CH2404 Process Economics
Unit – II

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Capital Cost Estimation

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Capital Cost

- The total capital cost of a project consists of the fixed capital cost plus the working capital plus the cost of land and other non-depreciable costs.

Capital cost = fixed capital + working capital + land cost

- Total capital investment includes funds required to purchase land, design, purchase, and install equipment and buildings, as well as to bring the facility into operation

Fixed Capital Investment

- The fixed capital investment for a plant includes the manufacturing equipment, piping, ductwork, automatic control equipment, structures, insulation, painting, site preparation, and environmental control equipment, as well as engineering and contractor's costs.

- One may think of it as that part of the total investment pertinent to the manufacturing of a product; it is "fixed" to the land. It is the depreciable part of the total capital investment.

- Land is not a part of the fixed capital investment and is not depreciable.

Working Capital

The working capital cost of a process or business normally includes the following items:

- Raw material, work in progress, and finished product inventories
- Cost of inventory control, warehouse, associated insurance, security arrangements, etc.
- Money to carry accounts receivable (i.e., credits extended to customers), less accounts payable (i.e., credit extended by suppliers).
- Money to meet payrolls
- Readily available cash for emergencies, and
- Any additional cash required to operate the business

Land

- Although land is a small part of the total capital investment, it should be included.

- Local chambers of commerce or real estate agents may be able to give information on land costs. In the absence of such data, and for preliminary estimates only, about 3% of the fixed capital investment may be used to estimate land costs.

Uses of Capital Cost Estimates

- To select a business opportunity from alternative proposals
- To select a process design from a number of alternatives
- To prepare feasibility studies
- To appropriate funds for construction
- To present and select engineering bids
- To facilitate cost control of a project during implementation

Factors contributing to the increase of Capital Cost

- Factors which tend to increase the capital cost of a plant more than necessary include the following:
  - Over provision for safety
  - Over provision of standby equipment
  - Unnecessary robust supporting structures
  - Enclosing equipment in buildings
  - Use of non-standard size equipment resulting from rigid adherence to design theory
  - Use of expensive materials of construction

Fixed Capital Cost Estimation

Estimation of Fixed Capital Cost

- Capital cost estimation is more an art than a science. An estimator must use a great deal of judgment in the preparation of an estimate. As the estimator gains experience, the accuracy of the estimate improves.

- Estimates may be classified based upon the quality and the amount of required information. In an attempt to bring order to the types of estimates, The American Association of Cost Engineers has proposed the following:

Estimate type	Accuracy range
Order of magnitude	−30 to +50%
Budget	−15 to +30%
Definitive	−5 to +15%

Five Different Types of Fixed Capital Cost Estimation Methods

Estimate Type	Probable Error	Purpose	Level of Eng'g Req'd	Cost of Estimate (as % of Total Project Cost)
Order-of-Magnitude	-40% to +40%	Feasibility study	None	0 to 0.1%
Study	-30% to +30%	Project evaluation	Preliminary flowsheets, Main equipment sized	0.1 to 0.2%
Preliminary	-20% to +20%	Budget authorisation	PIDs, mass and energy balances, equipment list, equipment specs and data sheets,site layouts incl buildings, project program, engineering manhour estimate	0.4 to 0.8%
Definitive	-10% to +10%	Project cost control	Substantial, but incomplete engineering	1 to 3%
Detailed	-5% to +5%	Contractors' tender	Complete project engineering	5 to 10%

Uses of Various Levels of Estimates

- Before preparing an estimate, it is advisable to consider carefully the purpose for which the estimate is to be used. For example, in the early stages of process development, an order-of-magnitude estimate may suffice for screening ideas whereas study estimates may be used for preparing preliminary economics.
- If the results appear promising, then perhaps a preliminary estimate with bids on selected major equipment items might be prepared.
- Preliminary estimates are often used for economic planning, refining economics, and perhaps requesting authorization from management to do further engineering.
- If the project economics are still promising, a definitive estimate may be prepared to seek project fund and construction authorization.
- Ultimately, a definitive or detailed estimate for plant construction and budget control will be prepared.

