Cost Analysis and Estimating for Engineering and Management

Chapter 2

Labor Analysis
Overview

- Labor and Labor Costs
  - Determining Costs
  - Labor Hour
- Time Study
- Work Sampling
- Wages and Fringe Benefits
  - Incentive Pay
Labor

- **Direct Labor**
  - “Touches” the Product
  - Changes – Adds Value to the Product

- **Indirect Labor**
  - Supports Direct Labor Efforts

- **Direct Labor Accounts for About 15% of the Product Cost**
Labor Costs

- Worker Pay
  - Wages
  - Fringe Benefits

- Equipment Costs
  - Capital Cost
  - Operating Costs
Determining Costs

- Products in Production
  - Historical Cost Records
  - Measurement of Time
  - Clock Time vs. Productive Time

- Proposed Products
  - Need an Estimate

- Labor Cost = Time x Wage
Labor Hour

- One Worker Working for One Hour
- Labor Year
  
  52 Weeks x 40 Hours = 2080 Hours
- Labor Month
  
  2080 / 12 = 173.3 Hours

- Should Be
  
  Time Working NOT Time at Work
Motivation

- Incentive Pay
  - More Production = More Pay
  - Requires “Fair” Standards
  - Leads to Other Problems
- Non-Incentive
  - Still Need to Know How Much Time a Job Should Take (Standard Time)
- Standards Are Needed for Estimates
Ergonomics

- Medical, Psychological & Engineering
- Human / Machine / Operation Interface
- Repetitive Motion Injury
- Legal and Moral Issue
- Financial Issue

Injury Prevention Costs Less than Injuries
Time Study

- Founder and Pioneers
  - Frederick W. Taylor
  - Frank & Lillian Gilbreth
    - Movie “Cheaper By the Dozen”

- Composed of 2 Parts
  - Analyze and Optimize the Operation
  - Measure the Time and Compute the Standard
Advantages of Time Study

- System for Estimating Costs
- Justification for Methods Improvement
- Reduction of Operation Costs
- Improvement of Engineering Design
- Information for Managing Productivity
Procedure for Time Study

- Methods Analysis and Improvement
- Record Info. About the Operation
- Separate Operation into Elements
- Record Time for Elements
- Rate Performance
Procedure for Time Study

- Convert to Normal Time
- Determine Allowances
- Calculate Standard Time
- Express Standard Time in Appropriate Terms
Methods Analysis

- Is the Job Ready for Timing?
  - Is the Physical Set-up Correct?
  - Is the Layout Efficient?
  - Are the Proper Tools & Equip. Used?
  - Is the Product Produced Correctly?
  - Is the Motion Pattern Optimized?
Recording of Information

- **Sketch Process Layout**
- **List Elements**
  - Short as Possible (but Time-able)
  - Have Identifiable Start & End Points
  - Separate Operator & Machine Elements
  - Separate Constant & Variable Elements
Example of Layout Sketch

- Stack bins
- Screwdriver
- Aside box
- For hand work

Dimensions:
- 26 in. (65 cm)
- 14 in. (35 cm)
- 18 in. (45 cm)
Taking the “Time Study”

- Stopwatch
  - Continuous vs. “Snap-Back” Methods

- Performance Rating
  - Trained Observer
  - Subjective Comparison
  - Observed Operator to Typical Operator Working at Normal Circumstances
Allowances

- Personal
- Fatigue
- Delay
- Together PF&D (in Percent)
- Convert to Factor

\[ F_a = \frac{100\%}{100\% - PF&D} \]

Eq 2.2
Analyzing the Study

- Find Average Time for Each Element
- Multiply by Performance Rating to Obtain “Normal Time”
- Multiply by Allowance Factor to Obtain “Standard Time”
### Time Study Example Part 1

