Course Outline

- Description of the industry
- The construction process
- Building life cycle
- Quantity surveying principles
- Estimating Earthworks
- Estimating concrete works
- Estimating finishing works
- Construction cost estimate
- Estimating labor cost
- Estimating material cost
- Estimating machinery and equipment cost
- Estimating overhead cost
- Pricing and profit margins
- Life cycle costing
Grading System

- Midterm Exam 30%
- Term Project 20%
- Final exam 50%

Good Luck

Text Book & References

**Text Book:**

**References:**
Communications & Contact

- You can use the Zajel system to post your comments and enquiries in the discussion forum.
- Frequently check the Zajel system to find assignments.

Before we start

- Attend the class on time
- Switch off your mobile
- Stop the side talks
- Be a smart listener
- Use your analytical skills
- Question every piece of information you acquire
Construction Industry

Description of the Industry

How large is the construction industry!!!

Construction includes all immobile structure such as:

1. Buildings
2. Tunnels
3. Pipelines
4) Dams
5. Canals
6. Airports
7. Power plants
8. Railroads
9. Bridges
10. Sewage Treatments plants
11. factories.
Manufacturing Versus Construction

<table>
<thead>
<tr>
<th>Manufacturing</th>
<th>Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass production</td>
<td>Custom built projects</td>
</tr>
<tr>
<td>Easy quality control</td>
<td>Complex quality control</td>
</tr>
<tr>
<td>One plant location</td>
<td>Unique plant location</td>
</tr>
<tr>
<td>Not seasonal work</td>
<td>Seasonal work</td>
</tr>
<tr>
<td>Relatively small products</td>
<td>Huge products</td>
</tr>
</tbody>
</table>
Units of measure

The most common units of measure are:

- Cubic Meter
- Square Meter
- Linear Meter
- Weight
- Number

Quantity Surveying (QS)

- Contractor QS
- Consultant QS
Project Break Down

The WBS
(Work Breakdown Structure)

- It is used to breakdown the project from one main and relatively big entity into smaller, defined, manageable and controllable units, usually called work groups (packages) or tasks, or, at the finest level of detail (which is undesirable) activities.
A construction activity

- Anything that must be accomplished in order to complete the project may be considered as an activity.
- Consumes time and resources.

Level 1

- House

Level 2

- Structure 1.1
- Mechanical 1.2
- Electrical 1.3

Level 3

- Sub-str. 1.1.1
- Super str. 1.1.2
- HVAC 1.2.1
- Plumbing 1.2.2

Level 4

- Earth work 1.1.1.1
- Foundation 1.1.1.2
- Str. elements 1.1.2.1
- Finishing 1.1.2.2
- Excavation
- Backfilling
- Blinding
- Footings
- Tie beams
- Ground slab
- Columns
- Beams
- Roof slab
- Plaster
- Tile
- Painting
- Doors & windows

Level 5
The WBS
(Work Breakdown Structure)

1.0 house

1.1 structure

1.1.1 sub – structure
   1.1.1.1 earth work
      E10 excavation
      E20 backfilling
      E30 leveling
   1.1.1.2 foundation
      F10 blinding
      F20 footings
      F30 tie beams
      F40 ground slab

1.1.2 super structure
   1.1.2.1 structural elements
      C10 columns
      C20 beams
      C30 roof slab
   1.1.2.2 finishing
      CF10 plaster
      CF20 tile
      CF30 painting
      CF40 doors & windows

1.2 mechanical

1.2.1 HVAC

Take care!!!

- The deeper you go into the lower levels of the WBS, the more detailed knowledge you’ll need to know.
The WBS

- it is a major task to undo.

Why???

- Because cost collections begins at a WBS element,

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ESTIMATING EARTHWORK
Earthwork

Earthwork includes:

- 1. Excavation
- 2. Grading & Leveling: Moving earth to change elevation
- 3. Temporary shoring
- 4. Back fill or fill: Adding soil to raise grade
- 5. Compaction: Increasing density
- 6. Disposal

Units of Measuring Earthwork

- Earth work measured in Cubic Meter (bank, loose, or compacted)

- Bank (BCM): Material in its natural place before disturbance (in Place or In situ)

- Loose (LCM): Material that has been disturbed or loaded.

- Compacted (CCM): Material after compaction
Swelling and shrinking of excavated materials

- Swelling: soil increases in volume when it is excavated
- Shrinkage: soil decreases in volume when it is compacted

<table>
<thead>
<tr>
<th>Natural Condition (In-Place)</th>
<th>After Digging (Loose)</th>
<th>After Compacted (Compacted)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0 cm</td>
<td>1.25 cm</td>
<td>0.90 cm</td>
</tr>
</tbody>
</table>

In place: 1.0 cm
Loose: 1.25 cm
Compacted: 0.90 cm
Swell Factor

The swell percentage is calculated as follows:

\[ \text{Swell (\%)} = \left( \frac{\text{Bank Density}}{\text{Loose Density}} - 1 \right) \times 100 \]

\[ \text{Swell Factor} = \frac{\text{Bank Density}}{\text{Loose Density}} \quad \text{or} \quad \frac{\text{Loose Volume}}{\text{Bank Volume}} \]

