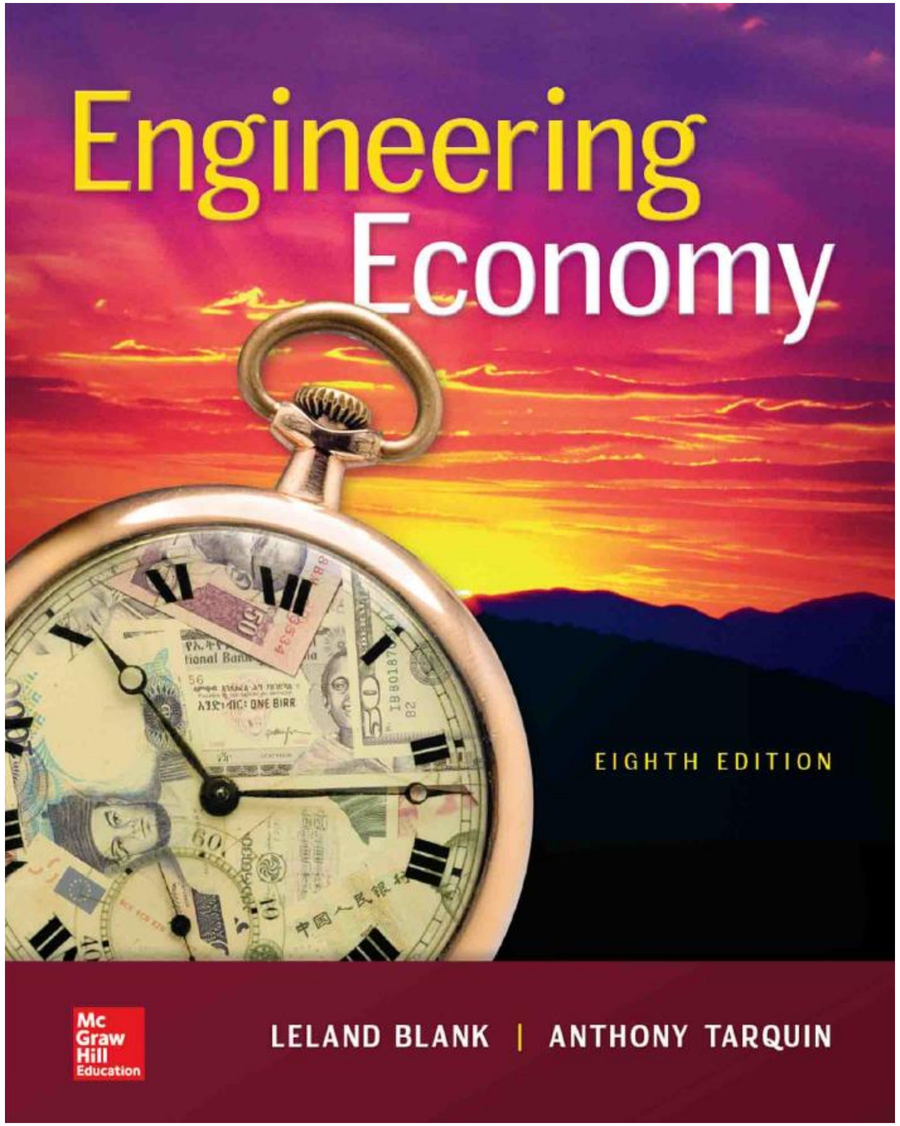


Chapter 15

Cost Estimation and Indirect Costs

Lecture slides to accompany

Engineering Economy

8th edition

Leland Blank

Anthony Tarquin

McGraw Hill Higher Education

LEARNING OUTCOMES

1. Approaches to estimation
2. Unit method
3. Cost indexes
4. Cost-capacity equations
5. Factor method
6. Indirect cost rates and allocation
7. ABC allocation
8. Ethical considerations

