Cost Engineering

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Labor Productivity and Analysis
Labor cost is classified in number of ways:

• 1. direct versus indirect cost
• 2. Recurring – non recurring cost
• 3. Designed – non designed cost
• 4. Exempt – non exempt cost
• 5. Wage – salary
• 6. union – non union
• Other ways of classifying labor.
• Social factors,
• political factors and
• educational factors and
• type of work
• Also payment for wages may be based on attendance or performance.
• We will adopt direct – indirect classification formula.
Basic Principle for Estimating Labor

• Total cost of labor = $\sum_{i=1}^{n} \text{total work hour (i) } \times \text{wage rate (i)}$

• Total work hours = $\sum_{i=1}^{n} \frac{\text{quantity of work (i)}}{\text{productivity rate (i)}}$

• Time may be individual or for crew
• Time is expected by unit of time, minute, hour, day ....
Wages

• Wages is defined in the context of the job.
  • It may be one worker and his toolbox, or crew with one equipment, or crew with several equipments.

• The mythical of Man hour
  • “Man hour” is defined as one worker working for one hour.
  • “man year” is 52 weeks of work with the popular 40 hours in each week, Or 2080 hours
• “a man month” is 173.3 hours per month or $(40 \times 52)/12 = 173.3$.

• Man minutes or man weeks are not familiar to be used.

• Man hours are regularly used for estimating.

• In theory, man hours can be effective if they are relatively constant, pre-known, and unaffected by changes in wage rate, overtime, connectivity between the trades.
• When applying man hour, it is credentials need to be openly understood such as:
• Guess from experience
• Time spent as actual clock hours
• Adjustment of actual clock hours to allowed time
• Measurement and analysis of the workers time with respect to constructive and non productive effort and idleness
• Data book
Labor cost

• The labor cost component of a building project often ranges from 30 to 50%, and can be as high as 60% of the overall project cost. Calculate the total worked hours in the year, and the cost per worked hour.

• The calculation is complicated by difference between hour worked and the hours paid which exceeds the hour worked by such items as overtime, public holiday and inclement weathers.
Working time

• The minimum earnings for construction workers is 39 hours based on 5 days working per week.

• during the 44 weeks summer period the working hours per day is 8.0 hrs to 5.30.

• This gives 8 hours + one over time working hours in summer and 7 hours from Monday to Thursday + 2 over time hours in Fridays making all working hrs is 39 hrs and + 6hrs OT.
• During winter, the 8 working hrs from 8 a.m to 4.30 p.m. this gives 8 hrs per day from Monday to Thursday plus 7 hours on Friday + one OT hrs giving the working week 39hrs + one OT hrs
- Holidays
- 2 w Summer Holiday
- 4 D Easter Holiday in Summer.
- 7 D Winter Holiday.
- 5 D Public Holiday in Summer.
- 3 D Public Holiday in Winter.
- The total holiday is 29 D or 5 W + 4 D
• **Inclement weather and Sick leave**
  • Assume 60 hrs inclement weather and 3D sick leave in summer and 2D sick leave in winter.

• **Weeks worked in one week.**
  • Total weeks in years = 52 Ws
  • Holidays = 5 Ws + 4 Ds
  • Sick leave = 1 W
  • Weeks worked in a Year= 45 Ws + 1 D
• Calculation of hrs worked
• Total hours in year:
  • Summer Period, 44 Ws X 45 hrs = 1980 hrs
  • Winter Period, 8 Ws X 40 hrs = 320 hrs
• Total = 2300 hrs
• Hours not worked due to holidays:
• Total holiday in summer = summer Holiday + Easter Holiday + Public Holiday = 2Ws + 4 Ds + 5 Ds = 19 days.
• Hours not worked due to summer holidays = 19 Ds X 9 hrs = 171 hours.
• Total holidays in winter = winter + public
• = 10 Ds X 8 hrs = 80 hrs
• Total hrs not worked due to holidays = 171+80= 251 hrs
• Hours not worked due to inclement weather = 60 hrs
• Hours not worked due to sick leaves = (3 Ds X 9 hrs) + ( 2 Ds X 8 hrs) = 43 hours
• Total hours not worked = 354
• Total hours worked in one year 2300 hrs – 354 hrs = 1946 hrs
• Calculation of over time:
  • Possible over time worked in summer = 44 Ws X 6 hrs = 264
  • Less 19 day holiday and 3 Ds sick leaves
  • Over time not worked = 22 ds X 1 work hrs = 21 hrs
  • Over time worked = 242.
Productivity Measurement