Shrinkage Factor

Shrinkage: soil decreases in volume when it is compacted

\[ \text{Shrinkage (\%)} = (1 - \frac{\text{Bank density}}{\text{Compacted density}}) \times 100 \]

\[ \text{Shrinkage factor} = 1 - \text{Shrinkage \%} \]

\[ \text{Compacted volume} = \text{Bank volume} \times \text{Shrinkage factor} \]
Example

- The loose density of soil is 1,250 Kg/cm, bank density is 1,500 Kg/cm and the compacted density is 1,700 Kg/cm. The excavation calculated net quantity is 1,000 cm and the calculated backfilling net quantity is 750 cm. Assuming:
  - 5 $/cm excavation cost.
  - 10 $/cm hauling cost
  - 20 $/cm for importing & compacting the backfilling material.

- Find:
  1. Earthworks total cost.
  2. Excavation & hauling unit cost
  3. Backfilling & compaction unit cost

solution

- Swelling Percentage = ((1,500/1,250) – 1)) x 100 = 20 %
- Swelling factor = 1,500 / 1,250 = 1.2
- Shrinkage Percentage = (1 – (1,250 / 1,700)) x 100 = 26.47 %
- Shrinkage factor = 1 – 26.47 = 0.74

- Excavation Cost = 1,000 Cm x 5 $/m^3 = 5,000 $
- Disposal Cost = (1,000 Cm x 1.2) x 10 $/Cm = 12,000 $
- Total Excavation & disposal cost = 17,000 $

- Backfilling & compaction Cost = (750 Cm / 0.74) x 20 $/Cm = 20,400 $

1) Earthworks total Cost = 17,000 + 20,400 = 37,400 $
2) Total Excavation & disposal Unit Cost = (17,000 / 1,000) = 17.00 $/cm
3) Total Backfilling & compaction Unit cost = (20,400 / 750) = 27.20 $/cm
Typical Soil Volume Conversion Factors

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Initial Soil Condition</th>
<th>Bank</th>
<th>Converted to:</th>
<th>Loose</th>
<th>Compact ed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay</td>
<td>Bank</td>
<td>1.00</td>
<td></td>
<td>1.27</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>0.79</td>
<td></td>
<td>1.00</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>Compact ed</td>
<td>1.11</td>
<td></td>
<td>1.41</td>
<td>1.00</td>
</tr>
<tr>
<td>Common earth</td>
<td>Bank</td>
<td>1.00</td>
<td></td>
<td>1.25</td>
<td>0.90</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>0.80</td>
<td></td>
<td>1.00</td>
<td>0.72</td>
</tr>
<tr>
<td></td>
<td>Compact ed</td>
<td>1.11</td>
<td></td>
<td>1.39</td>
<td>1.00</td>
</tr>
<tr>
<td>Rock (blasted)</td>
<td>Bank</td>
<td>1.00</td>
<td></td>
<td>1.50</td>
<td>1.30</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>0.67</td>
<td></td>
<td>1.00</td>
<td>0.87</td>
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<tr>
<td></td>
<td>Compact ed</td>
<td>0.77</td>
<td></td>
<td>1.15</td>
<td>1.00</td>
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<tr>
<td>Sand</td>
<td>Bank</td>
<td>1.00</td>
<td></td>
<td>1.12</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>Loose</td>
<td>0.89</td>
<td></td>
<td>1.00</td>
<td>0.85</td>
</tr>
<tr>
<td></td>
<td>Compact ed</td>
<td>1.05</td>
<td></td>
<td>1.18</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Excavation

- Allowance is added for measuring excavation for working space, e.g. nearly 0.5 m allowance should be added around footings and foundations walls for erecting and removing formwork.

- Allowance is added for sloping the sides of excavation for stability vary with type of ground (most common 45°).
Approximate Angle of Repose
For Sloping Sides of Excavation

Trimming and grading

- **Trimming and grading** generally measured in square meter. And should be considered separately.

- Hand (manual) excavations required to finish the bottom to the desired level. Since machines cannot always work to the required degree of accuracy.
Temporary shoring

- **Temporary shoring**: required wherever excavating vertical surfaces are unstable.
- Temporary shoring costs include the cost of labor required to erect and remove the shore (props) and the cost of material required for shoring.
- Temporary shoring is measured by the area of the excavation surfaces that are supported by shoring.

Backfilling

- **Backfilling of excavated materials**: is required in most projects.
- In some cases, native excavated materials are unsuitable for backfilling, therefore, filling materials should be imported.
- Like excavation, backfilling materials measured in cubic meter net in place.
Backfilling

- In the estimate, the total net volume of the required backfilling material are deducted form the total net volume of the excavated material.

  \[(\text{Excavated} - \text{backfilled} = X)\]

- If the result is positive (surplus) X is total net volume for disposal.

- If the result is minus quantity, more backfilling materials required than excavated. And the difference is total net volume of imported materials required.

The actual total quantity of backfilling required will be greater than the total net quantity (Bank Quantity) calculated.

