

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

$$52 \text{ Weeks} \times 40 \text{ Hours} = 2080 \text{ Hours}$$

- Labor Month

$$2080 / 12 = 173.3 \text{ Hours}$$

- 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

1. Methods Analysis and Improvement
2. Record Info. About the Operation
3. Separate Operation into Elements
4. Record Time for Elements
5. Rate Performance

Procedure for Time Study

6. Convert to Normal Time
7. Determine Allowances
8. Calculate Standard Time
9. Express Standard Time in Appropriate Terms

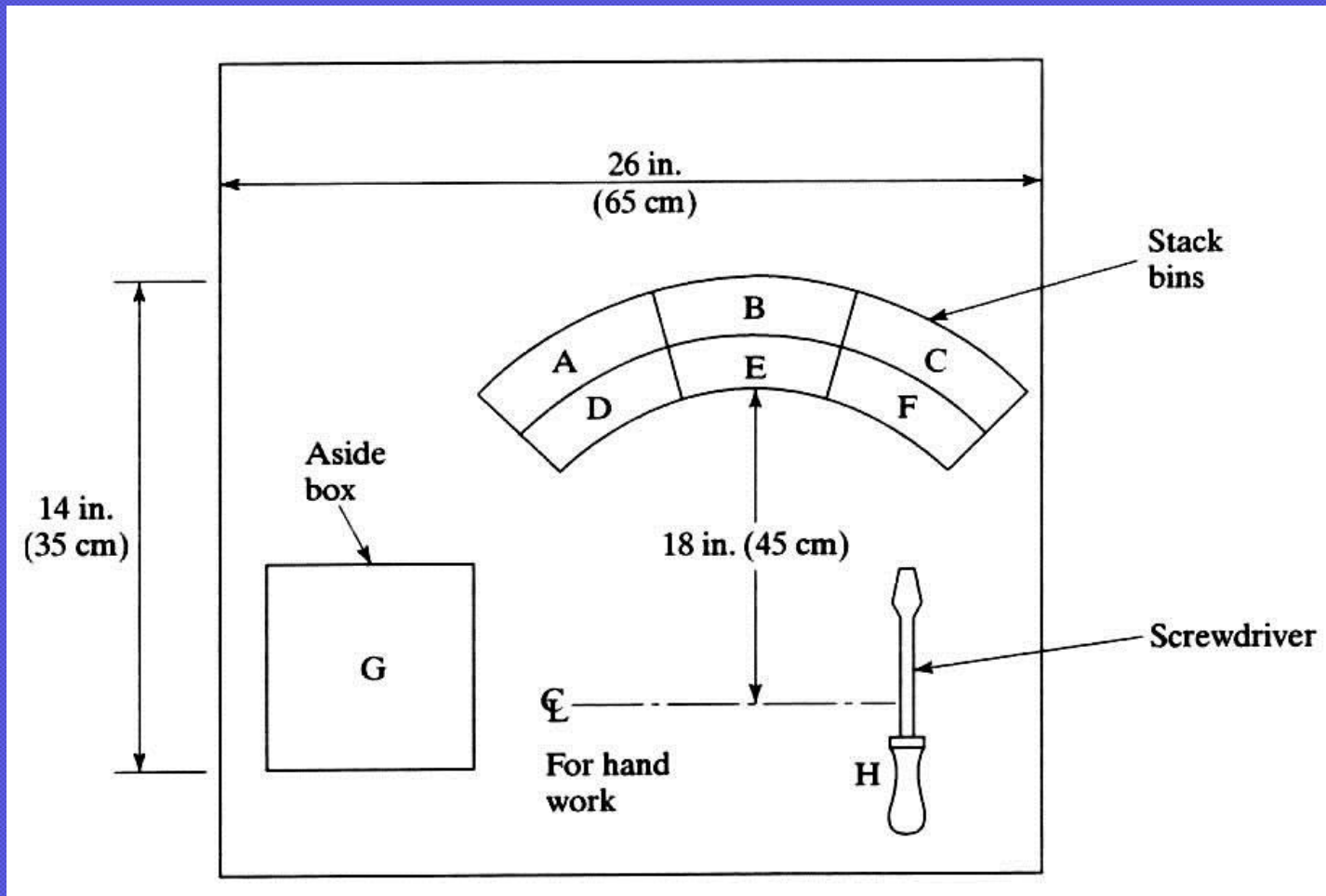
Methods Analysis

- 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



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

Elements	Infeed PCB to machine	Invert & Position PCB	Move to lower level	Getting below spray station	Exposing the PCB	Getting below comp. placement	Placing components on PCB	Reaching machine vision	Sending Defects	Waiting in queue	Going through oven	Reaching loader	Inserting PCB and change slot
	A	B	C	D	E	F	G	H	I	J	K	L	M
Line													
1	0.025	0.05	0.083	0.1	0.87	0.1	0.62	0.1	0.72	0.87	0.083	0.05	0.034
2	0.025	0.05	0.083	0.1	0.62	0.1	0.7	0.1	0.87	0.75	0.083	0.05	0.034
3	0.025	0.05	0.083	0.1	0.7	0.1	0.72	0.1	0.75	0.67	0.083	0.05	0.034
4	0.025	0.05	0.083	0.1	0.72	0.1	0.87	0.1	0.67	0.7	0.083	0.05	0.034
5	0.025	0.05	0.083	0.1	0.87	0.1	0.75	0.1	0.7	0.72	0.083	0.05	0.034
SUM =													