- “time is the measure of productivity”.
- The measurement of time is limited mostly to direct labor.
- There are four methods for measurement of construction time
  - 1. Job-ticket reports
  - 2. Non repetitive one-cycle time study
  - 3. Multiple – cycle time study
  - 4. Work sampling
**Job-ticket reports and man hour analysis**

- The job ticket is just **time card** with additional information.
- Information for man-hours analysis is obtained from the job ticket or the foreman report.
- Worker may completed this own job ticket.
- The ticket used for time and cost control.
Example

• Consider Table 2.2 for welding operation where job tickets are used to observe the productivity.
• No verification needed for the ticket by foreman.
• Job tickets are collected for similar work and spread sheet is devised for the data.
• Table 2.3 where welding operation for a building are collected
## Job tickets (Table 2.2)

<table>
<thead>
<tr>
<th>Name: Neil</th>
<th>emplyee No. 505</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date: June 11</td>
<td>order No. 101</td>
</tr>
<tr>
<td>Job No.</td>
<td>Location: 2\textsuperscript{nd} floor</td>
</tr>
<tr>
<td>Part No. 6682</td>
<td>Part Name: Gusset, A36</td>
</tr>
<tr>
<td>Time start : 9:15</td>
<td>Time stopped : 11:43</td>
</tr>
<tr>
<td>Quantity : 3</td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td>Arc weld gusset, 36x18x1/2 to column 54 in. of double welding. Overhead welding</td>
</tr>
</tbody>
</table>
### Spread sheet example for arc-welding analysis (Table 2.3)

<table>
<thead>
<tr>
<th>Part No</th>
<th>Material</th>
<th>thickness</th>
<th>method</th>
<th>actual manhours</th>
<th>remarks</th>
<th>allowed MHs</th>
</tr>
</thead>
<tbody>
<tr>
<td>6682</td>
<td>steel</td>
<td>3/4x24</td>
<td>Arc weld</td>
<td>2.47</td>
<td>Fillet 2 sides</td>
<td>1.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7216</td>
<td>steel</td>
<td>1/2x8.4</td>
<td>Arc weld</td>
<td>1.06</td>
<td>No change</td>
<td>1.06</td>
</tr>
<tr>
<td></td>
<td></td>
<td>in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8313</td>
<td>steel</td>
<td>3/16x34</td>
<td>Arc weld</td>
<td>1.18</td>
<td>Increase by 25%</td>
<td>1.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>.4 in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Non repetitive one cycle time study (day time study)

• It is non repetitive because in construction we are unable to study more than one cycle of a construction job.

• It provide information for cost analysis and estimating.

• A time recording is essential by using electronic timer or video camera
Procedures follow these steps:

• 1. inform the labor under control
• 2. record job, equipment, worker, environment conditions, before and during the timing.
• Time the work and write down the job elements as the job proceed,
• 4. as the key steps of the job change, record the new elements along with the elapsed time.
• 5. record the time consumed by each element as it occurs.
• 6. Rate the pace at which various elements of work are performed.
• 7. Calculate the normal time
• 8. Adopt preapproved allowances, calculate the allowance multiplier and extend normal time to a standard time.
• 9. Express the standard in common units of productivity.
• Normal time is found by multiplying a selected time for the element by rating factor using
  \[ T_n = T_o \times RF \]
  \[ T_n = \text{normal time, hours, days, etc.} \]
  \[ T_o = \text{observe time, hours,}... \]
  \[ RF = \text{rating factor, arbitrary set, number} \]
• If the worker is judged to be fast, then the rating factor is greater than 1.0 say 1.1.
• If the selected cycle is 1.2 hr, then normal time is 1.2 x 1.1 = 1.32 hr
• Allowance for interruptions are divided into three components: personal, fatigue, and delay (PF&D)
• The personal is 4-5% in USA
• Typical allowance for fatigue is 5%
• Delay can vary from 0.0 to 25%
Allowance multiplier is