Depending upon the type and moisture content of backfilling material specified, and the degree of compaction required.

Recall Loose and Bank volume
Measuring Concrete Work

Measuring Concrete

- Concrete is generally measured in CUBIC Meters.
- Concrete costs are affected by location in the building.
Concrete

- Concrete is a mixture of aggregate, cement and water
- One cubic meter of cement is about 1510 kg
- One bag of cement contains 50kg of material
- One cubic meter of concrete is about 2400 kg
- Strength of concrete is usually expressed in terms of the 28-day compressive strength

Types of Concreting Activities

- Costs of labor, equipment, and materials are relatively high
- Two major Categories:
  - Plain concrete
  - Reinforced concrete
- Examples of activities: foundation, slab, column, beam, stairway, etc.
Types of Concrete

- Cast-In-Place Concrete: consists of five major operations:
  - Form preparation
  - Reinforcement placement
  - Concrete placement
  - Curing
  - Form removal

- Precast Concrete: formed, placed, and cured in a manufacturing plant

Concrete Material

- Expressed as the volume of concrete required.
- Usually obtained from a ready-mix concrete supplier.
- If mixing is conducted on site, quantities of cement, sand, gravel must be taken off.
- Concrete mixture is expressed as a ratio (e.g., 1:2:3):
  - 1 Volume unit of cement
  - 2 Volume unit of fine aggregate
  - 3 Volume unit of coarse aggregate
Concrete Materials

- To obtain 1 m$^3$ of concrete, a total volume of 1.5 m$^3$ of dry materials is required.
  - Cement = $\frac{1}{6} \times 1.5 = 0.25$ m$^3$
  - Sand = $\frac{2}{6} \times 1.5 = 0.5$ m$^3$
  - Gravel = $\frac{3}{6} \times 1.5 = 0.75$ m$^3$
- Waste factors:
  - 5 to 10% cement, 10 to 30% aggregates

Take-Off Methods for Concrete

- Concrete quantity is expressed in terms of concrete volume
  - Volume = length x width x height
  - Section Area = Length x Width
- Three methods are used to determine the volume of concrete:
  - The unit method
  - The perimeter method
  - The centerline method
1) The unit method

Given the height of the walls is 3 m, then:
Concrete Volume = 2 (6 x 0.3 x 3) + 2 (7.4 x 0.3 x 3) = 24.12 m³

2) The Perimeter method

Given the height of the walls is 3 m, then:
Concrete Volume = (2 x 6) + (2 x 7.4) x 0.3 x 3 = 24.12 m³
3) The centerline method

Given the height of the walls is 3 m, then:

Concrete Volume = \((2 \times 5.7) + (2 \times 7.7) \times 0.3 \times 3\) = 24.12 m³

Formwork

- Formwork is a part of most concrete work and is a large part of its cost.
- Formwork is temporary work and not incorporated to the building.
- So, it is rarely shown on the drawings.
Formwork

- Formwork is generally measured in square meter of the actual concrete surfaces.

- Contact Area = $2(A + B) \times h$

- And the major cost of formwork is labor costs, since formwork is reusable as much as possible.
- Plywood formwork could be reused up to twenty to thirty times.
- And steel formwork could be used much longer.

Example

- The initial cost for a wooden formwork system that covers an area of 1,500 m$^2$ and can be used up to 50 time is around $250,000. Find the formwork total cost and unit cost for a 500 m$^2$ solid concrete slab.

  - Formwork system unit cost = 3.33 $/m^2$
  - Slab formwork unit cost = 3.33 $/m^2$
  - Slab formwork total cost = 1,665 $/m^2$
Steel Reinforcement

- From the drawings, determine total linear meter of each size bar
- Waste for lapping and splicing is about 10%
- Determine the weight of each size bar

- Weight per linear Meter

\[ W \ (kg) = \frac{D^2 \ (mm)}{162} \times \frac{X \ Length \ (m)}{ } \]

- D is the diameter of Circular bars in MM

Estimating Construction Cost

Text Book:

Cost Estimate Techniques

1) **Analogous estimating** *(Expert judgment)*  
   Budget used to estimate total project costs if there is a limited amount of detailed information.

2) **Parametric modeling**  
   Using project characteristics (or parameters) to predict costs (e.g., price per square meter).

3) **Bottom-up estimating** *(Definitive)*  
   Estimating the cost of individual work items and then rolling up the costs to arrive at a project total.

Estimating Project’s Cost

Construction costs includes:

1) Materials costs.
2) Labor costs.  
   a) Direct labor cost  
   b) Indirect labor cost  
3) Plant and equipment costs  
4) Overhead costs  
   a) Job overhead costs (site)  
   b) Operating overhead costs (head office)  
5) Profit.
(1) Material costs

- The material price in a competitive market determined by the SUPPLY & DEMAND and is affected by:
  1) quality of materials
  2) quantity of material
  3) time of purchase
  4) place of Delivery
  5) buyer & seller

Demand & Supply

- In the competitive market the price of a good mainly determined by the supply of that good by manufacturers and the demand to that good by consumers.