Cycle Time

3.705

3.565

3.465

3.585

3.665

17.985

Time Study Example Part 2

<i>Total time</i>	<i>0.125</i>	<i>0.025</i>	<i>0.415</i>	<i>0.5</i>	<i>3.76</i>	<i>0.5</i>	<i>3.65</i>	<i>0.5</i>	<i>3.7</i>	<i>3.7</i>	<i>0.415</i>	<i>0.075</i>	<i>0.17</i>
<i>No. of reading</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>	<i>5</i>
<i>Average reading</i>	<i>0.025</i>	<i>0.05</i>	<i>0.083</i>	<i>0.1</i>	<i>0.75</i>	<i>0.1</i>	<i>0.73</i>	<i>0.1</i>	<i>0.74</i>	<i>0.74</i>	<i>0.083</i>	<i>0.05</i>	<i>0.034</i>
<i>Frequency</i>		<i>One out of One</i>											
<i>Average Time</i>	<i>0.025</i>	<i>0.05</i>	<i>0.083</i>	<i>0.1</i>	<i>0.75</i>	<i>0.1</i>	<i>0.73</i>	<i>0.1</i>	<i>0.74</i>	<i>0.74</i>	<i>0.083</i>	<i>0.05</i>	<i>0.034</i>

Time Study Example Part 3

$$\text{Average Cycle Time} = \frac{17.985}{5}$$

$$= \underline{3.597 \text{ min}}$$

$$\text{Cycle rating factor} = \underline{1.00}$$

$$\text{Normal cycle time} = \underline{3.597}$$

Allowances:

$$\text{Personal} : \underline{5\%}$$

$$\text{Fatigue} : \underline{5}$$

$$\text{Delay} : \underline{5}$$

$$\text{Total} : \underline{15\%}$$

$$\text{Std. time per unit} : 4.232$$

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

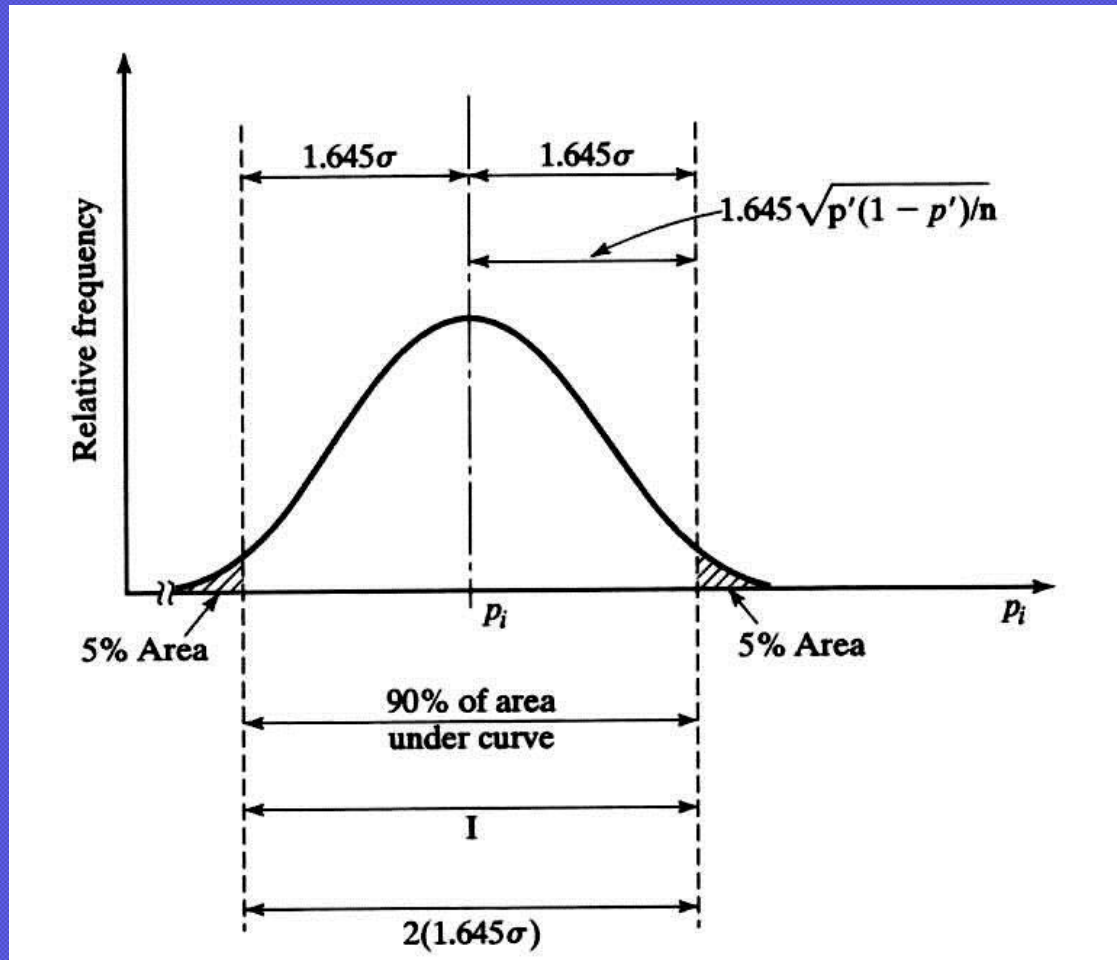
Fundamentals

- Proportion of Time Spent on Activity i

$$P'_i = N_i / N \quad \text{Eq 2.6}$$

- 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



Values for Z

Area Between Limits (%)	$-Z$ to $+Z$	Area Outside Limits (%)
68	± 1.000	32
90	± 1.645	10
95	± 1.960	5
99	± 2.576	1

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)

Standard Time

- 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

$$C_{dl} = H_a \times R_h \quad \text{Eq 2.11}$$

Incentive Wages

- Pure Incentive
–(e.g. Working on Commission)

$$C_{dl} = N_p R_p \quad \text{Eq 2.12}$$

- Guaranteed Wage Plus Incentive

$$C_{dl} = H_a R_h + R_h (H_s N_p - H_a) \quad \text{Eq 2.13}$$

- 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

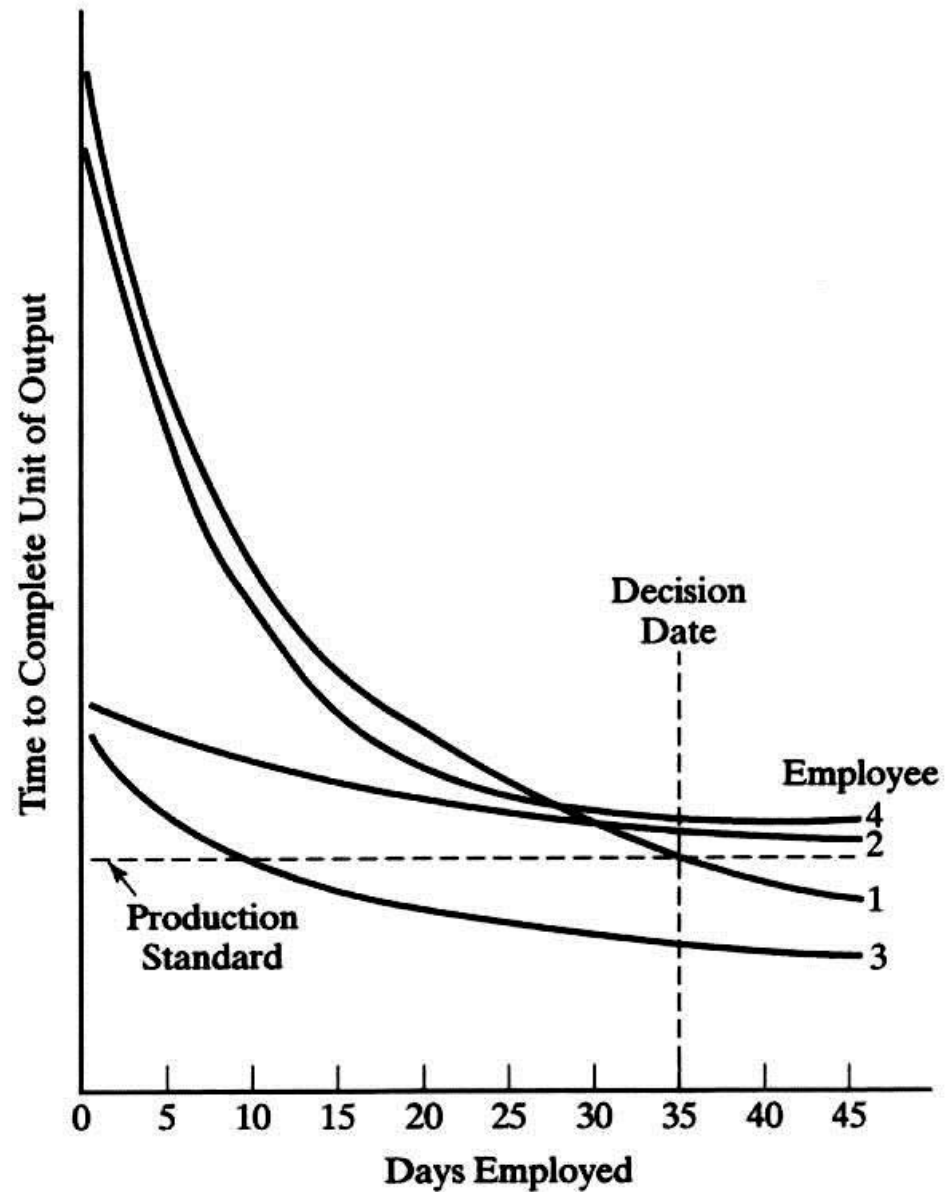
(De)Jointing Labor Costs

- 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