AACE International Recommended Practice No. 11R-88

REQUIRED SKILLS AND KNOWLEDGE OF A COST ENGINEER

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INTRODUCTION

The AACE Education Board was created in 1982 to provide advice and assistance to the Association Board of Directors in all matters pertaining to education. One of the first dilemmas faced by the Education Board was a lack of definition of a professional cost engineer in terms of skills and knowledge, since this would comprise the target for education program emphasis. Based on a 1983 survey, the numerous cost engineering subjects were catalogued as either "core" or "optional." By definition, the core subjects-are those whose usage was occasional to frequent and which were evaluated by the members as being desirable for professional cost engineers to know.

The next step by the Education Board was to take the core subjects and expand them into a series of performance statements to represent the level of' proficiency expected in each subject area. The compilation of these performance statements was published as a proposed AACE Recommended Practice in May 1985, and membership comments were solicited. Based upon the comments that were received, the document was revised, expanded, and republished for comment in August 1986. No further comments were received, and the document was therefore formally accepted by the AACE Board of Directors as an *AACE Recommended Practice* in June 1987. Subsequently, all AACE technical activities were reorganized into four technical divisions, i.e., cost estimating, cost control, planning and scheduling, and project management and the text of this recommended practice was rearranged to correspond with the new structure.

This recommended practice was originally proposed in May 1985 and was formally accepted by the AACE Board of Directors in June 1987. Editorial changes were subsequently made, and the recommended practice was published in its previous form in October 1988.

Further changes were made in January 1999 to better reflect the current status of the Required Skills and Knowledge of a Cost Engineer. It is anticipated that this document will continue to be modified as current practice changes.

SECTION I -- SUPPORTING SKILLS AND KNOWLEDGE

Engineering Economics

1. Calculate simple and compound interest rates and solve interest problems using the basic single payments, uniform series, and gradient formulas.

2. Calculate present value, future value, and equivalent uniform annual value of a cash flow series.

3. Perform sensitivity analysis.

4. Determine discounted rate of return of a cash flow series.

5. Evaluate and select the best alternative from two or more alternatives utilizing present value, future value, equivalent uniform annual value, and discounted rate of return.

6. Compare two alternatives using benefit/cost ratio.

7. Calculate the depreciation on an item of equipment using MACRS.

8. Know the significance and meaning of Life Cycle Costs.

Terminology

Be familiar with cost engineering terms as contained in AACE's **"Standard Cost Engineering Terminology"**.

Computers

1. For a major computer installation:

    a. Describe at least three methods for inputting data.
    b. Identify at least three peripherals.
    c. Explain the function of the central processing unit (CPU).
    d. Identify two methods of mass data storage.

2. Explain current terms as used in Information Technology (IT), such as:

    a. Software and hardware
    b. Alphanumeric
    c. Baud rate
    d. Bits, bytes, kilobytes, megabytes and gigabytes
    e. Cursor
    f. Laser printers, ink jet printers, plotters and digitizers
    g. Emulator, math coprocessors
    h. Fields, records, and files
    i. Database
    j. Random Access Memory (RAM)
    k. Modem
    l. Mainframe, desk top and laptop computers
    m. Remote, host
    n. User-friendly
    o. Video conferencing
    p. Floppy disk, hard drives and CD ROM
    q. Networks (LAN and WAN)
    r. Disk operating systems (DOS), Windows and Windows NT
    s. Ports, parallel and serial
    t. Micro Processors (Pentium, MMX technology)
    u. Internet, intranet , extranet URL, HTTP, WWW Hypertext and Hyperlinks, HTML
    v. Groupware, netware and shareware
    w. Plug and Play
    x. Multimedia system

3. Name at least three common computer languages.

Statistics and Probability

1. Given a set of data, determine:

    a. The arithmetic mean
    b. The median
    c. The mode
    d. The standard deviation
    e. The Variance

2. Given a curve of normal distribution and an accompanying table of areas under the curve, determine the probability of the variable-.

    a. Being between two given values.
    b. Not being higher than a given number, or lower than that number.

3. Given a curve of distribution for a variable that is other than normal, draw the resultant cumulative frequency curve. Determine the percent probability of a given value not being overrun or under run.

4. Handle basic statistic exercises involving:

    a. Chi-Squared Test
    b. Frequency Distributions
    c. Confidence intervals

5. Apply the concepts of probability to find expected value.

6. Discuss risk and how the concept of risk is used in forecasting costs.

7. Understand the difference between “Sample Population”. Know how sample values of the mean estimate the population mean.

