Cost of Construction Labor and Equipment

Detailed Cost Estimating

Steps of cost estimate

- Review the bidding documents. Check for general conditions, specifications and drawings. If any discrepancies exist, record them and check with the architect or engineer.
- Review the drawings to visualize the building size, height, shape, function and so on. Start with floor plans, cross-sections, exterior finish system, and the roof.
- Review structural drawings to get acquainted with specified systems.
- Review mechanical, electrical, fire extinguisher, and security drawings.
- Start identifying work to be done by general contractor and work to be done by subcontractors.
**Detailed Cost Estimating**

**Steps of cost estimate**

- Read and study thoroughly the specifications for the work to be done by the general contractor and those related to any subcontracted work.
- Visit the project site and have with you the project manager or field engineer.
- Call a meeting with the personnel who will hold the key supervisory positions. Establish with them the general guidelines for quantities take off and pricing.
- Develop a list of subcontractors. Notify subcontractors and suppliers that the company is preparing a proposal and ask if they intend to submit bids.
- Develop a list of items to be considered for site overhead and general overhead that need to be priced later.

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**Detailed Cost Estimating**

**Steps of cost estimate**

- Start the quantities takeoff for the category of construction work selected to be done in house.
- When taking off quantities, break each item down by size, type of material, and workmanship. Also list the type of construction equipment needed for each phase.
- Condense quantities from the work up sheet by work category and transfer them to a summary sheet for pricing.
- Pricing means the cost of materials, labor, and construction equipment. The prices used are from company available cost files adjusted to a particular location, or from quotes from suppliers and subcontractors.


**Detailed Cost Estimating**

**Sources of cost information**

- Published price books such as US Means. Price books are published annually and contain a range of prices for standard bills of quantities items
- Priced bills of quantities from previous projects. Adjust these costs to location, time, etc.
- Cost analysis produced in-house, this is the most reliable source of cost information, partly due to the fact that it is easier to ensure good quality control on the data. Also data presented in this format will be easily understood and interpreted. A disadvantage is the time and cost taken to prepare and store the information

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**Construction Labor**

- Construction is still remains as one of the few handcrafted products
- Construction industry is one of the most labor-intensive industries in the world
- The labor cost component of a building project often ranges from 30 to 50%
- A construction project is divided into work packages. These work packages assigned individual worker or a crew
- A crew is a team of workers and equipment
Construction Labor

Labor Productivity (Production rates)

- Productivity is the ratio of input versus the respective output. In construction, the input is the work hours of a worker or a crew, and the output is the amount of work produced.
- Construction productivity = quantity of work produced / time
- Example: If a bricklayer can lay 500 bricks in 8 hours, then the associated construction productivity is 500 bricks divided by 8 hours, which is 62 bricks per bricklayer hour.

- Productivity is sometimes named as production rates.
- A production rate is defined as the number of units of work produced by a person in a specified time.
- Production rates may also specify the time in man-hours or man-days required to produce a specified number of units of work.
- Production rates vary between labors, different projects, weather conditions, work environment, etc.
Construction Labor

Production rates sources

- Production rates can be determined from published sources such as Means' Building Construction Cost Data and Walker's Building Estimator's Reference Book, etc.
- Means provides the crew types as well as two forms of production rate: the daily output (unit/day) and labor hours (hr/unit).

### Line 09210-100-0900

- **Gypsum Plaster**
- **Daily output**: 72.74 m²/day
- **Labor hours per m²**: 0.550 hr
- **Bare labor cost**: $13.70/m²

### Line 09220-100-0900

- **Gypsum Plaster**
- **Daily output**: 72.74 m²/day
- **Labor hours per m²**: 0.550 hr
- **Bare labor cost**: $13.70/m²
Construction Labor

Production rates sources

The crew type for work in line 09210-100-0900 is Crew J-1

<table>
<thead>
<tr>
<th>Crew No.</th>
<th>Bare Costs</th>
<th>Subs Q &amp; P</th>
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<tr>
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<td>29.95</td>
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<tr>
<td>40 L.H., Daily Totals</td>
<td>$1091.70</td>
<td>$1588.35</td>
<td>$26.29</td>
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</table>

Weighted wage rate = \((26.65\times3 + 22.35\times2)/5 = $24.93/hr\)

Bare labor unit cost = 24.93 * 40 / 72.74 = $13.7/m²

Example: if the unit production for painting a wall is 0.55 hour per m². If the local wage rate including benefits is LE30 per hour, the unit labor cost becomes LE16.50 per m²

Construction Labor

Estimating work duration

- Determining the work duration for a task involves knowledge of the quantity of work and the production rate for the specific crew that will perform the work.
- The quantity of work associated with the material quantity is determined by the quantity take off.
- Production rates can be determined from published sources such as Means' Building Construction Cost Data, etc.