- The supply curve is upward curve
- The demand curve is downward curve
Supply Curve

Demand curve
Demand & Supply

- Pe: Equilibrium Price
- Qe: Equilibrium Quantity

Quality of Materials

- Which type of material?
- Specifications.
- The higher the quality, is the higher the price.
Quantity of materials

- Mostly, the more the quantity requested, the lower the price quotation.

Time of purchase or delivery

- If the delivery time requires the manufacturer or supplier to bear additional costs, he will back charge them to the material price.

- E.g. Supplying material in holydays
Place of delivery

- Affects the price through the means and distance of delivery, and the accessibility to the site.

The buyer and seller

- The buyer and seller affects the price through the market level from which they are able to buy.
  
  E.g. Retail Vs. Wholesale

- Cash discounts, Trade discounts
(2) Labor cost

- **Direct labor costs**: wages and other direct payments to workman.

- **Indirect labor costs**: any other amounts paid by the contractor on behalf of labors, e.g. transportation, insurance, accommodation, paid vacations, and etc.

(2) Labor costs

- **Two Methods of Estimation:**

  1) Labor rate: the hourly rates of employing workman, based on total labor costs (direct and indirect cost) divided by the total Hours worked. E.g. 10 $/hour

  2) Productivity: the amount of work done in a specific period of time paid for. E.g. 10 $/m²
Example

Example:

150 M³ ready-mixed Portland cement concrete (300 N/cm² x 1.5” max size aggregate) placed in continuous footings. Given that the concrete unite cost is 18 $/ M³, and the labor unite cost is 3 $/ M³

Calculate the work item total cost.

Solution

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Unit</th>
<th>Unit cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concrete (as specified)</td>
<td>150</td>
<td>m³</td>
<td>18 $</td>
<td>2700 $</td>
</tr>
<tr>
<td>Labor</td>
<td>150</td>
<td>M³</td>
<td>3 $</td>
<td>450 $</td>
</tr>
</tbody>
</table>

Total material and labor cost 3150 $
Example

A plaster mason works 10 hrs/day, 6 days/week and can produce 30 m²/day. A base wage of 10 $/hour is paid for all straight-time work (8 hrs/day). An overtime rate of time and one half is paid for all hours over 8 hrs/day. The social security tax is 7% and the health insurance is 10 %. (Tax is paid on actual wage and insurance is paid on base wage)

Calculate:
1) The average hourly, daily and weekly labor cost?
2) Labor unit cost

Solution

Actual hours = 10 hrs/day
Pay hours = day straight-time + day overtime
= (8 hrs x 1) + (2 hrs x 1.5)
= 8 + 3 = 11 hrs

Average hourly pay (Actual Wage)=(pay hours/actual hours) x base wage
= (11 / 10 ) x 10 $ = 11 $/hr

11 $/hr is the direct Labor Cost
Continued

Tax is paid on actual wage and insurance is paid on base wage.

Indirect Labor Cost:

- Social security tax: 7 % x 11 $ /hr = 0.77 $ /hr
- Health insurance: 10 % x 10 $ /hr = 1 $ /hr

Indirect Labor Cost: 0.77 + 1 = 1.77 $/hr (Indirect)

Average hourly cost = Direct Labor Cost + Indirect Labor Cost
= 11 $ /hr + 1.77 $ /hr = 12.77 $/hr

Daily cost = 10 hrs x 12.77 $/hr = 127.7 $/day
Weekly cost = 6 days x 127.7 $/day = 766.2 $/week

2) Labor unit cost = 127.7 $ / 30m²/day = 4.26 $/m²

Example 2

1. For a floor tile activity, the estimated tile quantity was around 600 m². A gang of one tile mason and one helper can produce 30 m²/day (8 hours per day). The tile mason cost per hour was estimated to be around 10 $/hour, while it was around 7 $/hour for the helper. Find:

1. The activity duration, total labor cost, total man hours, and the labor unit cost.
2. The total labor cost, total man hours, and the labor unit cost for completing the activity in a duration of 10 days.
(3) Equipment cost

- Whether to rent or own.
- Does not matter to the estimator since he should consider costs.

Equipment costs

- If the equipment is rented, the rental rate will be formed by offer and acceptance like any other contract.
- The PRICE of renting is your Equipment COST
- If equipment is self-owned, an economically realistic rental rate should be established for use within the company to assure accurate cost estimation.
Equipment costs

If your decision is to own equipment consider the following costs:

1) owning costs
2) operating costs

1) Owning costs of equipment

Can be identified as:

1) Depreciation: Loss in value
2) maintenance: major repairs
3) investment: cost arising from investment and ownership
Depreciation

- Loss in value of equipment resulting from use and age.

Straight line Depreciation.

Annual straight-line depreciation = \[
\frac{\text{initial cost } (P) - \text{estimated salvage Value } (F)}{\text{estimated life in years } (n)}
\]

= \(\frac{P - F}{n}\)

Where:

- P = initial capital cost
- F = salvage or resale value
- n = estimated life of equipment
Straight line method.