#### Table: Time Study

<table>
<thead>
<tr>
<th>Line</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>Cycle Time</th>
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<td>0.05</td>
<td>0.003</td>
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<td>0.75</td>
<td>0.1</td>
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**SUM = 17.985**
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<tr>
<td>Average Time</td>
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<td>0.05</td>
<td>0.003</td>
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<td>0.1</td>
<td>0.74</td>
<td>0.74</td>
<td>0.083</td>
<td>0.05</td>
<td>0.034</td>
</tr>
</tbody>
</table>
Time Study Example Part 3

Average Cycle Time = \frac{17.985}{5} = 3.597 \text{ min}

Cycle rating factor = 1.00

Normal cycle time = 3.597

Allowances:
- Personal : 5%
- Fatigue : 5
- Delay : 5
- Total : 15%

Std. time per unit : 4.232
Work Sampling

- Used for General Purposes:
  - Estimating Costs
  - Scheduling
  - Labor Requirements
  - Monitoring and Managing Performance

- Statistical Technique
Compared to Time Study

- Multiple Workers / Machines
- Study Large Area
- Can Handle Long Cycle Times
- Less Study Time Required (Lower Cost)
- Less Disruptive of Work
- Reduces Performance Issues
About Work Sampling

- Determines Proportion of Time Spent on Predetermined Activities
- Based on Probability & Statistics
  - Random, Discrete Observations
  - Sufficient Number of Observations
  - Representative of Distribution of Population
Fundamentals

- Proportion of Time Spent on Activity $i$
  \[
P'_i = \frac{N_i}{N} \quad \text{Eq 2.6}
  \]
- Need to Know (Assume or Specify)
  - How Close Does $P'_i$ Need to Be to $P_i$
  - How Confident Do We Want to Be That the Sample Interval Encompasses the Actual Value
- Need to Determine $Z$ for the Desired Confidence from the Statistics Table
Normal Curve

Fig. 2.4

Relative frequency

1.645σ 1.645σ

1.645 √ p′(1 − p′)/n

5% Area 5% Area

90% of area under curve

2(1.645σ)

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Ostwald and McLaren / Cost Analysis and Estimating for Engineering and Management
## Values for $Z$

<table>
<thead>
<tr>
<th>Area Between Limits (%)</th>
<th>$-Z$ to $+Z$</th>
<th>Area Outside Limits (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>68</td>
<td>±1.000</td>
<td>32</td>
</tr>
<tr>
<td>90</td>
<td>±1.645</td>
<td>10</td>
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<tr>
<td>95</td>
<td>±1.960</td>
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<tr>
<td>99</td>
<td>±2.576</td>
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</table>
Preliminary Sampling

- Uncovers Potential Problems
- Refines Activity Definitions
- Helps “Sell” the Sampling Study
- Provides an Estimate for $P_i'$
Determining Sample Size

- Obtain $Z$ for Desired Confidence
- Determine Confidence Interval $I$
- Estimate Sample Proportion $P'_i$
- Compute $N_i$ for Each Activity
- Select the Largest $N_i$ as $N$ for the Complete Study
Calculating $N_i$

\[
N_i = \frac{4Z^2 p_i'(1 - p_i')}{I^2}
\]

Eq 2.9
Conducting the Full Sampling

- Spread the $N$ Observations Evenly Over the Study Days
- Distribute Each Day’s Observations Randomly through the Day
- Determine Rating and PF&D Factors
- Obtain the Total Units Produced During the Study ($N_p$)
Compute the Standard Time

Do Not Include Idle Activities

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

Eq 2.10
Considerations for Sampling

- Explain and Sell Prior to Starting
- Appropriately Isolate Studies
- Use as Large a Sample Size as Practical
- Observe at Random Times
- Conduct the Study Over a Long Period
Other Methods to Determine Time

- Labor Hour Reports/Time Cards/Job Tickets
  - Objective: Time Job SHOULD Take
  - Span Time Records Only
  - Requires “Adjustment”
  - Collected into Labor-Hour Summary
Other Methods to Determine Time