Equipment Cost Data

- Cost data are stated as purchased, delivered, or installed costs.
- ***Purchased cost*** is the price of the equipment FOB (free on board) at the manufacturer's plant.
- ***Delivered cost*** is the price of the equipment plus delivery charges to the purchaser's plant FOB.
- Some cost data are reported as ***installed cost***. This means the equipment item, for instance, a centrifugal pump has been purchased, delivered, uncrated, and placed on a foundation in an operating department but does not include piping, electrical, insulation costs. Perhaps a more accurate term would be set-in-place cost.

Order-Of-Magnitude (OOM) Estimates

- This estimate is generally used by management in *feasibility studies*, for evaluating the best process, the establishment of plant size and the economic feasibility of the project.

- For the preparation of the OOM, the estimator requires the following general and engineering information:
  - Plant capacity
  - General Scope Description
  - Process Block Diagrams
  - General geographic location
  - The cost of a *similar* previous project

- Method of estimation: The cost of the present project is determined by the ratio method. The price of the previous project is adjusted for size (capacity) by using the 6-10th's rule. The size adjusted cost is then adjusted for inflation by using published price indices.
  - Other Methods: Turn over ratio method, fixed investments per ton of capacity

Cost Capacity Relation

- A simple convenient method of presenting cost data is by an equation:

$$C_2 = C_1 \left(\frac{S_2}{S_1} \right)^n$$

where

C_1 = cost for equipment capacity S_1
C_2 = cost for equipment capacity S_2
n = an exponent that varies between 0.30 and 1.20 depending on the type of equipment

- The above equation is known as the six-tenths or 0.6, rule. This equation permits the user to obtain a cost for an equipment item of a different size when the cost for given size is known.

- For most process equipment, the exponent varies between 0.4 and 0.8 with an average value of about 0.6. When the exponent is unknown, this value may be used.

Cost Capacity Exponent

- If we assume that for an equipment item, a cost-capacity exponent is 0.6, doubling the capacity will increase the cost about 50–60%, not 100%. The economy of scale is reflected in the exponent.

- If the exponent is less than 1.0, there is an economy of scale. As n approaches the value of 1, the economy of scale disappears.

- An exponent greater than 1.0 is a negative economy of scale and multiple equipment units should be used.

Example Problem

Problem Statement:

Recently a cast iron leaf pressure filter with 100 ft^2 was purchased for clarifying an inorganic liquid stream for \$15,000. In a similar application, the company will need a 450 ft^2 cast iron leaf pressure filter. The size exponent for this type filter is 0.6. Estimate the purchased price of the 450 ft^2 unit.

Solution:

$$\text{Cost}_{450} = \text{cost}_{100}\left(\frac{\text{capacity}_{450}}{\text{capacity}_{100}}\right)^{0.6}$$

$$= \$15,000\left(\frac{450}{100}\right)^{0.6} = \$15,000(2.47) = \$37,050$$

Cost Index to Correct for Inflation

- Cost data are presented as of a specific date. They are adjusted through the use of cost indexes that are based upon constant dollars in a base year and actual dollars in a specified year. The base year selected for each index was a period in which inflation was flat and the economy stable.

$$\text{Cost at } \theta_2 = \text{cost at } \theta_1 \left[\frac{\text{index at } \theta_2}{\text{index at } \theta_1}\right]$$