A concrete vibrator having an initial cost of 10,000$ and an estimated salvage value of 2,000$ after 8 years. Calculate the annual depreciation?

Depreciation = (P – F) / n

= (10,000 – 2,000) / 8 = 1,000 $ /year

Investment

- Investment cost includes:
  1) interest on investment
  2) insurance and taxes.
  3) storage costs.
Ownership costs calculations

- Ownership cost can be calculated as follows:

\[
A = P \left[ \frac{i(1+i)^n}{(1+i)^n - 1} \right] - F \left[ \frac{i}{(1+i)^n - 1} \right]
\]

- Where:
  - \(A\) = Annual Cost
  - \(P\) = Purchase Price
  - \(F\) = Future Salvage Value
  - \(I\) = Annual interest rate
  - \(n\) = useful life, in years

Example

- The purchase price for new equipment is 145,000$. The estimated salvage value is 25,000$ after the end of its expected useful life of 6 years. Assume interest for borrowing money is 9%, 5% risk allowance and 3% for taxes, insurance, and storage.

1) Calculate the annual ownership cost
2) Calculate ownership cost per hour considering that the equipment will work 40 hrs/week
Solution

- Analyze Data:
  - A = ??
  - P = 145,000 $
  - F = 25,000 $
  - I = 9 % + 5 % + 3 % = 17 %
  - n = 6

- Apply Equation:
  \[ A = P \left[ \frac{i(1+i)^n}{(1+i)^n-1} \right] - F \left[ \frac{i}{(1+i)^n-1} \right] \]

Continued

\[ A = 145,000 \left[ \frac{0.17(1+0.17)^6}{(1+0.17)^6-1} \right] - 25,000 \left[ \frac{0.17}{(1+0.17)^6-1} \right] \]

\[ = 145,000 \times (0.2786148) - 25,000 \times (0.108614802) \]

\[ = 37,683.78 \text{ $ / year} \]

Hourly ownership cost = \[ \frac{37,683.78 \text{ $ / year}}{2080 \text{ hrs / year}} = 18.12 \text{ $ / hr} \]
2) Operating costs

- Operating costs includes:
  1) Fuel
  2) running repairs (minor repairs and parts replacement)
  3) Transportation: (transporting to and from the site, setting up and dismantling)
  4) operator: direct and indirect costs
Example

- A contractor borrowed 150,000 $ with 10% interest rate to buy a diesel engine shovel. No salvage value is assumed for this equipment after 6 years. tax and insurance is 5%. Maintenance and repairs costs are expected to be around 80% of the annual straight line depreciation cost. Fuel gallon costs 1 $ and the average fuel consumption is 30 gal/day.

- Determine the probable cost per hour of owning and operating the shovel considering that the equipment will work 40 hrs/week?

Solution

1) Calculate hourly owning cost:

Annual Ownership cost = \[ P \left( \frac{i(1+i)^n}{(1+i)^n - 1} \right) - F \left( \frac{i}{(1+i)^n - 1} \right) \]

\[ A = 150,000 \left[ 0.15 \frac{(1+0.15)^6}{(1+0.15)^6 - 1} \right] - 0 \left[ \frac{0.15}{(1+0.15)^6 - 1} \right] \]

\[ A = 150,000 \times 0.264237 - 0 \]

\[ A = 39,635.54 \text{ $ / year} \]

Hourly ownership cost = \[ \frac{39,635.54 \text{ $}}{2080 \text{ hr/year}} = 19.05 \text{ $ / Hr} \]
Continued

2) Calculate Hourly operating cost:

- Annual Depreciation: 
  \[ \text{Annual Depreciation} = \frac{(P - F)}{n} = \frac{(150,000 - 0)}{6} = 25,000 \text{ $ / year} \]

- Maintenance and Repair: 
  \[ \text{Maintenance and Repair} = 0.80 \times 25,000 = 20,000 \text{ $ / Year} \]

- Hourly Maintenance and repair Cost: 
  \[ \text{Hourly Maintenance and repair Cost} = \frac{20,000}{2,080 \text{ hr/year}} = 9.61 \text{ $ / hr} \]

- Fuel Cost: 
  \[ \text{Fuel Cost} = 30 \text{ gal/day} \times 6 \text{ days/week} = 180 \text{ gal/week} \times 1 \text{ $/gal} = 180 \text{ $/week} \]

- Hourly Fuel cost: 
  \[ \text{Hourly Fuel cost} = \frac{180 \text{ $/week}}{40 \text{ hr/week}} = 4.5 \text{ $/hr} \]

- Total Hourly operating cost: 
  \[ \text{Total Hourly operating cost} = 9.61 \text{ $} + 4.5 \text{ $} = 14.11 \text{ $/hr} \]

- Total hourly (Owning + operating) Cost: 
  \[ \text{Total hourly (Owning + operating) Cost} = 19.05 \text{ $} + 14.11 \text{ $} = 33.16 \text{ $/hr} \]

(4) Overhead Costs

- Overhead costs can be specified as:

  1) Job overhead costs
  2) Operating overhead costs.
Job overhead costs

- If the costs can be attributed to a specific project, and cannot be attributed to a specific work item. these costs are JOB OVERHEAD COST.