Work duration = quantity of work / number of crews × production rate
**Construction Labor**

**Estimating work duration: Examples**

- Find the duration of an interior and exterior painting activities with quantities of 440 m² and 378 m² respectively, using crews of 11 m²/hours and 14 m²/hours for the interior and exterior painting activities respectively.

  - Interior painting duration = \( \frac{440}{11} = 40 \) hours
  - Exterior painting duration = \( \frac{378}{14} = 27 \) hours

  - Total work hours = 67 hours

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**Construction Labor**

**Estimating work duration: Examples**

- What is the duration in days to install 6000 square feet of walls shuttering if:
  - A. Crew of 2 carpenters is used with output of 2000 square feet/day
  - B. Productivity is measured as 0.008 man-hour/square feet. Number of carpenters = 3, and number of working hours/day = 8 hours

  - A. Duration = \( \frac{6000}{200} = 3 \) days
  - B. Total man-hours needed = \( 6000 \times 0.008 = 48 \) man-hours (if one man used); Duration = \( \frac{48}{8} = 6 \) days (if one man used); Duration using 3 men = \( \frac{6}{3} = 2 \) days
Estimating labor cost

- Labor costs in construction are determined by two factors: monetary and productivity
- The monetary factor is related to hourly wage rates, wage premiums, insurance and taxes
- Calculating labor cost requires the knowledge of the total work hours or labor hours needed to perform all the tasks and then applying the corresponding wage rates
- Total cost of labor = total work hour × wage rate

Estimating labor cost: Example

An ironworker works 10hr/day, 6 days/week. A base wage of LE20.97/hr is paid for all straight-time work, 8 hr/day, 5 day/week. An overtime rate of one time and one-half is paid for all hours over 8 hr/day, Saturday through Wednesday, and double time is paid for all Thursday work. The social security tax is 7.65% and the unemployment tax is 3% of actual wages. The rate for worker’s compensation insurance is LE12.5 per LE100 of base wage. Calculate the average hourly cost to hire the ironworker
Estimating labor cost: Example 1

- Actual hours = 10 × 6 = 60 hr
- Pay hours = weekly straight time + weekly overtime + Thursday overtime = 5×8×1 + 5×2×1.5 + 10×2 = 75 hr
- Taxes are paid on actual wage and insurance is paid on base wage
- Average hourly pay = (75/60) × LE20.97 = LE26.21/hr
- Social security tax = 26.21 × 0.0765 = 2.01
- Unemployment tax = 26.21 × 0.03 = 0.79
- Compensation = 12.5/100 × 20.97 = 2.62
- Then, the average hourly cost = LE 31.63/hr

Estimating labor cost: Example 2

- The construction of a reinforced concrete wall involves placing 660 m³ concrete, fixing 50 ton of steel, and 790 m² of formwork. The following information belongs to the jobs involved in this activity:
  - A 6 man concrete crew can place 16 m³ of concrete/day
  - A steel-fixer and assistant can fix 0.5 ton of reinforcement/day
  - A carpenter and assistant can fix and remove 16 m² of shuttering/day
- Calculate the duration of the activity considering the steel-fixer as the critical resource
**Construction Labor**

**Estimating labor cost: Example 2**

- Using one steel-fixer: duration = 50 / 0.5 = 100 days
- Using one carpenter: duration = 790 / 16 = 49.4 days
- Using one concreting crew: duration = 660 / 16 = 41.25 days

Then, for a balanced mix of resources, use 2 steel-fixer crews, one carpenter crew, and one concreting crew. Accordingly, the activity duration = 50 / 0.5 x 2 = 50 days

**Construction Equipment**

- Modern construction is characterized by the increasing utilization of equipment to accomplish numerous construction activities.
- In a construction project, equipment costs are typically divided into portions.
- The first and bigger portion covers the cost of equipment and represents the cost of acquiring and operating the equipment during the construction processes.
- The second and smaller portion covers the cost of hand tools. This represents a smaller portion of the project cost and is often calculated as a percentage of payroll costs.
Construction Equipment

Equipment classification

- Equipment are classified based on their use as specific use or general use.
- Specific use equipment is only for specific construction operations and is removed from the job site after the task is completed.
- Its usage is shorter term when compared to general use equipment.
- The most equipment-intensive operations are: site work, concrete and metal works. Some typical equipment used for site work includes: tractors, scrapers, front shovels, hoes, loaders and backhoe loaders, hauling units, and compactors.