where

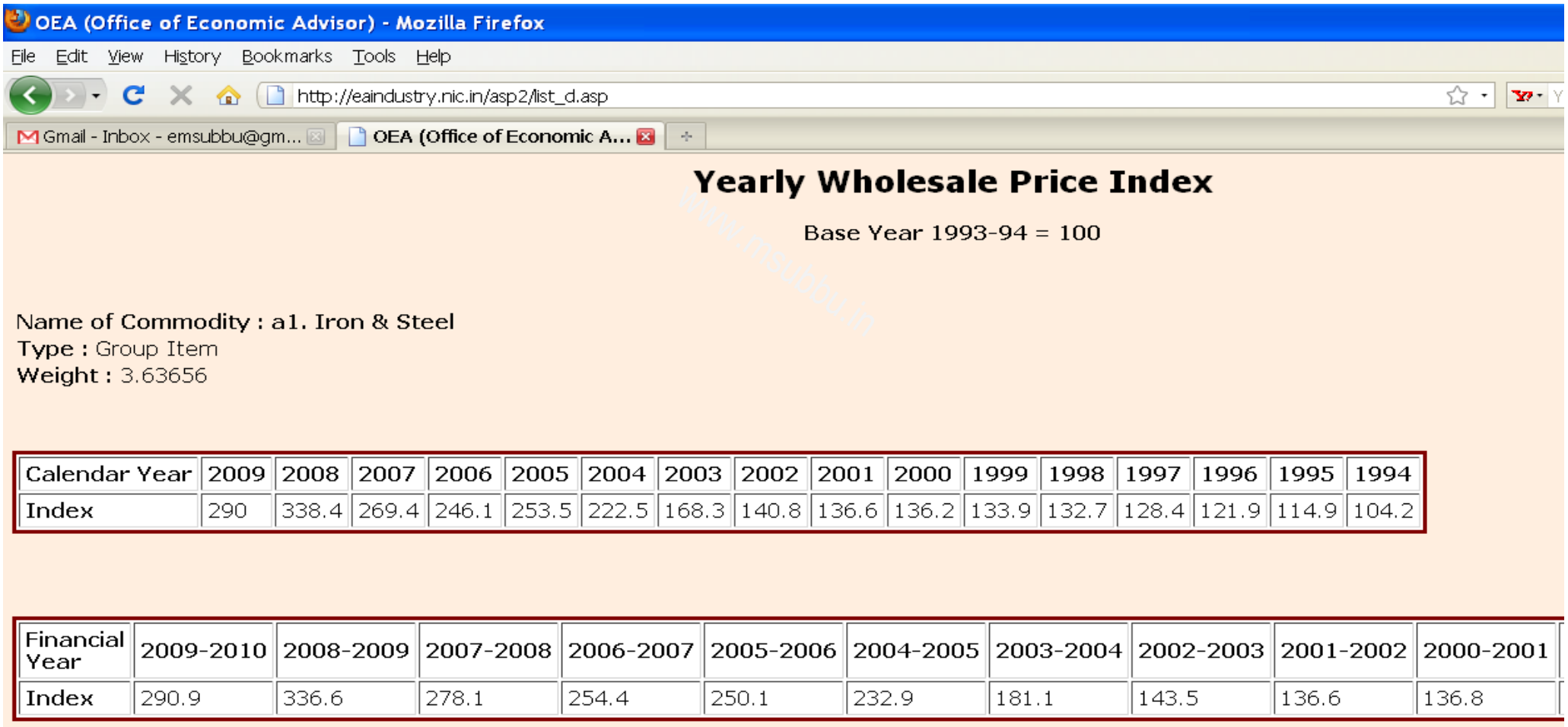
θ_1 = base year
θ_2 = selected year

Common Cost Indexes in USA

- *Engineering News-Record* construction and building indexes
- Marshall and Swift installed equipment index (from Chemical Engineering magazine)
- Nelson refinery construction index (from Oil and Gas Journal)
- *Chemical Engineering* index (from Chemical Engineering magazine)
- Wholesale price index of the US Department of Commerce

Cost Index in India

- Wholesale Price Index (WPI) Data (1993-94=100)
  - by Ministry of Commerce and Industry



Yearly Wholesale Price Index

Base Year 1993-94 = 100

Name of Commodity : a1. Iron & Steel
Type : Group Item
Weight : 3.63656

Calendar Year	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	1999	1998	1997	1996	1995	1994
Index	290	338.4	269.4	246.1	253.5	222.5	168.3	140.8	136.6	136.2	133.9	132.7	128.4	121.9	114.9	104.2

Financial Year	2009-2010	2008-2009	2007-2008	2006-2007	2005-2006	2004-2005	2003-2004	2002-2003	2001-2002	2000-2001
Index	290.9	336.6	278.1	254.4	250.1	232.9	181.1	143.5	136.6	136.8

In a desalination plant, an evaporator of area 200 m^2 was purchased in 1996 at a cost of $3,00,000. In 2002, another evaporator of area 50 m^2 was added. What was the cost of the second evaporator (in $)? Assume that the cost of evaporators scales as (capacity)$^{0.54}$. The Marshall land Swift index was 1048.5 in 1996 and 1116.9 in 2002.