- Similar Products
  - Use Actual Data
  - Decompose Times by Components
  - Reassemble Times for New Product
  - Can Ratio Actual Times by Ratio of Product Complexities
Other Methods to Determine Time

- Engineering Performance Data
  - Micro-Motion Systems (e.g. MTM)
  - Some Capable of Producing Standards
- In-House Systems
- Experience and Judgment
Wages

- **Wage** –
  - Money Paid for an Amount of Work
  - Usually for Direct Labor
  - Sometimes for Indirect Labor

- **Salary** –
  - Money Paid for a Given Period of Time
Fringe Benefits

- Additional Costs to Company
- For Employees
- Required by Law, Contract, Agreement
- Can Be Included in Hourly Rates
- Or
- Covered in Overhead
Determining Wages

- **Wage Only**
- **Gross Hourly Cost**
  - Wages and Fringe Benefits Costs
- **Wage Only Calculation**
  - Based on Time in Attendance

\[ C_{dl} = H_a \times R_h \]  
Eq 2.11
Incentive Wages

- **Pure Incentive**
  - (e.g. Working on Commission)
  \[ C_{dl} = N_p R_p \]  
  Eq 2.12

- **Guaranteed Wage Plus Incentive**
  \[ C_{dl} = H_a R_h + R_h \left( H_s N_p - H_a \right) \]  
  Eq 2.13

- **Minimum** \[ C_{dl} = H_a R_h \]
Efficiency

- Ratio of Standard Hours Produced to Actual Hours Worked
- Measure of Labor Efficiency or Productivity

\[ E = N_p \frac{H_s}{H_a} \times 100 \]

Eq 2.14
Gross Hourly Cost

- Wages Plus Fringe Benefits Costs
- Detailed Calculations Required
  - By Engineering
  - Or (Preferably) Accounting
- Fringe Costs Include:
  - Legally Required Employee Costs
  - Contractual Costs
  - Voluntary Program Costs
  - Costs for Time Paid but Not Worked
Legally Required Costs

- **Social Security**
  - Employer’s Contribution
  7.65% of First $87,000 (as of 2003)

- **Medicare**
  - Employer’s Contribution
  1.45% of All Wages Paid

Click for Current Rates
More Legal Requirements

- **Worker’s Compensation**
  - Income for Worker Who Cannot Work Due to Injury on the Job

- **Unemployment Insurance**
  - Pays Workers Laid Off Through No Fault of Their Own

- **Non-Exempt Time-and-a-Half Pay**
  - Over 8 Hours/Day and/or 40 Hours/Week
Other Fringe Costs

- Supplemental Medical Insurance
  - All or a Portion of the Premiums
  - Can Be Around $500/Month ($2.89/Hr)
- Life Insurance Premiums
- Disability Insurance Premiums
- Supplemental Pension
Pay for Time Not Worked

- Vacation, Holidays, Sick Pay
  - Amount of Pay for this Time Is Apportioned Over Total Hours in the Work Year
  - Added to Wage Rate
Joint Labor Costs

- More Than One Product Produced By Common Labor
- Common Production Up to a Split Point
- Common Labor Costs Need to Be Apportioned to the Different Products
(De)Jointing Labor Costs

- Determine a Common Metric
- Find a Proportional Relationship for the Products
- Apply the Same Proportions to the Costs
- Market Effects/Strategy Can Distort
  - Some Products Subsidize Others
  - Price Is Not Proportional to Cost
Learning

- First Units Produced Take Longer
- Familiarization with the Job Reduces Time
- Predictable
- Covered in Chapters 6 & 8
Learning
Summary

- Definitions Relative to Labor Costs
- How to Determine Time for the Job
  - Time Study
  - Work Sampling
  - Other
- Finding the Labor Cost Rate
  - Wages, Fringe Benefits, Gross Hourly Cost