Construction Equipment

Equipment classification

- General use equipment has shared utilization by all subcontractors the construction site and is not associated with any particular work item or items.
- These pieces of equipment are kept on the site over a longer period of time, throughout almost the entire construction phase.
- Some examples of general use equipment include: cranes, air compressors, light towers, forklifts and pumps.
Many factors can influence the selection of equipment on a construction site: site conditions, the nature of the work, and equipment characteristics. Site conditions such as: types of material to be handled, onsite physical constraints, and hauling distances. The compaction of clayey soil is done best with a sheep's foot roller, whereas more sandy soil is best compacted with a vibratory roller. Site area and layout, surface condition, topography, and adjacent neighborhood. The bearing capacity of the soil; low bearing capacity soil may require track-type instead of wheel-type equipment. The neighborhood of the construction site, such as other buildings and traffic in the area, as it can also offer obstacles to equipment movement or certain construction operations. Hauling distances, for short hauls a loader can pick up the load and move it to a dump area. Longer hauling distances, a dump truck can be used for hauling and dumping. The longer the hauling distance, the more advantage is in using higher capacity hauling units since they can be more cost effective.
Construction Equipment

Equipment Selection

- The payload, the total quantity of work, and the schedule
- the particular crane selected must be able to lift the maximum load the work may require
- A higher quantity of work can influence and justify the selection of higher capacity equipment
- On some projects, costs may not be the governing constraint; instead, the construction schedule might be
- A tighter schedule often requires higher productivity units, such as those with higher power, bigger capacity, more mobility

Equipment characteristics are related to equipment capabilities (capacities and versatility) and costs

- Capacity can be in the form of maximum allowable payload and maximum volume that can be handled
- Versatility refers to the degree of applicability of a unit to perform many different operations
- Versatility can make a piece of equipment more useful on a site, thus replacing the need for more specialized units.
- The selected pieces of equipment that produce the lowest cost are ideal for the project
Construction Equipment

Renting versus purchasing Equipment

- Construction equipment could be purchased or rented
- The choice between purchase and rental depends on the amount of time the equipment will be used in the contractor’s operations
- If extensive use of the equipment is required, the equipment is always purchased
- If the equipment is to be used a limited amount of time, it is typically rented
- The purchase of equipment represents a capital investment by the construction contractor

Renting advantages

- No need to maintain a large inventory of specialized equipment
- Continuous access to the newest and most efficient items of available equipment
- No need for equipment warehouse and storage facilities
- Reduced need to employ maintenance staff and operate facilities for their use
- Equipment cost accounting is simpler when equipment is rented
Factors pertaining to ownership and economics make purchasing alternative more favorable

Steady use for certain equipment, owing such equipment may be financially better

Ownership shows financial stability

Owners ask contractors who bid on their projects to list the company-owned equipment, bid evaluation

Decisions on maintenance and servicing can be easily made

Absolute control on the use and disposition of equipment

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The value of money is dependent on the time at which it is received

Investing a current amount of money, \( P \), for \( n \) years, with interest rate \( (i) \) will result in a future amount, \( F \)

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

The present value (the discounted value), \( P \), of a future some of money, \( F \), that will be received after \( n \) years if the discount rate is "\( i \)"

\[
P = \frac{F}{(1 + i)^n}
\]
The Future Value, \( F \), of a uniform annual payment, \( C \), is calculated at the end of the period, \( n \), in which the last payment occurs with an investment rate \( i \)

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

The annual uniform amount, \( C \), to be invested at the end of each period in order to produce a fixed amount, \( F \), at the end of \( n \) periods with interest rate \( i \) (Sinking fund equation)

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

The present value, \( P \), of a future amount of money, \( F \), from a uniform series payments, \( C \)

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

The value of a uniform series payment, \( C \), when the present sum, \( P \), (capital recovery equation)

\[
C = P \left[ \frac{i(1+i)^n}{(1+i)^n - 1} \right]
\]
Equipment Costs

Estimating Equipment Cost

- Estimating equipment cost involves identifying the ownership and operating costs
- Ownership costs include: initial cost, financing (investment) costs, depreciation costs and taxes and insurance costs
- The operating costs include: maintenance and repair costs, storage costs and fuel and lubrication costs