Examples

세종대왕함(KDX-III), 훈련함(ATX) 운영유지비 산출

안보경영연구원 온종열

서울과학기술대학교 안재경

SMI 안보경영연구원 · 대한민국해군 · SEOULTECH 서울과학기술대학교

Examples

(1) 표준비용명세구조

2.공학적 추정분석

표준비용명세구조				
계층1	계층2	계층3	계층4	계층5
인력운영	직접비	급여	기본급여	봉급
				정근수당
			일반수당	시간외근무수당
				정액수당
			특수업무수당	
			복리후생비	교통보조비
				연가보상비
				명절휴가비
				가계지원비
			직급보조비	
			부사관수당	
			성과상여금	
		급식비	기본급식비	
			증식비	
			심해식품가공비	
			특전식량	
		피복비	기본피복	
			특수피복	
	간접비	기여금(연금부담금)		
		건강보험부담금		
부대활동지원	각급부대 운영비	참모부운영비		
		지휘부운영비		
	월액기준경비	주임원사활동비		
교육훈련	교육용탄약			
장비유지 및 운영	정비비	부대정비		
		야전정비		
		창정비		
	유류비			
물자관리	의약품			

Examples

NASA Cost Estimating Overview

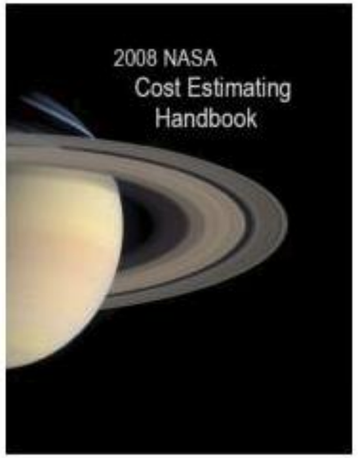
Integrated Design Capability / Instrument Design Laboratory

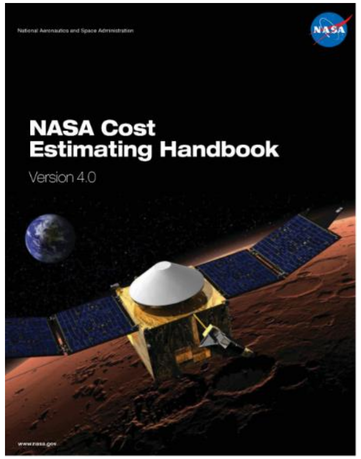
NASA Cost Estimating Handbook 2008

- Defines three cost estimating Methodologies
  - **Parametric**: based on key engineering data and Cost Estimating Relationships (CERs)
  - **Analogy**: comparison and extrapolation to like items or efforts
  - Engineering Build-Up (i.e., "**grass-roots**"): Labor and Material estimates based on experience and "professional judgment"
- Defines two cost estimating Processes
  - **Advocacy Cost Estimates (ACE)**
    - Cost Estimators are members of program/project team
  - **Independent Cost Estimates (ICE)**
    - Cost Estimators are from an organization separate from project
- Encourages parametric modeling and analogy estimates during pre-Phase A and Phase A studies