- $F_a = 100\% / (100\%-PF&D\%)$

- The final step is to find the standard productivity
  - $H_s = T_n \times F_a$
  - $H_s = \text{standard time for construction job per unit}$
Multiple-cycle time study and man-hour analysis

• It observing several cycles, on the same occasion or on different ones
• At each location, time is calculated for crow using stop watch. At the end of each element the watch is reset to zero and timing began again for next element.. The timing is suspended if the worker are idle.
Working Sampling Man hour

• Work sampling is a technique for gathering information about large segment of a work force population.
• It is used to measure labor efficiency and equipment utilization and their cost
• Advantages of work sampling include:
  • Productivity measurement and improvement
  • Statistical definition
  • Relatively low cost
• On work sampling only discrete observation are made.
• The key to accuracy is the number of observation.
• \( P'_i = \frac{N_i}{N} \)
• \( P'_i \) = observed proportion of occurrence \( i \)
• \( N_i \) = instantaneous observation of event \( i \)
• \( N \) = total number of random observations
A model for estimating work sampling cost

\[ H_s = \frac{(N_i/N)HR(1+PF&D)}{N_p} \]

- \( H_s \): standard man-hours per job element
- \( N_rh \): event I observation number
- \( H \): total man hours worked during man hour sampling
- \( R \): rating factor
- \( PF&D \): personal, fatigue & delay
- \( N_p \): construction unit accomplished during the period of observation.
Wage & Fringe Rate

• Labor cost (Wages or Salaries) are major ingredient of an estimate.
• Labor cost constitute 40% in heavy construction cost.
• A wage is paid by hour, day or week
• Payroll cover two classes of workers, first for Management, second hourly labor of direct
Fringe benefits

• It is one of the cost of labor. Wages is the total sum of labor cost.
• Fringe benefits which are related to wages represent 30% of the actual labor cost.
• Wages and fringe effects are calculated by one of two methods:
  • Wage only
  • Wage and fringe combined
Partial listing of fringe cost may include:

• **Legally required payments** (social security, unemployment, insurance, worker compensation)

• **Voluntary or required payment** such as group Insurance & pension plans.

• **Wash-up time**, paid rest period, travel time

• **Paying for time not worked**, holidays, vacations & sick pay.

• **Profit sharing payments**, service awards, and payment to union stewards
Types of Construction Labor

• A crew is a team of workers, which can be of the same trade or composite of many different trades. Due to the diverse nature of the different tasks associated with all the building systems, many types of craftsmen from many different trades are required in a building construction project.
Components of Labor Costs

• Labor costs in construction are determined by two factors: monetary and productivity.
• The monetary factor is related to hourly wage rates, wage premiums, insurance, fringe benefits, and taxes.
• Construction productivity = quantity of work/produced time duration.
• An example of this calculation used to determine the work hours for a painting job can be seen below

<table>
<thead>
<tr>
<th></th>
<th>Hours</th>
<th>Straight Time Rate ($/hr)</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bricklayers</td>
<td>3 bricklayers X 3 days X 8 hr/day = 72 hr</td>
<td>$28.55</td>
<td>$2,055.60</td>
</tr>
<tr>
<td>Helpers</td>
<td>2 helpers X 3 days X 8 hr/day = 48 hr</td>
<td>$22.40</td>
<td>$1,075.20</td>
</tr>
</tbody>
</table>

**Figure 4-1** Cost of labor computation example.
example

- For example, assume that a crew for a work item includes three bricklayers and two helpers. The crew works for three days under straight time (8-hr day) to complete the work package. The wage rate for each bricklayer is $28.55 and each helper is $22.40. In this instance, the total cost of labor is $3131 as determined by computations.
<table>
<thead>
<tr>
<th>Work Description</th>
<th>Quantity</th>
<th>Productivity per Hour</th>
<th>Unit</th>
<th>Total Men-Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior Painting</td>
<td>440</td>
<td>11</td>
<td>m²</td>
<td>40</td>
</tr>
<tr>
<td>Interior Painting</td>
<td>378</td>
<td>14</td>
<td>m³</td>
<td>27</td>
</tr>
</tbody>
</table>

**Figure 4-2** Work hours computation example.