Construction Equipment

Initial cost

- The initial cost is the total cost required to purchase a piece of equipment
- This initial cost is the basis for determining other costs related to ownership as well as operating costs
- Generally, initial cost is made up of: price at the factory or used equipment price, extra options and accessories, sales tax, freight and assembly or setup charges
- The initial cost is very straightforward, whereas the other costs require more analysis and computation
The purchase of construction equipment requires a significant investment of money. This money either be borrowed from a lender, or it will be taken from reserve fund of the contractor. In order to calculate the cost of finance, both the purchase price, \( P \), and the salvage value, \( F \), should be converted into uniform annual values.

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

An excavator purchase price is LE460,000 and its salvage value is LE40,000 after 10 years of useful life. Find the annual cost of finance of this excavator if the annual interest rate is 15%.

\[
P = 460,000; \quad F = 40,000; \quad n = 10; \quad i = 15\%
\]

\[
\text{Annual cost of finance} = \left[ \frac{460000 \left( 0.15 \cdot (1.15)^{10} \right)}{(1.15)^{10} - 1} - \frac{460000}{10} \right] - \left[ \frac{40000 \left( 0.15 \right)}{(1.15)^{10} - 1} - \frac{40000}{10} \right]
\]

\[
\text{Annual cost of finance} = \text{LE47,684/year}
\]
Construction Equipment

Depreciation

- The depreciation is defined as “the decrease in market value of an asset”
- A machine may depreciate because it is wearing out and no longer performing its function as well as when it was new
- Another aspect of depreciation is that caused by obsolescence
  A machine is described as obsolete when the function it performs can be done in some better manner
- A machine may be in excellent working condition, yet may still be obsolete. For example, electronic machines, computers

Construction Equipment

Depreciation

- The initial value represents the purchase price of an asset
- Salvage value represents the expected price for selling the asset at the end of its useful life
- The book value represents the current value in the accounting systems
- The book value equals the initial value of the asset minus all the depreciation costs till given time
- The market value represents the value of the asset if it is sold in the free market
The simplest and best known of the various depreciation methods is the straight-line method. This method assumes linear depreciation or the depreciation cost is allocated equally over the asset’s useful life. The formula for calculating the annual depreciation charge is:

\[ D_n = \frac{P - F}{N} \]

Example: If the purchase price of an equipment is LE60,000 and its salvage value after 8 years is LE6,000, calculate the annual depreciation and the book value of the equipment each year.

Total depreciation = 60000 - 6000 = LE54,000
Annual depreciation = 54000 / 8 = LE6,750

**Construction Equipment**

**Depreciation: straight-line method**

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual depreciation</th>
<th>Book value</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
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<tr>
<td>8</td>
<td>6,750</td>
<td>6,000</td>
</tr>
</tbody>
</table>
**Construction Equipment**

**Depreciation: Sum-of-years digits**

- This method results in faster depreciation at the early life of an asset.
- Each year, the depreciation is computed as the remaining life at the beginning of the year divided by the sum of the years digits for the total life, multiplied by the total amount of depreciation.

\[
D_n = \left( \frac{N - n + 1}{N(N + 1)/2} \right) \times (P - F)
\]

**Example:** If the purchase price of an equipment is LE60,000 and its salvage value after 8 years is LE6,000, calculate the annual depreciation and the book value of the equipment each year.

- \( P = 60,000; \quad F = 6,000; \quad N = 8 \)
- Total depreciation = 60000 – 6000 = LE54,000
- Sum-of-years digits = 8 (8 + 1) / 2 = 36 years
- Depreciation = (8-n+1)/36 x 54000
- Calculate for \( n = 1, 2, 3, 4, 5, 6, 7, 8 \)
### Construction Equipment

#### Depreciation: Sum-of-years digits

<table>
<thead>
<tr>
<th>Year</th>
<th>Remaining life / sum-of-years</th>
<th>Annual depreciation</th>
<th>Book value</th>
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<tbody>
<tr>
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<td>8</td>
<td>1/36</td>
<td>1,500</td>
<td>6,000</td>
</tr>
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</table>

This method assumes that the asset initial value – the salvage value are converted into a series of uniform payments over the asset life. The amount of yearly depreciation is invested in a compound manner for the remaining period:

\[ D_n = C \times (1 + i)^{n-1} \quad ; \quad n = 1, 2, 3, \ldots, N \]