http://www.nasa.gov/offices/pae/organization/cost_analysis_division.html

http://ceh.nasa.gov



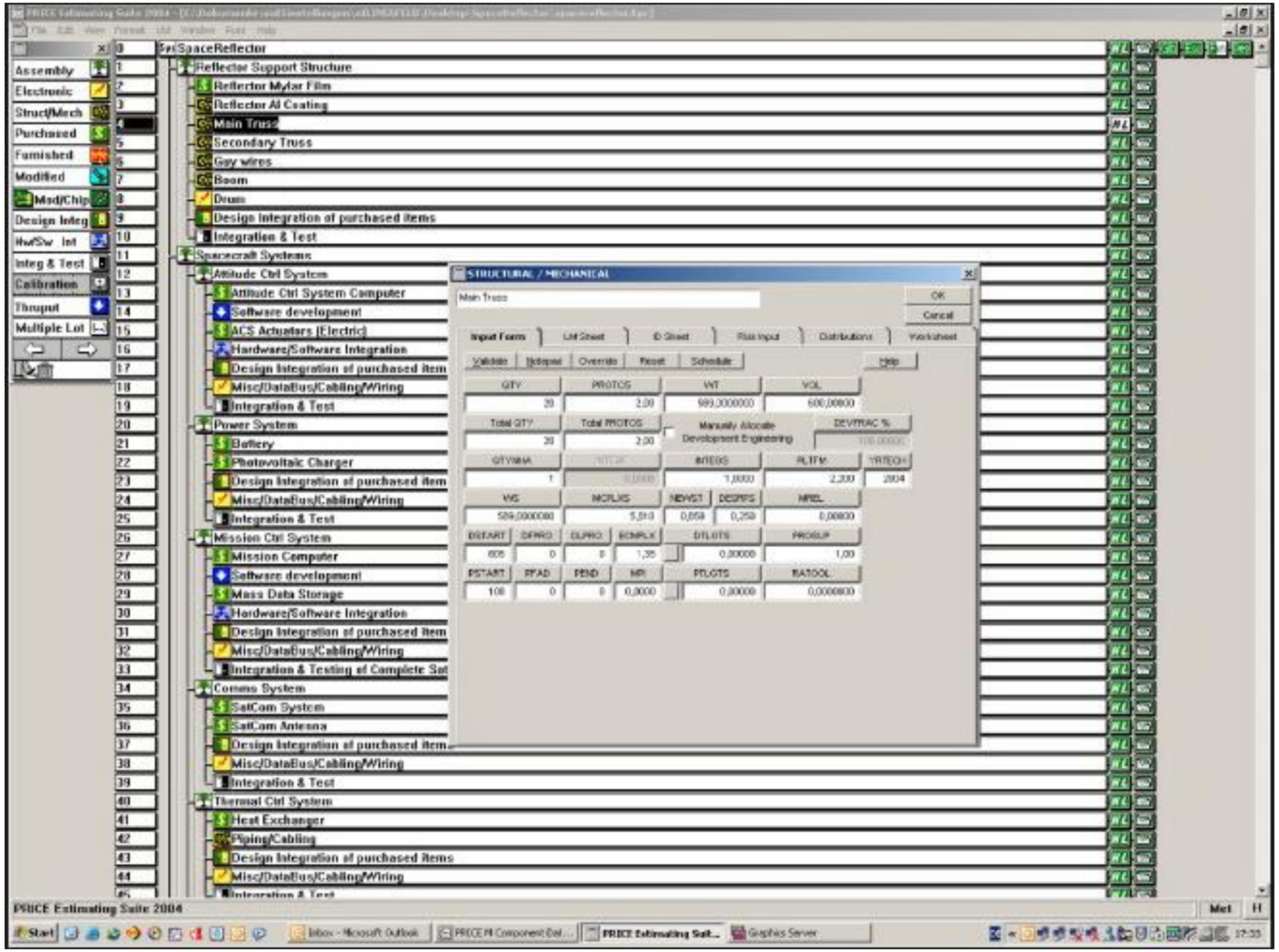


Proposal cost estimates evaluated at NASA Langley Research Center during Technical, Management, and Cost (TMCO) review

- Parametric models used to validate proposal cost estimate
- Assumed criteria for validation of Step 1 proposal (based on feedback): proposal estimate and TMCO consensus estimate within 20%

PRICE(Parametric Review of Information for Costing and Evaluation)

Examples



PRICE(Parametric Review of Information for Costing and Evaluation)

Direct and Indirect Cost Estimates

Direct cost examples

- Physical assets
- Maintenance and operating costs (M&O)
- Materials
- Direct human labor (costs and benefits)
- Scrapped and reworked product
- Direct supervision of personnel

Indirect cost examples

- Utilities
- IT systems and networks
- Purchasing
- Management
- Taxes
- Legal functions
- Warranty and guarantees
- Quality assurance
- Accounting functions
- Marketing and publicity

What Direct Cost Estimation Includes

Direct costs are more commonly estimated than revenue in an engineering environment. Preliminary decisions required are:

- ✓ What **cost components** should be estimated?
- ✓ What **approach** to estimation is best to apply?
- ✓ How **accurate** should the estimates be?
- ✓ What **technique(s)** will be applied to estimate costs?