Optimization

1. Given an optimization goal involving a result Y which is a function of a single variable X, use graphical or incremental methods to establish the optimum value of Y.

2. Explain any two of the following decision making tools and how they can be used to analyze specific cost problems:

    a. Simulation
    b. Breakeven analysis
    c. Decision Tree
    d. Linear Programming
    e. Forecasting

Productivity Management

1. Define "productivity”. Distinguish between “production" and "productivity."

2. Discuss how the following can influence productivity:

    a. Individual worker skills
    b. Worker attitude
    c. Work force sociological characteristics
    d. Project demographics
    e. Absenteeism and turnover
    f. Technology employed
    g. Management/supervisor competence
    h. Immediate work area environment
    i. Relationship to other work or contractors
    j. Project geographic location
    k. Job layout
    l. Weather
    m. Overtime
    n. Learning curve
    o. Work rules
    p. Safety program
    q. Materials/tools equipment availability
    r. Crew balance
    s. First level quality control
    t. Salary, compensation plan and social benefits
    u. Social and Cultural differences
    v. Effective management, planning, scheduling at worker and overall level

3. Describe programs that can be undertaken to improve productivity on a project.

4. Describe time-lapse photography (unattended) and at least one direct observation (attended) type of work sampling system.

5. Describe the application of work sampling in a productivity management program to include its major strengths and weaknesses.

Human Relations/Behavioral Science

1. Given a listing of a number of commonly referenced management theories or authors, such as those below, be able to discuss at least three of them.

    a. Abraham Maslow (Hierarchy of Needs)
    b. Douglas McGregor (Theory X and Theory Y)
    c. Rensis Likert (Four Model Systems)
    d. Chris Argyris (Effects of organization Life on individuals)
    e. Robert Blake and Jane S. Mouton (Managerial Grid)
    f. Frederick Herzberg (Motivation-Hygiene Theory)
    g. Koontz and O'Donnell (The Japanese Experience: Theory Z)
    h. Tom Peters [In Search of Excellence; and others]
    i. Phillip Crosby
    j. Peter Drucker
    k. Steven Covey
    l. Dr. Peter Bono
    m. Dr. Edward Deming

2. Why is it essential that all senior project control personnel possess good inter-personnel skills and be effective communicators?

3. Discuss the meaning and provide examples of "participative management."

4. Discuss "motivators" and de-motivators" as related to labor attitudes and productivity.

5. Given a case study situation involving a personnel or productivity problem in a company, analyze the situation and provide appropriate recommendations for solving the problem.

6. Describe the purpose, functioning and limitations of "quality circles."

Organizational Structures

1. A large industrial firm includes the functions of administration, finance, research and development, engineering, marketing, and manufacturing. For such a firm:

    a. Draw an organization chart, which reflects an hierarchical, vertical, functional organization.
    b. Draw an organization chart for the same company if the intent is to include a manager of projects while still maintaining a vertical, hierarchical organization. In effect, the organization is to be "projectized" on a team basis.
    c. Draw an organization chart for the same company if the intent is to maintain centralized functional responsibilities but to manage projects on a matrix basis.
    d. For each of the above, discuss how costs are best reported and controlled.

2. In an organization where projects are managed on a matrix basis, discuss the roles, responsibilities, and methods for its successful operation.

3. Compare the advantages and disadvantages of a vertical, hierarchical organization to a matrix organization.

4. Describe the organization and operation of a project team or task force.

Measurements

1. Be able to convert English and metric measurements.

SECTION II -- COST ESTIMATING

Estimating Basics

1. Describe the importance of a good technical scope definition on the quality of the estimate.

2. What project conditions have a significant impact on the quality of the estimate?

3. Describe the differences in the mechanics of compensation for wage and salaried employees. Explain the meanings of "exempt" and "nonexempt" employees.

4. Describe the possible included components of "fringes" or "burdens

5. Describe the basic differences in the handling of base compensation and fringes in a union atmosphere as compared to an open shop atmosphere.

6. Describe the basic mechanics of mandatory government programs that are part of employee benefit packages such as:

   a. Retirement (e.g., Social Security)
   b. Unemployment insurance
   c. Accident compensation (e.g., Worker's Compensation)

   In this description, identify agency (federal, state or provincial, local) involved in its administration; how rates are established; who pays the bill; what affects rates, if they are variable.

7. A worker is paid a basic wage rate per regular hour. Be able to convert this to an effective cost per hour due to:

   a. Overtime premium.
   b. Other premium pays.
   c. Shortened shift time.
   d. Travel time.
   e. Show-up pay.