(A) 1,30,500 (B) 1,39,100

(B) (C)1,41,900 (D) 1,51,200

Solution:

Cost of second evaporator in 2002 = (1116.9/1048.5) x $(50/200)^{0.54}$ = **1,51,166**

Order of Magnitude Estimates

Turn-over ratio method - This is a rapid, simple method for estimating the fixed capital investment

$$\text{Turnover ratio (TOR)} = \frac{\text{annual gross sales}}{\text{fixed capital investment}}$$

- The annual gross sales figure is the product of the annual production rate and the selling price per unit of production. A basic assumption is that all product made is sold.

- For a large number of chemical processes operating near ambient conditions, the turnover ratio is near 1.0. These ratios may vary from 0.2 to 5.0. Values less than 1.0 are for large volume, capital-intensive industries and those greater than 1.0 are for processes with a small number of equipment items.

TABLE 4.6 Turnover Ratios[a]

Product	TOR
Acetic acid	1.70
Acrylonitrile	1.55
Ammonia	0.65
Ammonium sulfate	3.82
Benzaldehyde	1.00
Benzene	8.25
Butadiene	1.68
Butanol	1.10
Carbon tetrachloride	1.00
Ethylene dichloride	0.51
Sodium carbonate	0.39
Styrene	5.21
Sulfuric acid	0.63
Urea	2.36
Vinyl chloride	3.40

Sources: Refs. 2, 11.

[a] Turnover ratio (TOR) $= \dfrac{\text{annual gross sales, \$}}{\text{fixed capital investment, \$}}$

Process Engineering Economics - James R. Couper

Example Problem

Estimate the fixed capital investment for a 1500 ton/day ammonia plant using the turnover ratio. The current gross selling price of ammonia is $150/ton. The plant will operate at a 95% stream time.

From Table 4.6, the TOR for an ammonia plant is 0.65.

$$\text{Annual gross sales} = \$150/\text{ton} \times 365 \times 0.95 \times 1500\ \text{ton/day}$$

$$= \$78{,}000{,}000$$

$$\text{FCI} = \frac{\text{annual gross sales}}{0.65} = \frac{\$78{,}000{,}000}{0.65} = \$120{,}000{,}000$$

Order of Magnitude Estimates (contd.)

Fixed Investment per Annual Ton of Capacity

- Fixed capital investments may be calculated in an approximate manner using this method.
- The data for this method are often in the open literature or from information that will allow one to calculate this information. *Chemical Week* or *Hydrocarbon Processing* are potential sources.

TABLE 4.7 Fixed Investment per Annual Ton of Capacity

Product	Capacity M tons/year	Fixed investment, $/annual ton capacity
Acetaldehyde	50	400
Ammonia	350	120
Butadiene	240	150
Carbon dioxide	550	80
Ethylene oxide	200	700
Ethyl ether	40	170
Maleic anhydride	60	270
Methanol	300	120
Nitric acid	175	50
Phenol	180	275
Phthalic anhydride	185	220
Polyethylene	20	1800
Propylene	25	210
Sulfuric acid	350	90
Vinyl chloride	500	300

Example Problem

Estimate the fixed capital investment of a 75,000 ton/yr maleic anhydride plant using the data for fixed investment per annual ton capacity in Table 4.7.

Solution:

From Table 4.7 a 60,000 ton/yr plant is \$270 investment per annual ton capacity. Therefore, the fixed capital investment of the plant is 75,000 ton/yr × \$270 per annual ton, or \$20,300,000.

Since this method is sensitive to time and the data presented in Table 4.7 was based on 1986 information, cost indexes must be applied to get a 2001 cost.

CE Index for 1986 = 331

CE Index for late 2001 = 396.8

Therefore, the cost in 2001 is estimated to be (\$20,300,000)(396.8/331), or \$24,335,000.