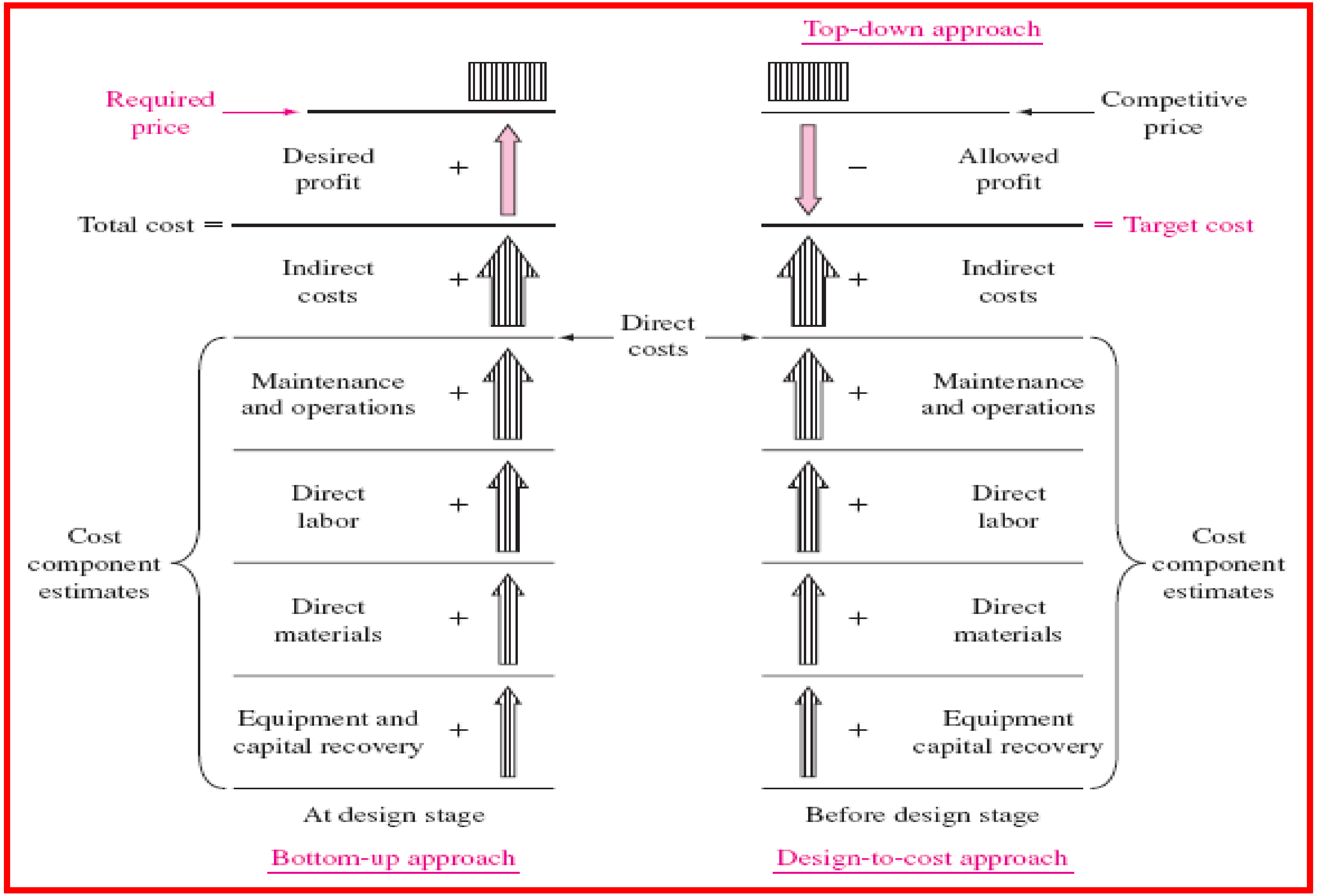
Sample direct cost components: first costs and its elements (P); annual costs (AOC or M&O); salvage/market value (S)