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#### Construction Equipment

#### Depreciation: Sinking fund

- This method assumes that the asset initial value – the salvage value are converted into a series of uniform payments over the asset life.
- The amount of yearly depreciation is invested in a compound manner for the remaining period.

\[ C = (P - F) \times \frac{i}{(1+i)^n - 1} \]

- \( D_n = C \times (1 + i)^{n-1} \); \( n = 1, 2, 3, \ldots, N \)
Example: Assume the same previous example with interest rate of 10%

\[ P = 60,000; \quad F = 6,000; \quad N = 8; \quad i = 10\% \]

\[ C = (60000 - 6000) \times \left[ \frac{(0.1)}{(1.1^8 - 1)} \right] = LE4,722 \]

At the first year: \( D_1 = LE4,722 \)

At the second year: \( D_2 = 4722 \times (1.1) = LE5,194 \)

At the third year: \( D_3 = 4722 \times (1.1)^2 = LE5,714 \)

... 

At the eighth year: \( D_8 = 4722 \times (1.1)^7 = LE9,202 \)

### Construction Equipment

**Depreciation: Sinking fund**

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<tr>
<th>Year</th>
<th>Annual depreciation</th>
<th>Book value</th>
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<td>8</td>
<td>9,202</td>
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Construction Equipment

Depreciation: Comparison

Operating Costs

- Operating cost accrue only when the equipment is used, whereas ownership costs accrue whether or not the equipment is used.
- Operating costs include maintenance and repairs, fuel, oil and lubricants.
- The cost for maintenance and repairs include the expenditures for parts and labor required to keep the equipment in good condition.
- The annual cost of maintenance and repairs is often expressed as a percentage of purchase prices or as a percentage of the straight-line depreciation costs.
Construction Equipment

Operating Costs

- Fuel consumption: a gasoline engine consume approximately 0.06 gallon of fuel for each horsepower-hour. A diesel engine consume approximately 0.04 gallon of fuel for each horsepower-hour.
- Lubricating oil consumption: The quantity of lubricating oil consumed by an engine varies with the engine size, the capacity, the equipment condition and number of hours between oil change.
- Cost of rubber tires: tires life usually not be the same as the equipment on which they are used.
- Thus, the cost of depreciation and repairs for tires should be estimated separately from the equipment.

Example

- Calculate the ownership cost per hour for an excavator powered by a 250-hp engine based on the following data:
- Purchase price (P) = LE420,000; Salvage value (F) = LE250,000
- Operation factor = 50%; Useful life (N) = 6 years
- Working hours per year = 2000
- Maintenance and repair costs = 110% of annual depreciation
- Diesel fuel price = 3.8/gallon
- Fuel consumption = 0.04 gallon/hp/hr
- Lube oil cost = 10% of fuel; Interest rate (i) = 10%
**Construction Equipment**

**Solution**

- **Depreciation (assume straight-line)**: \((420000 - 250000) / 6 = \text{LE}28333.33/\text{year}\)
- **Annual investment**: 
  \[ \begin{align*}
  &\left[ 420000 \left( \frac{0.1 (1.1)^0}{(1.1)^6 - 1} \right) - \frac{420000}{6} \right] - \\
  &\left[ 250000 \left( \frac{0.1}{(1.1)^6 - 1} \right) - \frac{250000}{6} \right] \\
  \end{align*} \]
  - **Annual investment** = \((420000 \times 0.2296 - 70000) - (250000 \times 0.1296 - 41666.67) = 26432 - (-9264.82) = \text{LE}35696.82/\text{year}\)
- **Maintenance and repair cost** = \(1.1 \times 28333.33 = \text{LE}31166.67/\text{year}\)
- **Then, the total yearly costs** = \(28333.33 + 35696.82 + 31166.67 = \text{LE}95196.81/\text{year}\)

Accordingly, the hourly cost = \(95196.81 / 2000 = \text{LE}47.6/\text{hr}\)

- **Fuel consumption** = \(250 \times 0.04 \times 0.5 = 5 \text{ gallon/hr}\)
- **Fuel cost** = \(5 \times 3.8 = \text{LE}19/\text{hr}\)
- **Lubricate oil cost** = \(19 \times 0.1 = \text{LE}1.9/\text{hr}\)
- **Finally, the total hourly cost** = \(47.6 + 19 + 1.9 = \text{LE}68.5/\text{hr}\)