8. Describe the included elements of materials cost from a supplier's viewpoint and from a buyer's viewpoint.

9. Describe and distinguish among the various estimates categories such as conceptual, approximate, definitive, budget, appropriation, order-of magnitude, engineer's, contractor's or bidder's. In this discussion refer to applications and relative accuracy.

10. Distinguish between factored and parametric estimating.

11. Understand these terms and their influence on the cost of materials:

    a. Carrying charges
    b. Demurrage
    c. Escalation clauses,
    d. Currency exchange

e. Catalog price and market price
f. F.O.B. and DDP (Delivery Duty Paid), Carried in Freight (CIF)
g. Shrinkage, waste, theft, and damage
h. Export/Import duties
i. Agent Cost
j. Taxes

12. Identify elements of equipment cost included in:

    a. Owner costs
    b. Operating costs
    c. Maintenance cost
    d. Schedule
    e. Owner spares/inventory, contract start-up spares
    f. Lease versus purchase

13. Know application of these elements of current tax laws with respect to capital equipment:

    a. Investment and other tax credit
    b. Depreciation

14. Given factors of usage and included elements of cost, develop an equivalent cost per hour to be charged for a piece of equipment.

15. Distinguish between the terms “operating life" and "economic life” as applied to equipment.

16. Explain the mechanics of common rental, lease, and purchase contracts for equipment.

17. Given the options of rental, lease, or purchase of equipment and all the economic and use data pertaining to the problem (purchase price, rental price, lease price, down payments, anticipated usage, fixed costs, operating costs, investment tax credit, depreciation, tax rates, time value of money, etc..), determine the most economical option.

18. Explain the difference between "costing" and "pricing."

19. Define and give examples of distributable costs. Describe various methods for handling these in a cost estimate.

20. Other than an established company estimating program, what published estimating programs/data bases are available on the open market?

Contractors Costs

1. Describe included components of these costs associated with design engineering/construction work:

    a. Direct salaries
    b. Reimbursable directs
    c. Non-reimbursable directs
    d. Overhead / indirect
    e. Profit
    f. License and/or fees of royalties

2. Given a unit-price bid form for a construction contract, plus all direct cost data pertaining to bid line items, overhead/indirect costs, and profit markup, calculate the bid unit prices assuming no unbalancing.

3. Explain the mechanics of unit-price bid unbalancing. Explain "front-end loading."

4. Given the construction drawings for a relatively simple structure or system, complete the quantity takeoff of selected items.

5. Given the quantity takeoff summary for a given civil, electrical, or mechanical work package plus crew composition, labor production rates, labor wage rates, and labor burden, determine the craft labor direct cost for that work package.

Owners Costs

1. Define contingency and explain how it differs from allowances or management reserve. Discuss a reasonable method for determining the contingency to be included in a budget for a capital project.

2. Discuss the use of factors, ratios, indices, escalation and inflation in capital cost estimation.

3. Select a process or manufacturing industry with which you are familiar and describe a system by which conceptual estimates of capital cost of a now facility can be made.

4. Given the following scale of operations conversion formula, plus relative outputs/sizes of A and B, location indices, inflation indices, and the value of the "x" factor, estimate the cost for a new facility at location B, given actual data for a comparable facility at location A.

   $CB = CA\ [QB / QA]^{X}$

5. With respect to a parametric estimating system:

   a. Describe the basic mechanics of such a system.
   b. Given the baseline data for an existing facility plus the standard parametric measures, location factors, and escalation/inflation factors, estimate the cost of a comparable proposed facility at another location.

6. Given the estimated fixed and variable components of cost for a manufactured product, determine the break- even price to be charged per unit for a given level of production. or, given the estimated fixed and variable price components, the desired profit, and the expected to be charged per unit, determine the minimum level of production and sales required.

7. Define the following with respect to a manufacturing/process facility:

   a. Operating/manufacturing cost
   b. General expense
   c. Total product cost
   d. Direct cost
   e. Daily cost
   f. Unit-of-product costs
   g. Production schedule
   h. Just-in-Time (JIT)

8. Distinguish among products, co-products, and byproducts.

9. Explain the cost factors included in packing and shipping and inventory of a product.

10. Explain Activity Based Costing (ABC)

SECTION III -- COST CONTROL

Work Breakdown Structure and Code of Accounts

1. Given a structure or manufacturing Process whose components are generally known, develop a work breakdown structure of four levels. For this purpose the total structure is Level 0 major components are Level I sub components are Level II and sub-sub components are Level III. Show at least three components at each level, choosing one of those for subsequent breakdown into three components at the next lower level.