Approaches: bottom-up; design-to-cost (top down)

Accuracy: feasibility stage through detailed design estimates require more exacting estimates

Some techniques: unit; factor; cost estimating relations (CER)

Different Approaches to Cost Estimation



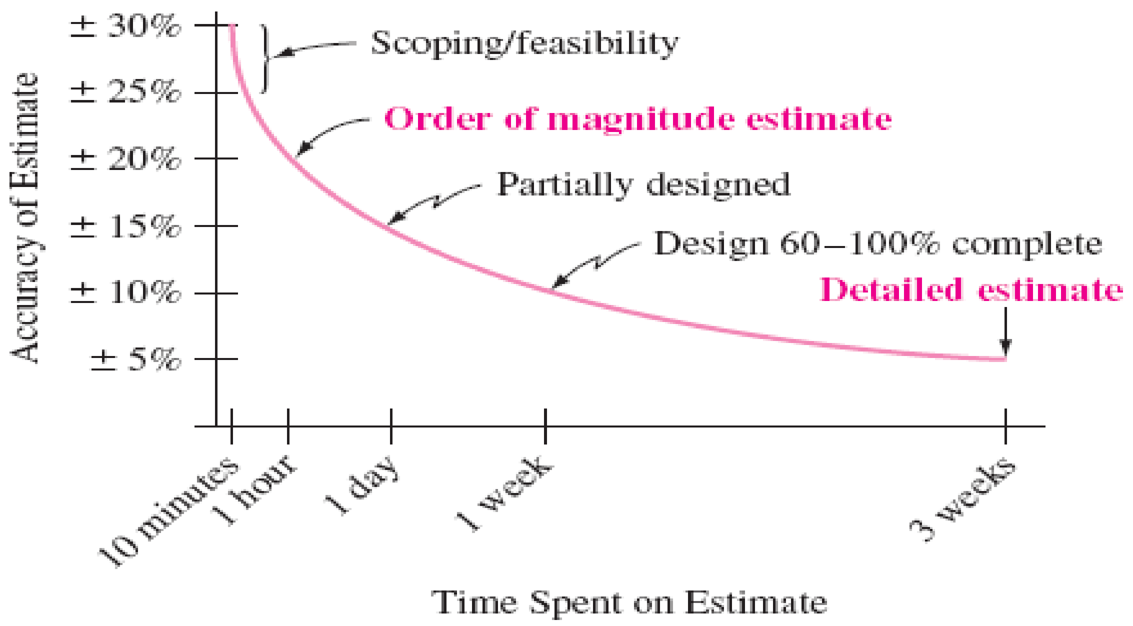
Accuracy of Cost Estimates

General guidelines for accuracy

Conceptual/Feasibility stage – order-of-magnitude estimates are in range of ±20% of actual costs

Detailed design stage - Detailed estimates are in range of ±5% of actual costs

Characteristic curve of accuracy vs. time to make estimates



Unit Method

- Commonly used technique for ***preliminary design stage*** estimates
- Total cost estimate C_T is **per unit cost (u)** times **number of units (N)**

$$C_T = u \times N$$

- **Example uses:**

➢ Cost to operate a car at 60¢/mile for 500 miles: **$C_T = 0.60 \times 500 = \$300$**
➢ Cost to build a 250 m^2 house at \$2250/m^2: **$C_T = 2250 \times 250 = \$562{,}500$**