- E.g. Project manager salary. Security fence. site offices services. Water and power supply and etc.

- These costs estimated to be 5 – 15 % of the projects direct cost.

Operating Overhead costs

- If the cost cannot be attributed to any specific project, they are operating overhead costs.

- Costs of running business

- These costs exist as long as firm exists. Regardless projects running or not.
Operating Overhead costs

- Operating Overhead costs may include:
  (head office costs)

1) Management and staff.
2) Business offices.
3) Communications.
4) Rentals

Operating Overhead costs

- Usually is not a part of the estimator's duties.

- It is the duty of the firms accountants to provide the estimator with the required data.
Operating Overhead costs

- Can be calculated as follows:

- The accountant predicts the annual operating overhead cost for the coming year, say 600,000 $, and the total expected amount of work for the coming year, say 20,000,000 $.

- History records are these data sources.

Then:

A percentage allowance can be calculated

\[
\frac{600,000}{20,000,000} \times 100 = 3 \text{ percent}
\]

This allowance should be added to each job total cost.
(5) Profit

- The profit is an indicator to success and efficiency of the firms.

- The profit = total income – total expenditures.

- Usually added as a percentage to the total project cost. e.g. 15 %

- Can be determined in relation to the market situation and the work conditions.

---

**example**

- A contractor estimated a project direct cost to be 1,500,000 $, 10 % is the estimated job overhead costs, 3 % is the operating overhead costs, his profit margin is 5 %.

- Calculate:
  1. Job overhead costs
  2. Operating overhead costs
  3. Total project cost
  4. Profit and
  5. Bid price.
Solution:

Direct cost = $1,500,000

1) Job overhead = $1,500,000 \times 0.10 = $150,000

2) Operating overhead = $1,650,000 \times 0.03 = $49,500

3) Total project cost = $1,500,000 + $150,000 + $49,500 = $1,699,500

4) Profit = $1,699,500 \times 0.05 = $84,975

5) Bid price = $1,699,500 + $84,975 = $1,784,475
Introduction to Engineering Economy

Text Book:

Time Value of Money

- The key concept of Engineering Economy is that money makes money over time.
- The value of money whether owned (invested) or owed (borrowed) changes with time.
- A $1,000 today is not equivalent to $1,000 next year, why?
Basic Terminology

- **Present Value (PV):** the value of money at present or at time 0.
- **Future Value (FV):** the value of money at any point of time in the future, or at time (n).
- **Equivalent Annual Value (A):** series of consecutive, equal, end-of-period amounts of money.
- **Interest:** the difference between an ending amount of money and the beginning amount.
- **Interest Rate (i):** interest paid over a specific time unit is expressed as a percentage of the principal.
- **Rate of Return (RoR)/Return on Investment (ROI):** interest earned over a specific period of time is expressed as a percentage of the original amount.
- **Payback Period:** The estimated time for the revenues, savings, and any other monetary benefits to completely recover the initial investment plus a stated rate of return i.

Time Value of Money

- If an amount P is invested at time t = 0, the amount F, accumulated n year at an interest rate of i percent per year will be:
  \[ F = P(1+i)^n \]
- Reverse the situation to determine the P value for a stated amount F that occurs n periods in the future:
  \[ P = F(1+i)^{-n} \]

Where:
- F: Future value at year n.
- P: Present value at time 0.
- i: interest rate.
- n: number of years/interest periods.
Time Value of money

- Find the economic equivalence (future value) for a $100 today for the forthcoming 5 years at 5% interest rate.

<table>
<thead>
<tr>
<th>Year</th>
<th>Principal</th>
<th>Future Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>$105.00</td>
</tr>
<tr>
<td>2</td>
<td>100</td>
<td>$110.25</td>
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<td>3</td>
<td>100</td>
<td>$115.76</td>
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<td>4</td>
<td>100</td>
<td>$121.55</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
<td>$127.63</td>
</tr>
</tbody>
</table>

Time Value of money

- Find the Present value (PV) for a $100 that will be earned five years from now at 5% interest rate.

\[ P = \frac{F(1+i)^n}{(1+0.05)^5} \]

\[ P = \frac{100}{(1+0.05)^5} \]

\[ P = $78.35 \]
Time Value of money

How much money should you be willing to pay now for a guaranteed income of $600 per year for 9 years starting next year, at a rate of return of 16% per year?