2. Develop a code of accounts to parallel the work breakdown structure developed above. The format of this code of accounts must be designed to facilitate computer summary of data at each level assuming raw data is input at Level III.

3. Define "work package."

4. Define “Deliverables”

Earned Value (Also called Achieved and Accomplished Value)

1. Explain each of the following terms and, given data relating to an example project, calculate them.

    a. Budgeted Cost of Work Scheduled (BCWS)
    b. Budgeted Cost of Work Performed (BCWP)
    c. Actual Cost of Work Performed (ACWP)
    d. Budget at Completion (BAC)
    e. Estimate at Completion (EAC)
    f. Schedule Variance (SV)
    g. Cost Variance (CV)
    h. Schedule Performance Index (SPI)
    i. Cost Performance Index (CPI)

2. Be able to explain and handle calculations similar to those of Item 1, above, using work-hour instead of cost data.

3. Given data relating to individual control accounts, determine earned value of each account and determine percent complete of each account plus the percent complete at summary levels.

Key Cost Control Techniques

1. Given contractual provisions concerning reimbursable and non reimbursable costs on a proposed engineering contract, and also given historical and projected cost data for the company, develop the break-even marker to be applied to direct salaries for current contracts.

2. Explain how engineering tasks (which are system oriented), procurement tasks (which are commodity oriented) and construction tasks (which tend to be area oriented) can be combined to provide integrated engineering-procurement-construction control.

3. Apply the line-of-balance method to control of a manufacturing process.

4. Explain effective cost trending and the relationship between cost trending and project cost forecasting.

    a. What are potential trends
    b. What are actual trends

5. As the contingency is often the largest single cost line item, how would you manage and control this item?

    a. Are scope changes part of contingency?
    b. Is design allowance part of the contingency?
    c. Are variations in exchange rates and escalation part of contingency?

d. What is the “slush fund approach” to managing contingency?
e. Should contingency be controlled by the project manager or senior company management?

SECTION IV -- PLANNING and SCHEDULING

Planning Basics

1. Explain the difference between planning and scheduling.

2. This function involves the development of the project logic diagram, so as to identify the correct relationships of all related work. Activity times and resources are not yet developed.

3. This requires an assessment of site limitations, equipment deliveries, engineering / design restraints, availability of resources and the requirements or enforcement of a completion date.

Scheduling Basics

1. Given a series of logic statements relating to the activities in a project, draw the logic diagram for that project.

2. Given an Arrow Diagram Method (ADM) Logic diagram and duration's for each activity, calculate early start, early finish, late start, late finish total float and free float times for all activities. Identify the critical points and minimum project completion time

3. Given a Precedence Diagram Method (PDM) logic diagram with duration's and which includes at least one each finish-start finish-finish, start-finish, and start-start relationships with lags, calculate early start, early finish, late start, late finish, total float, and free float times for all activities. Identify the critical path(s) and minimum project completion time.

4. Given a summary of all activities in a project network to include duration, early and late start and finish times, and total float, draw a bar chart schedule based on early start of all activities. Show total float of activities where applicable.

5. Discuss the relationship and significance of total float and free float in the scheduling of an activity.

6. Compare characteristics of ADM and PDM networks.

7. Convert an ADM type network into a time-scaled network based on early start.

8. For a simple ADM type network with activities whose crew sizes are given, resource level this network within early and late start limits. Draw histograms of worker-loading for early start, late start, and resource leveled configurations.

9. Explain the difference between barchart/Gantt chart and logic diagram.

10. What is the key usage of the barchart/Gantt chart.

Schedule Control

1. Work packages in a construction or manufacturing -project will be some combination of the following types:

    a. Those composed entirely of single, measurable units of work, such an placing concrete (cubic yards) or installation of a component (each).

b. Those composed of a number of separate, overlapping tasks, each with a different unit of measure. An example would be major pipe Installation where the included tasks are hanger installation, pipe erection, valve installation, and welding.
c. Those composed of easily identified sequential tasks, such as those associated with installation of a piece of mechanical equipment receipt, setting, alignment, grouting, test.
d. Those involving level of effort or apportioned effort such as management, administration, quality control, etc.
e. Those for which start and completion are well defined, but there is no basis for determining intermediate progress. Examples are rotary equipment alignment, testing, and planning.

2. For each of the above, describe a progress control system that can be established that becomes the baseline for schedule status determination.

3. Describe reasonable methods for planning and statusing engineering work such as drawings, specification writing, etc..