- **Cost factors must be updated periodically to remain timely**

When several components are involved, estimate cost of each component and add to determine total cost estimate C_T

Cost Indexes

- **Definition: Cost Index is ratio of cost today to cost in the past**

- Indicates change in cost **over time**; therefore, they account for the **impact of inflation**
- Index is dimensionless
- CPI (Consumer Price Index) is a good example

Formula for total cost is

$$C_t = C_0\left(\frac{I_t}{I_0}\right)$$

C_t = estimated cost at present time t

C_0 = cost at previous time t_0

I_t = index value at time t

I_0 = index value at base time 0

Example: Cost Index Method

Problem: Estimate the total cost of labor today in US dollars for a maritime construction project using data from a similar project in Europe completed in 1998.

Labor index, 1998: 789.6
Labor index, current: 1165.8

Cost in 1998: €3.9 million
Currently, 1 € = 1.5 US$

Solution: Let t = today and 0 = 1998 base

$$C_t = 3.9 \text{ million} \times (1165.8/789.6) = €5.76 \text{ million}$$
$$= €5.76 \times 1.5 = \$8.64 \text{ million}$$

Finding Cost Indexes

Cost indexes are maintained in areas such as construction, chemical and mechanical industries

- Updated monthly and annually; many include regionalized and international project indexes
- Indexes in these areas are often subdivided into smaller components and can be used in preliminary, as well as detailed design stages

Examples are:

- ✓ Chemical Engineering Plant Cost Index (CEPCI)
  www.che.com/pci
- ✓ McGraw-Hill Construction Index
  www.construction.com
- ✓ US Department of Labor, Bureau of Labor Statistics
  www.bls.gov

Cost-Estimating Relationships (CER)

- CER equations are **used in early design stages** to estimate plant, equipment and construction costs
- CERs are generically different from index relations, because they estimate based on **design variables** (weight, thrust, force, pressure, speed, etc.)

Two commonly used CERs

- **Cost-capacity equation** (relates cost to capacity)
- **Factor method** (total plant cost estimator, including indirect costs)

Cost-Capacity Equation

Also called ***power law and sizing model***

$$C_2 = C_1\left(\frac{Q_2}{Q_1}\right)^x$$

Exponent defines relation between capacities

$$\begin{aligned} C_1 &= \text{cost at capacity } Q_1 \\ C_2 &= \text{cost at capacity } Q_2 \\ x &= \text{correlating exponent} \end{aligned}$$

x = 1, relationship is **linear**
x < 1, economies of scale (larger capacity is **less costly than linear**)
x > 1, diseconomies of scale

Cost-Capacity Combined with Cost Index

Multiply the cost-capacity equation by a cost index (I_t/I_0) to adjust for time differences and obtain estimates of current cost (in then-current dollars)

$$C_2 = C_1\left(\frac{Q_2}{Q_1}\right)^x\left(\frac{I_t}{I_0}\right)$$

Example: A 100 hp air compressor costs $3000 five years ago when the cost index was 130. Estimate the cost of a 300 hp compressor today when the cost index is 255. The exponent for a 300 hp air compressor is 0.9.

Solution: Let C_{300} represent the cost estimate today

$$C_{300} = 3000(300/100)^{0.9}(255/130)$$
$$= \$15{,}817$$

Factor Method

- Factor method is especially useful in estimating **total plant cost** in processing industries
- Both **direct and indirect costs** can be included

Total plant cost estimate C_T is **overall cost factor (h)** times **total cost of major equipment items (C_E)**

$$C_T = h \times C_E$$

Overall cost factor h is determined using one of two bases:

- **Delivered-equipment cost** (purchase cost of major equipment)
- **Installed-equipment cost** (equipment cost plus all make-ready costs)

Cost Factor h

The cost factor is commonly the sum of a direct cost component and an indirect cost component, that is,

$$h = 1 + \Sigma f_i$$

for i = 1, 2, …, n components, including indirect costs

Example: Equipment is expected to cost \$20 million delivered to a new facility. A cost factor for direct costs of 1.61 will make the plant ready to operate. An indirect cost factor of 0.25 is used. What will the plant cost?