Capital Cost Estimation Based on Design

The main steps involved in preparing a capital cost estimation based on design are as follows:

- Initial idea for the process and specification of the size and type of operation
- Collection of physical and chemical data from literature, by prediction methods or from laboratory experiments
- Preparation of preliminary equipment flow sheet incorporating the required unit operations and showing main items of equipment
- Preparation of mass and heat balances
- Specification of temperatures and pressures at various points on the flow sheet
- Design calculations to size the main items of equipment
- Preparation of coded list of items of major process equipment
- Collection of cost data from literature, company records, or quotations
- Estimation of the total delivered cost of the major equipments
- Estimation of fixed capital cost from **factorial method** using the delivered cost and the factor as applicable to the industry type

Lang factor method

- The simplest **factorial method** for estimating the fixed capital cost C_{FC} of plant based on design is the Lang factor method, given by:

$$C_{\mathrm{FC}} = f_{\mathrm{L}} \sum C_{\mathrm{EQ}}$$

where f_L = 3.10 for solids processing plant

f_L = 3.63 for solid-fluid processing plant

f_L = 4.74 for fluid processing plant

and ΣC_{EQ} is the sum of delivered costs of all major items of flow sheet

Typical percentages of fixed-capital investment values for direct and indirect cost segments for multipurpose plants or large additions to existing facilities

Component:	Range, %
Direct costs	
Purchased equipment	15-40
Purchasedequipment installation	6-14
Instrumentation and controls (installed)	2-8
Piping (installed)	3-20
Electrical (installed)	2-10
Buildings (including services)	3-18
Yard improvements	2-5
Service facilities (installed)	8-20
Land	1-2
Total direct costs	
Indirect costs	
Engineering and supervision	4-21
Construction expense	4-16
Contractor's fee	2-6
Contingency	5-15
Total fixed-capital investment	

Components	Assumed % of total	Cost	Ratioed % of total
Purchased equipment	25	$100,000	23.0
Purchased-equipment installation	9	36,000	8.3
Instrumentation (installed)	7	28,000	6.4
Piping (installed)	8	32,000	7.3
Electrical (installed)	5	20,000	4.6
Buildings (including services)	5	20,000	4.6
Yard improvements	2	8,000	1.8
Service facilities (installed)	15	60,000	13.8
Land	1	4,000	0.9
Engineering and supervision	10	40,000	9.2
Construction expense	12	48,000	11.0
Contractor's fee	2	8,000	1.8
Contingency	8	32,000	7.3
		$436,000	100.0

Working Capital Cost Estimation

Working Capital

- ***Working capital*** are the "working funds" necessary to conduct a day-to-day business of the firm. These funds are necessary to pay wages and salaries, purchase raw materials, supplies, etc.

- Although the initial input of working capital funds come from the company's financial resources, it is regenerated from the sale of products or services. Working capital is continuously liquidated and regenerated but is generally not available for another purpose, so it is regarded as an investment item.

- If an adequate amount of working capital is available, management has the necessary flexibility to cover expenses in case of delays, strikes, fires, or recessions. Many small firms fail due to an insufficient amount of working capital to pay the expenses as the new venture begins to become established.

Working Capital Estimation Methods

- Several methods are available for estimating an adequate amount of working capital for a proposed venture. These methods may be classified into two broad categories:

  1. Percentage methods

  2. Inventory method

1. Percentage Methods

- These methods are adequate for order-of-magnitude, study, and preliminary methods of estimating.

- The working capital requirements are based upon either ***annual sales*** or ***capital investment***.

1. a) Percentage of Capital Investment Methods

- The ratio of working capital to total capital investment varies with different companies and different types of business.
- If a company manufactures and sells a product at a uniform yearly rate, then 15–25% of the total capital investment is an adequate amount of working capital.
- Some companies are in a seasonal business, such as agricultural chemicals. If that is the case, then it would be advisable to provide 20–30% of the total capital investment for working capital

Example Problem

Problem Statement:

A company is considering an investment in an aldehyde facility. The engineering department has estimated that the battery-limits fixed capital investment to be $19,000,000. Land allocated for the project is $500,000 and start-up expenses to be capitalized are expected to be $900,000. The company normally uses 15% of the total capital investment for working capital. Determine the estimated amount of working capital for this project.

