 + \$7{,}950{,}000) = \$14{,}245{,}000/\text{yr}$$

$$(\$14{,}245{,}000/\text{yr})/(92{,}000\ \text{tonne/yr}) = \$155/\text{tonne}$$

From the relationships given in Table 6.2:

Direct Manufacturing Costs = \$7,950,000 + \$1,000,000 + \$356,000 + (1.33)(\$300,000) + (0.069)(\$11,000,000) + (0.03)(\$14,245,000) = \$10,891,000

Percentage of manufacturing cost = (100)(10.891)/14.25 = 76%

Fixed Manufacturing Costs = (0.708)(\$300,000) + (0.068)(\$11,000,000) = \$960,000

Percentage of manufacturing cost = (100)(0.960)/14.25 = 7%

General Expenses = (0.177)(\$300,000) + (0.009)(\$11,000,000) + (0.16)(\$14,245,000) = \$2,431,000

Percentage of manufacturing cost = (100)(2.431)/14.25 = 17%

Labor Cost

$$N_{OL} = (6.29 + 31.7P^2 + 0.23N_{np})^{0.5}$$

N_{OL} = the number of operators per shift

P = the number of particulate processing steps = 0 for liquid-gas processes.

N_{np} = non-particulate processing steps – compression, heating/cooling, mixing, separation, and reaction

Labor Cost

$$N_{np} = \sum Equipment$$

compressors
towers
reactors
heaters
exchangers

Labor Cost

Example 6.2

Estimate the operating labor requirement and cost of the THDA facility shown in Figures 1.3 and 1.5

Labor Cost

Equipment	Number	N_{np}
Compressors	1	1
Exchangers	7	7
Heaters/Furnaces	1	1
Pumps	2	-
Reactors	1	1
Towers	1	1
Vessels	4	-
	Total	11

Labor Cost

$N_{OL} = [6.29 + (31.7)(0)^2 + (0.23)(11)]^{0.5} = 2.97$

# of shifts/year/operator = (49 wk/yr) (5 shifts/operator/wk)
= 245 shifts/year/operator

Total shifts per year = (365)(3 shifts per day)
= 1095 shifts/year

Number of operators required for one process per shift = 1095 / 245
= 4.5

Labor Cost

Total Operators = (2.97)(4.5) = 13.4 $\Rightarrow$ 14

Salary = $50,000/yr (2001 gulf coast average)

COL = (50,000)(14) = $700,000/yr