<table>
<thead>
<tr>
<th>Year</th>
<th>A</th>
<th>PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>600</td>
<td>517.24</td>
</tr>
<tr>
<td>2</td>
<td>600</td>
<td>445.90</td>
</tr>
<tr>
<td>3</td>
<td>600</td>
<td>384.39</td>
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<td>331.37</td>
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<td>600</td>
<td>285.67</td>
</tr>
<tr>
<td>6</td>
<td>600</td>
<td>246.27</td>
</tr>
<tr>
<td>7</td>
<td>600</td>
<td>212.30</td>
</tr>
<tr>
<td>8</td>
<td>600</td>
<td>183.02</td>
</tr>
<tr>
<td>9</td>
<td>600</td>
<td>157.77</td>
</tr>
</tbody>
</table>

PV = $2,763.93

OR

PV = $2,763.93

Purchase power of money

- Inflation
- Deflation
- Constant Dollars – without inflation effect (real cost)
- Current Dollars – with inflation effect (nominal cost)
Effect of Inflation on Money

What is the equivalence of $100 in term of purchase power after 5 years if the inflation rate is 5%.

\[ F = P(1 + f)^n \]

\[ F = 100(1.05)^5 \]

\[ F = $127.63 \]

What is the equivalence before 5 years?

Purchase power of money

The current cost of 1 kWh of energy is around 0.65 ILS/kWh. How much the cost of 1 kWh will be after 10 years at 2% annual inflation rate?

\[ \text{Future cost} = \text{current cost} (1 + f)^n \]

\[ \text{Future cost} = 0.65(1.02)^{10} \]

\[ \text{Future cost} = 0.79 \text{ ILS/kWh} \]

At the same inflation rate, how much was the cost in 1997?
Purchase power of money

How the value of a $100 increases for the forthcoming years at 5% real interest rate and considering a 5% inflation rate?

<table>
<thead>
<tr>
<th>Year</th>
<th>Principal</th>
<th>Real Interest Rate (I = 5%)</th>
<th>Purchase power (inflation rate) f = 5%</th>
<th>Inflation adjusted Interest rate i = 10.25%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>105.00</td>
<td>105.00</td>
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</tr>
<tr>
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<td>100</td>
<td>110.25</td>
<td>110.25</td>
<td>121.55</td>
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<td>100</td>
<td>115.76</td>
<td>115.76</td>
<td>134.01</td>
</tr>
<tr>
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<td>121.55</td>
<td>147.75</td>
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<tr>
<td>5</td>
<td>100</td>
<td>127.63</td>
<td>127.63</td>
<td>162.89</td>
</tr>
</tbody>
</table>

Applications of Engineering Economy

For a green building, the initial cost of installing a PV system was around $2,000. In return, 300 $/year is expected to be saved constantly from energy consumption. The energy price is expected to be inflated at an annual rate of 2%, does the PV system pay off for an analysis period of 10 years?

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Energy Saving (Constant)</th>
<th>Present worth of energy saving (I = 5%)</th>
<th>Inflated energy saving (f = 2%)</th>
<th>Present worth of energy saving (l = 7.10%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>300</td>
<td>285.71</td>
<td>306.00</td>
<td>285.71</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>272.11</td>
<td>312.12</td>
<td>272.11</td>
</tr>
<tr>
<td>3</td>
<td>300</td>
<td>259.15</td>
<td>318.36</td>
<td>259.15</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
<td>246.81</td>
<td>324.73</td>
<td>246.81</td>
</tr>
<tr>
<td>5</td>
<td>300</td>
<td>235.06</td>
<td>331.22</td>
<td>235.06</td>
</tr>
<tr>
<td>6</td>
<td>300</td>
<td>223.86</td>
<td>337.85</td>
<td>223.86</td>
</tr>
<tr>
<td>7</td>
<td>300</td>
<td>213.20</td>
<td>344.61</td>
<td>213.20</td>
</tr>
<tr>
<td>8</td>
<td>300</td>
<td>203.05</td>
<td>351.50</td>
<td>203.05</td>
</tr>
<tr>
<td>9</td>
<td>300</td>
<td>193.38</td>
<td>358.53</td>
<td>193.38</td>
</tr>
<tr>
<td>10</td>
<td>300</td>
<td>184.17</td>
<td>365.70</td>
<td>184.17</td>
</tr>
</tbody>
</table>

Total: 2316.52
Payback Period

- How long it takes the previous investment to recover its initial cost?

Building Life Cycle Cost

Text Book:

Basic Terminology

1. Building life cycle.
2. Life cycle cost (LCC)
3. Life cycle costing
4. Whole life cost (WLC)
5. Interest rate
6. Discount rate (d)
7. Inflation rate (i)
8. Deflation rate
9. Net present value (NPV)
10. Recurring cost
11. Period of analysis

The life cycle of a product or a system

The life cycle of a product or a system can be defined by five major phases:

1. concept and definition
2. design and development
3. manufacturing and installation
4. operation and maintenance
5. disposal
The life cycle of a building

What is Life Cycle Costing?

- life cycle costing is an economic assessment of an item, area, system, or facility that considers all the significant costs of ownership over its economic life, expressed in term of equivalent dollar.

- The method requires estimating the life cycle cost for different building design alternatives, or system specifications, to determine the best design with the lowest life cycle cost over a predefined study period.
Life Cycle Costing Methodology

- Life cycle costing, in its principle, considers both cost and time, its methodology can be summarized as:

1. Identifying all the current and future life cycle costs that arise from owning and operating a facility.
2. Aggregating these costs based on the expected accrual time.
3. **Discounting** the costs to a common base date to come up with the present worth (the current value of all costs and savings), or the annual equivalent value of the life cycle cost components.
4. Selecting the lowest life cycle cost alternative after considering non-economic factors, if any.