Solution: $h = 1 + 1.61 + 0.25 = 2.86$

C_T = 20 million (2.86) = **\$57.2 million**

Cost Factor h

If indirect costs are charged separately against all direct costs, the indirect cost component is added separately, that is,

$$h = 1 + \Sigma f_i \qquad \text{(direct costs components)}$$

and

$$C_T = hC_E(1 + f_{indirect})$$

Example: Conveyor delivered-equipment cost is \$1.2 million. Factors for installation costs (0.4) and training (0.2) are determined. An **indirect cost factor of 0.3** is applied to all direct costs. Estimate total cost.

Solution:

$$h = 1 + 0.4 + 0.2 = 1.6$$

$$C_T = hC_E(1 + f_{indirect})$$

$$= 1.6(1.2 \text{ million})(1 + 0.3) = \$2.5 \text{ million}$$

Indirect Costs

Indirect costs (IDC) are incurred in production, processes and service delivery that are not easily tracked and assignable to a specific function.

- **Indirect costs (IDC) are shared by many functions because they are necessary to perform the overall objective of the company**
- **Indirect costs make up a significant percentage of the overall costs in many organizations – 25 to 50%**

<u>Sample indirect costs</u>

- **IT services**
- **Quality assurance**
- **Human resources**
- **Management**
- **Safety and security**
- **Purchasing; contracting**
- **Accounting; finance; legal**

Indirect Cost Allocation - Traditional Method

- **Cost center --** Department, function, or process used by the cost accounting system to collect both direct and indirect costs
- **Indirect-cost rate –** Traditionally, a predetermined rate is used to allocate indirect costs to a cost center using a **specified basis**. General relation is:

$$\text{Indirect-cost rate} = \frac{\text{Estimated total indirect costs}}{\text{Estimated basis level}}$$

Example:

Cost Source	Allocation Basis	Estimated Activity Level
Machine 1	Direct labor cost	\$100,000
Machine 2	Direct labor hours	2000 hours
Machine 3	Direct material cost	\$250,000

Allocation rates for \$50,000 to each machine

Machine 1: Rate = \$50,000/100,000 = \$0.50 per DL \$
Machine 2: Rate = \$50,000/2,000 = \$25 per DL hour
Machine 3: Rate = \$50,000/250,000 = \$0.20 per DM \$

Example: AW Analysis - Traditional IDC Allocation

MAKE/BUY DECISION

Buy: AW = $-2.2 million per year

Make: P = $-2 million S = $50,000 n = 10 years MARR = 15%

- Direct costs of $800,000 per year are detailed below
- Indirect cost rates are established by department

Department	Indirect Costs: Basis, Hours	Indirect Costs: Rate Per Hour	Indirect Costs: Allocated Hours	Direct Material Cost	Direct Labor Cost
A	Labor	$10	25,000	$200,000	$200,000
B	Machine	5	25,000	50,000	200,000
C	Labor	15	10,000	50,000	100,000
				$300,000	$500,000

Example: Indirect Cost Analysis - Traditional Method

INDIRECT COST ALLOCATION FOR MAKE ALTERNATIVE

Dept A: Basis is -- Direct labor hours — 25,000(10) = $250,000
Dept B: Basis is -- Machine hours — 25,000(5) = $125,000
Dept C: Basis is -- Direct labor hours — 10,000(15) = $150,000

$$\left.\begin{array}{r} 25{,}000(10) = \$250{,}000 \\ 25{,}000(5) = \$125{,}000 \\ 10{,}000(15) = \$150{,}000 \end{array}\right\} \$525{,}000$$