Solution:

Land	$ 500,000
Fixed capital investment	$ 19,000,000
Start-up expenses	$ 900,000
Subtotal	$ **20,400,000**

Since the working capital is 15% of the total capital investment, the subtotal above is 85%, providing no other capital items are added.

Therefore,

Total capital investment = $20,400,000 / 0.85
= $24,000,000

and

Working capital = $24,000,000 - $20,400,000
= $**3,600,000**

1. b) Percentage of Sales Method

- The estimate of an adequate amount of working capital for certain specialty chemicals is frequently based upon a percentage of annual sales.
- Products that may fall into this category are fragrances, cosmetics, flavors, perfumes, food additives, etc.
- A perfume producer may have considerable money tied up in raw materials and finished goods inventory and only a modest amount in fixed capital. Therefore, it would be reasonable to base the estimate of working capital on a percentage of sales as reported by one manufacturer
- The percentage values vary from 15 to 49% with **30 to 35%** being a reasonable value.

Example Problem

Problem Statement:

A perfume manufacturer is planning to produce a new product. Annual sales are expected to be about $15,000,000. Estimate the amount of working capital required for this product.

Solution:

Since this is a high-cost product due to the raw materials and the fact that little fixed capital is required, the working capital should be based on a percentage of annual sales. A mean value of 35% of sales will be used.

Annual sales	=	$15,000,000
Estimated working capital	=	$15,000,000 x 0.35
	=	$**5,250,000**

Inventory Method

This method uses the categories in current assets and current liabilities from a balance sheet

TABLE 4.22 Working Capital—Inventory Method[a]

Item	Factors
Raw materials	Two weeks supply depending on availability—use purchase price.
Goods in process	Estimate on an average retention time in tanks. Convert back to raw materials and charge at purchase price plus one-half the sum of the direct and indirect conversion costs.
Finished product	Two weeks supply depending on product sales and charge at selling price.
Supplies and stores	10% of the annual maintenance expense.
Cash	One month's manufacturing expense.
Accounts receivable	5% of annual net sales.
Accounts payable	One month's average accounts payable.

Source: James R. Couper, Process Engineering Economics, Marcel Dekker, Inc., New York, 2003

Working Capital Estimation by Inventory Method

2009-Nov-Q.14

Problem Statement

From the following particulars given, prepare an estimate of working capital requirement.

i. Proposed level of activity 240000 units per annum.
ii. Selling price Rs. 12 per unit.
iii. Cost of materials 40%, labour 20%, overheads 20%.
iv. Raw materials are expected to be in stock for one month.
v. Materials will be in process for two months.
vi. Fininshed goods to remain in stores for two months.
vii. Credit allowed to customers two months. 75% of sales is against cash
viii. Credit allowed by suppliers one month.
ix. Lag in payment of overheads one month.

Solution

1 **Raw material cost**

Total production per year	240000	units
One month production	20000	units
Selling price	12	Rs/unit
Cost of raw materials/ selling price	0.4	40% of selling price
Cost of raw materials	**96000**	Rs.

2 **Materials in process**

Two months of production	40000	units
Selling price	12	Rs/unit
(costs of materials + labour + overheads) / selling price	0.8	
Costs of goods in process	**384000**	Rs.

3 **Finished goods**

Two months of production	40000	units
Selling price	12	Rs/unit
Finished goods costs	**480000**	Rs.

4 **Credit allowed to customers**

Two months of sales	40000	units
Credit sales / total sales	0.25	25% of sales is by credit
Selling price	12	Rs/unit
Credit allowed to customers	**120000**	Rs.

5 **Credit allowed by suppliers**

One month of production	20000	units
Cost of raw materials/ selling price	0.4	40% of selling price
Selling price	12	Rs/unit
Credit allowed by suppliers	**96000**	Rs.

6 **Lag in payment of overheads for one month**

One month of production	20000	units
Cost of overheads/ selling price	0.2	20% of selling price
Selling price	12	Rs/unit
Overheads for one month	**48000**	Rs.

Working capital = items (1 + 2 + 3 + 4) - items (5 + 6)

936000 Rs.

Check

Sales for one year **2880000** Rs.

% of sales of working capital **32.50**

Normal range is 30 to 35%