Life Cycle Costing Model

\[ X_{NPV} = \sum (Cn \times q) = \sum_{n=1}^{p} \frac{Cn}{(1+i)^n} \]

Where:
- \( c \): the cost in year \( n \)
- \( q \): the discounting factor
- \( i \): the expected real discount rate per annum
- \( n \): the number of years between the base date and the occurrence of the cost
- \( p \): the period of analysis
Life Cycle Costing Simple Model

\[ \text{LCC} = \text{Construction cost} + \text{PV} \text{(Recurring Cost)} - \text{PV} \text{(Residual Cost)} \]

Example:

- Two design alternatives were prepared for a green building, the initial design and construction cost for alternative (A) was around $85,000, while it was around $80,000 for design alternative (B). The annual energy consumption according to the design alternative (A) was estimated to be around 6,200 kWh/year, while it was estimated to be around 16,000 kWh/year for design alternative (B). Given that the energy price rate was around 0.16 $/kWh, and at a discount rate of 5%, which design alternative is more economical from life cycle perspective for an analysis period of 25 years?
Solution:

- Life cycle cost analysis for design alternative A:

  - Design and construction cost = $85,000
  - Annual energy recurring cost = 6,200 kWh/year x 0.16 $.kWh = $992
  - Net present value for energy = \[ \sum_{n=1}^{25} \frac{\text{Energy cost}(n)}{(1+i)^n} = $13,981.19 \]
  - LCC = Design and Construction cost + PV (Energy cost) = $85,000 + $13,981.19 = $98,981.19

\[ \text{PV(Energy Cost)} = \text{Annual energy cost} \times \left[ \frac{(1+i)^n - 1}{i(1+i)^n} \right] \]

<table>
<thead>
<tr>
<th>Year</th>
<th>Future Value</th>
<th>Present Value (PV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>992</td>
<td>944.76</td>
</tr>
<tr>
<td>2</td>
<td>992</td>
<td>899.77</td>
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<tr>
<td>3</td>
<td>992</td>
<td>856.93</td>
</tr>
<tr>
<td>4</td>
<td>992</td>
<td>816.12</td>
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<td>5</td>
<td>992</td>
<td>777.26</td>
</tr>
<tr>
<td>6</td>
<td>992</td>
<td>740.25</td>
</tr>
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<td>7</td>
<td>992</td>
<td>705.00</td>
</tr>
<tr>
<td>8</td>
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<td>671.42</td>
</tr>
<tr>
<td>9</td>
<td>992</td>
<td>639.45</td>
</tr>
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<td>10</td>
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<tr>
<td>11</td>
<td>992</td>
<td>580.00</td>
</tr>
<tr>
<td>12</td>
<td>992</td>
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</tr>
<tr>
<td>13</td>
<td>992</td>
<td>526.08</td>
</tr>
<tr>
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<td>992</td>
<td>501.03</td>
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<td>992</td>
<td>477.17</td>
</tr>
<tr>
<td>16</td>
<td>992</td>
<td>454.45</td>
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<td>17</td>
<td>992</td>
<td>432.81</td>
</tr>
<tr>
<td>18</td>
<td>992</td>
<td>412.20</td>
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<td>992</td>
<td>392.57</td>
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<td>20</td>
<td>992</td>
<td>373.87</td>
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<td>21</td>
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<td>356.07</td>
</tr>
<tr>
<td>22</td>
<td>992</td>
<td>339.12</td>
</tr>
<tr>
<td>23</td>
<td>992</td>
<td>322.97</td>
</tr>
<tr>
<td>24</td>
<td>992</td>
<td>307.59</td>
</tr>
<tr>
<td>25</td>
<td>992</td>
<td>292.94</td>
</tr>
<tr>
<td>Total</td>
<td>24,800</td>
<td>13,981.19</td>
</tr>
</tbody>
</table>

Solution:

- Life cycle cost analysis for design alternative B:

  - Design and construction cost = $80,000
  - Annual energy recurring cost = 16,000 kWh/year x 0.16 $.kWh = $2,560
  - Net present value for energy = \[ \sum_{n=1}^{25} \frac{Cn}{(1+i)^n} = $36,080.50 \]
  - LCC = Design and Construction cost + PV (Energy cost) = $80,000 + $36,080.50 = $116,080.50

\[ \text{PV(Energy Cost)} = \text{Annual energy cost} \times \left[ \frac{(1+i)^n - 1}{i(1+i)^n} \right] \]

<table>
<thead>
<tr>
<th>Year</th>
<th>Future Value</th>
<th>Present Value (PV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2,560</td>
<td>2,438.10</td>
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<tr>
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<td>2,560</td>
<td>2,322.00</td>
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<td>2,560</td>
<td>2,211.42</td>
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<td>2,106.12</td>
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<td>2,560</td>
<td>2,005.83</td>
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<td>1,910.31</td>
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<td>2,560</td>
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<tr>
<td>Total</td>
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<td>36,080.50</td>
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