ECONOMIC COMPARISON AT MARR = 15%

AOC_{make} = direct labor + direct materials + indirect allocation

= 500,000 + 300,000 + 525,000 = $1.325 M

AW_{make} = - 2 M(A/P,15%,10) + 50,000(A/F,15%,10) - 1.325 M

= $-1.72 M

AW_{buy} = $-2.2 M

Conclusion: Cheaper to **make**

ABC Allocation

- **Activity-Based Costing —** Provides excellent **allocation strategy and analysis of costs** for more advanced, high overhead, technologically-based systems
- **Cost Centers (cost pools) —** Final products/services that **receive allocations**
- **Activities —** Support departments that **generate indirect costs** for distribution to cost centers (maintenance, engineering, management)
- **Cost drivers —** These are the **volumes that drive consumption** of shared resources (# of POs, # of machine setups, # of safety violations, # of scrapped items)

Steps to implement ABC:

1. Identify each ***activity*** and its ***total cost*** (e.g., maintenance at $5 million/year)
2. Identify ***cost drivers*** and expected ***volume***

   (e.g., 3,500 requested repairs and 500 scheduled maintenances per year)
3. Calculate cost rate for each activity using the relation:

   ABC rate = total activity cost/volume of cost driver
4. Use ***ABC rate*** to allocate IDC to ***cost centers*** for each activity

Example: ABC Allocation

Use ABC to allocate safety program costs to plants in US and Europe

Cost centers: US and European plants

Activity and cost: Safety program costs $200,200 per year

Cost driver: # of accidents

Volume: 560 accidents; 425 in US plants and 135 in European plants

Solution:

ABC rate for accident basis = 200,200/560 = $357.50/accident

US allocation: 357.50(425) = $151,938

Europe allocation: 357.50(135) = $48,262

Example: Traditional Allocation Comparison

Use traditional rates to allocate safety costs to US and EU plants

Cost centers: US and European plants
Activity and cost: Safety program costs $200,200 per year
Basis: # of employees
Volume: 1400 employees; 900 in US plants and 500 in European plants

Solution:

Rate for employee basis = 200,200/1400 = $143/employee

US allocation: 143(900) = $128,700
Europe allocation: 143(500) = $71,500

Comparison: US allocation went down;
European allocation increased

Traditional vs. ABC Allocation

- Traditional method is easier to set up and use
- Traditional method is usually better when making cost estimates
- ABC is more accurate when process is in operation
- ABC is more costly, but provides more information for cost analysis and decision making
- **Traditional and ABC methods complement each other:**
  - **Traditional is good for cost estimation and allocation**
  - **ABC is better for cost tracking and cost control**

Ethics and Cost Estimating

Unethical practices in estimation may be the result of:

- ❑ Personal gain motivation
- ❑ Bias
- ❑ Deception
- ❑ Favoritism toward an individual or organization
- ❑ Intentional poor accuracy
- ❑ Pre-arranged financial favors (bribes, kickbacks)

When making any type of estimates, always comply with the

Code of Ethics for Engineers

Avoid deceptive acts

Summary of Important Points

- Required accuracy of cost estimates depends on the stage of a system design; accuracy varies from ±20% to ±5% of actual cost
- Costs can be updated using the **unit method** and **cost indexes,** where time differences are considered (inflation over time)
- The **factor method** estimates total plant costs, including indirect costs

- Indirect costs comprise a large percentage of product and service costs
- Traditional indirect cost allocation use **bases** such as direct labor hours, costs, and direct materials
- The ABC method of indirect cost allocation uses cost drivers to allocate to cost centers; it is better for understanding and analyzing cost accumulation

- **Unethical practices** in cost estimation result from personal financial motives, deception, financial pre-arrangements. **Avoid deceptive acts**