4. Given a "soft logic" work package, such as installation of a pressure piping system, where included activities (e.g., hanger installation, pipe installation, valve Installation, and welding) are overlapping, parallel, and have no strict interrelationship, discuss methods for reasonably scheduling this work.

5. Distinguish between a batch and a continuous process. How does scheduling for these two types of operation differ?

SECTION V - CONTRACT MANAGEMENT

Contracting Arrangement

1. Describe the relationship between risk allocation and contract type.

2. Explain the advantages, disadvantages, and uses of these types of contracts:

   a. Fixed-price contracts
   b. Unit-price contracts
   c. Cost-plus contracts -- (1) Fixed fee, (2) Incentive fee, (3) Award fee, (4) Time and Materials (T and M) Contracts

3. Describe the contracting roles among the various potential parties: Project-owner, engineer, project manager, prime contractors, and subcontractors.

4. Describe the general contents and purposes of the following documents which may be part of bidding and contract packages:

   a. Invitation to Bid or Request for Proposal
   b. Bid Form
   c. Agreement
   d. General Conditions
   e. Supplementary or Special Conditions
   f. Technical Specifications
   g. Drawings
   h. Addenda
   i. Modifications
   j. Bid Bond and Contract bond
   k. Performance Guarantee
   l. Equipment Warranties

5. Distinguish among performance, proprietary, and descriptive specifications.

6. Describe major reasons for changes in a contract and how changes are initiated. Distinguish between formal, constructive, and cardinal changes.

7. Describe the general approach to determination of cost and schedule impact of changes.

8. Distinguish between changes and claims.

9. Distinguish among various types of delay excusable, non-excusable, compensatory, and concurrent.

Contract Administration

1. Describe the concept of integrated project control to include:

    a. Systems included
    b. The objectives
    c. The basic mechanics of such a system its structure and information flow

2. Describe the types of bonds that may be required as part of a construction contract.

3. Describe the various types of insurance that may be required as part of a construction contract.

4. Describe the various types of taxes that may be included in a construction contract.

5. Describe examples of "construction plant."

6. Identify typical items included in the category "General Expense" in a construction contract.

7. Distinguish between "Job (project) overhead" and "general overhead' and provide examples of each.

8. A supplier offers a contractor payment terms such as “2/15 net 30”. Given this information, the current time-value of money for the contractor, the timing of contractor requests for payment from the owner, and the timing of owner reimbursement of contractor, determine the method of payment that is economically most advantageous.

9. For a construction project, explain the difference between and give examples of “permanent materials" and "construction materials and supplies.”

10. Calculate the effective cost of a “retention” given the terms of the contract and time-value of money.

11. Explain “liquidated damages.”

12. Explain contractor considerations in the determination of profit markup (risk, competition, desired rate of return, current economic conditions, etc.).

SECTION VI -- ECONOMIC ANALYSIS and BUSINESS PLANNING

Budgeting and cash flow

1. Given the items listed, develop the cost “s-curve” for a project.

    a. The schedule for completion of each component account.
    b. The estimated rate of incurring costs in each component account.
    c. The estimated total amount of indirect costs
    d. The estimated rate of incurring indirect costs

2. Given the information below, develop the cash flow profile for a project.

a. The projected expense curve for the project
b. The projected progress curve for the project
c. The dollar value of the contract
d. The payment terms of the contract (frequency, basis of payment, retention, delay between completion of work and payment)

3. For an investment opportunity, calculate the cash flow during an annual period given the following information:

   a. Anticipated expenses
   b. Anticipated receipts
   c. Depreciation or depletion (to include method to be used)
   d. Investment tax credit
   e. Taxation conditions
   f. Resale, residual, or salvage value

Value Engineering

1. Explain the meanings, using examples if desired, of these four kinds of value that may be associated with an item:

   a. Use value
   b. Esteem value
   c. Exchange value
   d. Cost value

2. The Value Engineering Job Plan is a basic format for organizing and executing the value engineering effort. Although there is no standard labeling of the phases of such a plan, commonly used labels are given:

   a. Information phase
   b. Creative phase
   c. Judgment phase
   d. Development phase
   e. Recommendation phase.
   f. Execution phase

   Briefly describe activity within each of these phases.

3. Describe each of the following problem solving techniques:

   a. Brainstorming
   b. Checklists
   c. Morphological analysis
   d. Attribute listing
   e. Function analysis

4. Distinguish “value engineering" from "scope control.”

5. Distinguish among the terms "lowest life-cycle cost," "best quality,” and “best value."

6. Explain "life-cycle" costs.

7. Explain constructability and construction pre-planning in relation to value engineering.

